MVM PAKS II ZRT

IMPLEMENTATION OF NEW NUCLEAR POWER PLANT UNITS AT THE PAKS SITE

ENVIRONMENTAL IMPACT STUDY

VOLUME I

MVM PAKS II Zrt. contract number: 4000018343

MVM ERBE Zrt. contract number: 13A380069000

APPLICANT'S DATA

Applicant's name:	MVM Paks II Atomerőmű Fejlesztő Zártkörűen Működő Részvénytársaság
Official abbreviation of the Applicant's name:	MVM Paks II Zrt.
Applicant's registered seat:	7030 Paks, Gagarin u. 1-3. 302/B
Applicant's company registration number:	17-10-001282
Applicant's tax registration number:	24086954-2-17
Applicant's statistical code:	24086954-4222-114-17
Applicant's manager:	Sándor Nagy – CEO
Contact details of the Applicant's contact person:	László Puskás – Head of Department for Licensing and Nuclear Safety
Contact details of the Applicant's contact person:	+36 75 503 730

DATA OF THE PLANNED ACTIVITY

Name of the planned nuclear power plant:	Paks II Nuclear Power Plant
Abbreviated name of the planned nuclear power plant:	Paks II
Planned activity:	implementation and operation of two III+ generation pressurized water reactor nuclear power plant units
Purpose of the planned activity:	generation of electric power for public purposes
Gross electrical output of the planned nuclear power plant:	maximum 1200 MW_e per unit
Gross thermal output of the planned nuclear power plant:	maximum 3200 MW_e per unit
Installation area of the planned nuclear power plant:	site of the Paks Nuclear Power Plant
Planned start of the commercial operation of the new units:	2025 - Paks II Nuclear Power Plant, unit 1
	2030 - Paks II Nuclear Power Plant, unit 2
Planned life of the new units:	at least 60 years

DETAILS OF THE PLANNED INSTALLATION SITE

Parcel number of the planned installation site:	Paks 8803/15
Owner of the planned installation area:	MVM Paksi Atomerőmű Zrt.

DETAILS OF THE EXPERTS (DESIGNERS) WHO PREPARED THE ENVIRONMENTAL IMPACT ASSESSMENT STUDY

The environmental impact assessment study of the planned nuclear power plant units was compiled by MVM ERBE Zrt.

Designer's name: *MVM ERBE ENERGETIKA Mérnökiroda Zártkörűen Működő Részvénytársaság*

(MVM ERBE ENERGETIKA Engineering Company Limited by Shares)

Official abbreviation of the Designer's name: *MVM ERBE Zrt.*

Address of the designer's registered office: *1117 Budapest, Budafoki út 95.*

Designer's company registration number: *01-10-045821*

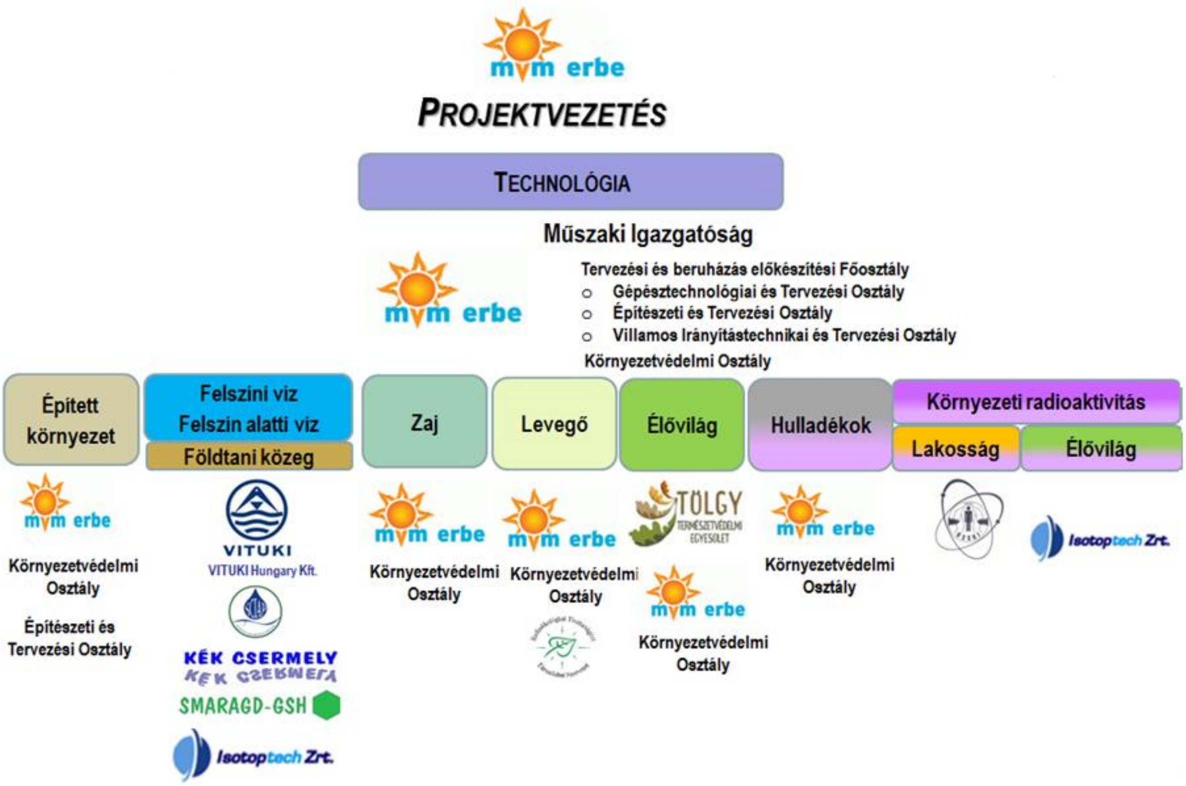
Head of the designer: *Farkas Dohán - Chief Executive Officer*

The technical conditions of the environmental impact assessment study and licensing for the planned nuclear power plant units are provided by the basic technical parameters elaborated on the basis of the maximum environmental emission values causing maximum environmental load, which are based on the preliminary data reported by the supplier of the units, the published data of nuclear power plants already being built, and the reference data of similar units that have been implemented. On the installation site plan the buildings and structures were arranged on the basis of technological considerations, taking into account those technological units with the maximum spatial requirement. The basic specifications were prepared by MVM ERBE Zrt. (ERBE).

The environmental impact assessment of a nuclear power plant is a highly complex task comprising a large number of specialisations, the implementation of which requires broad professional cooperation.

To this end, ERBE used the services of professionally recognized, certified subcontractors for the purpose of elaborating the environmental impact assessment programme and compiling the environmental impact assessment study.

The system of professional organisations cooperating in each specialisation was the following.



Projektvezetés–Project management
Technológia–Technology
Műszaki Igazgatóság–Technical Directorate
Tervezési és beruházás előkészítési Főosztály– Department of Design and Project Preparation

- ***Gépésztechnológiai és Tervezési Osztály –Department of Engineering Technology and Design***
- ***Építészeti és Tervezési Osztály – Department of Architecture and Design***
- ***Villamos Irányítástechnikai és Tervezési Osztály –Department of Electrical Control Engineering and Design***

Környezetvédelmi Osztály–Department of Environmental Protection

Épített környezet–Built environment

Felszíni víz –Surface water
Felszín alatti víz –Subsurface water
Földtani közeg –Geological medium

Zaj–Noise

Levegő–Air

Élővilág–Wildlife

Hulladékok–Waste

Környezeti radioaktivitás–Ambient radio activity
Lakosság–Population
Élővilág–Wildlife

Környezetvédelmi Osztály–Department of Environmental Protection
Építészeti és Tervezési Osztály–Architecture and Design Department

The following experts contributed to the elaboration of the environmental impact assessment of the planned nuclear power plant units and to the compilation of the impact assessment study:

MVM ERBE Zrt.

Technical Directorate

- Department of Environmental Protection

Zsuzsanna Rudi – Department Head
Registration number at the Hungarian Chamber of Engineers: 13-8475
Experts' licences:
SzKV-1.1; SzKV-1.2; SzKV-1.3, SzKV-1.4 (Valid: for an indefinite period)
Zsófia Fehér – Environmental Specialist
Registration number at the Hungarian Chamber of Engineers: 13-11655
KB-T; SzKV-1.1; SzKV-1.2; SzKV-1.3 (11/29/2018)
SzKV-1.4 (03/27/2018)
Sz-010/2010: SzTjV, SzTV (until withdrawal)
Benedek Tóth – Environmental Specialist
Registration number at the Hungarian Chamber of Engineers: 13-14747
KB-T; SzKV-1.1; SzKV-1.2; SzKV-1.3 (03/28/2018)
Dávid Pintér – Environmental Specialist
Registration number at the Hungarian Chamber of Engineers: 07-51764
SzKV-1.1; SzKV-1.2; SzKV-1.3, SzKV-1.4 (for an indefinite period)

- Department of Design and Project Preparation

Gábor Kovács - Department Head
Department of Mechanical Engineering Technology and Design
György Kottner – Department Head
Registration number at the Hungarian Chamber of Engineers: 01-63942
ME-EN/I, BB
Tivadar Tajti – senior engineering specialist
Registration number at the Hungarian Chamber of Engineers: 01-64755
SzÉM 6 (08/01/2017); NSZ-4.2; NSZ-10.1.
Attila Solcz – senior engineering specialist
Registration number at the Hungarian Chamber of Engineers: 01-13485
GP-T
Attila Tóth – mechanical engineering specialist
Registration number at the Hungarian Chamber of Engineers: 01-10925, 01-50634
MV-ÉG; ME-G; TÉ; G; NSz-4.3; ME-EN; ME-EN-VE
Gábor Péter Kiss – mechanical engineering specialist
Mátyás Hunyadi – mechanical engineering specialist
Mátyás Pintér – mechanical engineering specialist

Department of Electrical Control Engineering and Design
László Kökény – Deputy Department Head
Registration number at the Hungarian Chamber of Engineers: 01-8103, 01-64952
SzÉM 6, NSZ-8.1, EN-HŐ, EN-VI, EN-ME (valid up to: 02/16/2015)
Gábor Lengyel – senior electrical engineering specialist

Department of Architecture and Design
Szilvia Ligeti – architect and licensing specialist
Registration number at the Chamber of Architects: É 01-4151
Attila Lepp-Gazdag –specialist in supporting structures, nuclear specialist
Registration number at the Hungarian Chamber of Engineers: 13-12800, 13-50657
NSz 7; T, ME-É, ME-M, TÉ
Zita Sárosi – architect
Registration number at the Chamber of Architects: É 01-1827

Nuclear Power Plant Engineering Head Department

- Department of Mechanical Engineering Technology

Zója Müller – senior engineering specialist

	Registration number at the Hungarian Chamber of Engineers: 13-63726 *NSz 4.2, NSz 5.1, NSz 5.2, NSz 6* *OSSKI-2012-Á-3377-09*
VITUKI VITUKI Hungary Kft.	***VITUKI Hungary Kft.*** *Sándor Szél – managing director, engineer, senior research fellow* *Registration number at the Hungarian Chamber of Engineers: 01-11986* *VZ-TEL, VZ-TER, VZ-VKG, KB-T (02/09/2017), SZÉM3, NSz 7. (10/04/2017)* *SzVV-3.1, SzVV-3.2, SzVV-3.3, SzVV-3.4, SzVV-3.5, SzVV-3.6, SzVV-3.7, SzVV-3.9, SzVV-3.10, SzKV-1.1; SzKV-1.2; SzKV-1.3; SzKV-1.4 (02/09/2017)* *Dr István Zsuffa - PhD, engineer, scientific consultant* *Dr István Galambos - PhD, engineer, scientific consultant* *Gábor Kránitz – managing director, engineer, senior research fellow* *Registration number at the Hungarian Chamber of Engineers: 01-15089* *VZ-TEL, VZ-TER, VZ-VKG, KB-T (11/02/2019)* *Béla Licskó, engineer, senior research fellow* *Registration number at the Hungarian Chamber of Engineers: 01-9488* *VZ-Sz, SzVV-3.1, SzVV-3.5 (03/31/2016)* *Károly Szalavári – engineer, senior research fellow*
Isotoptech Zrt.	***Isotoptech Zrt.*** *Mihály Veres – Chairman, CEO* *Registration number at the Hungarian Chamber of Engineers: 09-51745* *NSz 10.1, NSz 10.2, NSz 10.3, NSz 11* Andor Hajnal – *research fellow* *Dr Zoltán Dezső – senior research fellow, PhD in physics* *Andrea Czébely – senior research fellow* *Registration number at the Hungarian Chamber of Engineers: 09-1118* *SzKV-1.3 (07/25/2018)* *Dr László Rinyu – technical director, PhD in physics* *Gergely Orsovszki – research fellow* *Árpád Bihari – research fellow* *Róbert Janovics – research fellow* *Dr István Futó – head of quality and environmental management*
KÉK CSERMELY	***Kék Csermely Kft*** *György Maján – managing director* *Registration number at the Hungarian Chamber of Engineers: 01-3036* *SzKV-1.1; SzKV-1.3; VZ-T (08/22/2018)* *Péter Nagy – managing director* *Pál Gulyás – CSc in biological sciences*
SMARAGD-GSH	***Smaragd GSH Kft.*** *Károly Gondár – managing director* *Registration number at the Hungarian Chamber of Engineers: 13-8288* *VZ-T, SzKV-1.1; SzKV-1.3, SzVV-3.1, SzVV-3.9, SzVV-3.10 (02/24/2019)* *Katalin Gondár Sőregi – deputy managing director* *Registration number at the Hungarian Chamber of Engineers: 13-8286* *VZ-T, SzKV-1.1; SzKV-1.3, SzVV-3.1, SzVV-3.9, SzVV-3.10 (02/24/2019)* *Éva Kun – project engineer* *Registration number at the Hungarian Chamber of Engineers: 01-10911* *VZ-T, SzKV-1.3, SzVV-3.9, SzVV-3.10 (02/24/2019)* *László Weiszer – project engineer* *Mrs Nándor Könczöl – Geographic Information System specialist*

SCIAP Kutatás-Fejlesztési és Tanácsadó Kft

Béla Halasi-Kovács – managing director, nature conservation specialist
Sz-002/2013 SZTV wildlife protection
József Németh – hydrobiologist
Dr Gábor Borics – ecologist
Dr Balázs András Lukács – nature conservation expert
Sz-029/2008: SzTjV, SzTV (07/02/2013 extension in progress)
Dr Csaba Deák – ecologist

Frédéric Joliot-Curie National Research Institute for Radiobiology and Radiohygiene

- Department of Radiohygiene
  Nándor Fülöp – Department Head
- Division of Nuclear, Occupational and Medical Radiation Protection and Safety
  László Juhász – Division Head
  Ádám Salik – researcher
  Máté Lajos – researcher
  Anna Mária Motoc – researcher
- Division of Environmental and Public Radiohygiene
  István Szabó, Division Head
  Zsolt Homoki – researcher
  Júlia Kövendi Kónya – researcher
  - Environmental Modelling and Dosimetry Group
    Nándor Glavatszkih – group head, senior counselor
- Division of Cellular and Immune-radiobiology
  Dr Katalin Lumniczky – Division Head

Tölgy Természetvédelmi Egyesület

Dr Gábor Bakonyi
Wildlife protection specialist license number: Sz-018/2013: SzTV
Dr Nándor Oertel – Sz-023/2013 SzTV
Dr János Nosek
Dr Zsolt Gergely Szövényi – Sz-015/2013: SzTV
Tibor Kovács – Sz-014/2013: SzTV
László Peregovits – Sz-024/2013: SzTV
Csaba Szabóki
Dr Erzsébet Hornung – Sz-011/2013: SzTV
Dávid Fülöp – Sz-068/2013: SzTV
Dr Tibor Erdős – Sz-022/2013: SzTV
Péter Sály
Dr István Kiss – Sz-006/2013: SzTV
Dr Norbert Mátrai – Sz-017/2013: SzTV
Dr Vilmos Altbäcker

Civil Society Organisation for Radio-ecological Cleanliness

Tibor Kovács
Registration number: 19/1005
KB-T; SzKV-1.1; SzKV-1.2; SzKV-1.3 (05/20/2019)
Róbert Mészáros
Chamber registration number: 01-15261
István Lagzi

Dr Árpád Nényei
Registration number at the Hungarian Chamber of Engineers: 17-0651
N-S-1, N-S-2
17085/2011/EFIK

CONCEPT OF THE EIAS CONTENT STRUCTURE

The purpose of the environmental impact assessment analysis performed before building the Paks II Nuclear Power Plant on the Paks site is to identify and evaluate the environmental impacts of the planned nuclear power plant technology on the individual elements and systems of the environment depending on the condition and load capacity of the design area.

The preliminary consultation documentation examined the five potential unit types. The competent environmental authority designated to act in the matters of the Paks Nuclear Power Plant, i.e. the South-Transdanubian Environmental and Nature Conservation Supervisory Authority (DdKTF) issued its opinion No. 8588-32/2012 on the basis of this documentation.

On 14 January 2014, the Hungarian Government entered into an agreement with the Government of the Russian Federation on the renewal of the nuclear cooperation agreement, which was concluded by the two countries several decades earlier. Hungary's Parliament approved the agreement concluded between the two governments in ***Act II of 2014*** on the promulgation of the Treaty on cooperation between the Government of Hungary and the Government of the Russian Federation in the field of the peaceful use of nuclear energy. Based on the agreement, two additional 1200 MW units will be built on the site of the Paks Nuclear Power Plant, with the Russian Competent Authority acting as the main contractor.

Thus, from among the versions taken into consideration in the Preliminary Consultation Documentation (PCD), the Environmental Impact Assessment Study (EIAS), which describes the completion of and sums up the Paks II environmental impact assessment, analysed the possibility to assess significant environmental impacts of the Russian nuclear power plant technology selected for implementation, its main connections, cooling water intake, discharge of the hot water into the river Danube, and the unit power line that carries the electricity generated in the power plant, also taking into account the opinion given on PCD.

The environmental impact assessment study did not address any economic or financial matters related to the installation of the planned units.

The environmental impacts of a project can be assessed either in time sequence, i.e. in the order of the implementation, operation and decommissioning processes, or according to the individual environmental elements and systems.

The impact assessment study of Paks II takes the latter approach: it examines the impact processes and impacts caused by the impact factors in the various stages of the project, and their territorial coverage, i.e. affected zone by the individual environmental elements and systems.

The content of the environmental impact assessment study is structured on the basis of the general descriptions given in Annexes 6, 7 and 10 of Government Decree 314/2005. (XII. 25.) on the procedural rules of performing environmental impact assessment analyses and issuing integrated permits for use of the environment.

The impact assessment study of Paks II describes and reviews the following topics:

- detailed description of the planned nuclear power plant project and presentation of the basic technological data,
    - volume of the activity,
    - expected date and duration of the installation and operation,
    - description of the implementation of the planned technology,
    - list of the facilities required for the implementation of the activity and their locations,
    - water supply,
    - management of waste water and sewage generated in the course of implementation,
    - main indicators of material use,
    - the magnitude of freight and passenger transport required for the activity,
    - related operations required for the implementation of the activity,
    - other related operations;
- description of the selected installation area and its immediate and wider environment, location and size of the area required for the activity, and the presentation of the installation site plan
- presentation of the previously examined and considered versions

- specification and calculation of the environmental impacts of the power plant technology on the individual elements and systems of the environment
- delimitation of the areas affected by the planned project
- description of cross-border impacts.

Based on all these, the Paks II. Environmental Impact Assessment Study is divided into the following main chapters:

1 Basic information on the planned project
2 Forecasts and strategies related to the planned project
3 A general guide to nuclear engineering
4 Description of the planned installation site
5 Possible methods of condenser cooling in the new nuclear power plant units
6 Characteristics and basic specifications of the Paks II Nuclear Power Plant planned to be built on the Paks site
7 Connection to the Hungarian power grid
8 Potential impact factors and impact matrices of Paks II
9 Social and economic effects
10 Climate Profile of Paks and its Environs Within a 30 km Radius
11 Modelling the Danube bed morphology and heat load on the Danube
12 Assessment of water quality in the Danube and other surface waters according to the Water Framework Directive
13 The geological formation and subsurface waters on the site and in its immediate environs
14 Geological formation and subsurface waters in the Danube valley downstream of Paks
15 Noise and vibration
16 Ambient air
17 Non-radioactive wastes
18 Wildlife and ecosystem
19 Radioactive wastes and spent fuels
20 Ambient radioactivity, and exposure of the population living in the vicinity of the site to radiation
21 Exposure of wildlife to radiation in the vicinity of the site
22 Summary impact matrices and aggregate impact areas

Detailed contents of the individual chapters of the Impact Assessment Study of Paks II

1 Basic information regarding the planned project

This chapter describes the activities during the preparation of the planned project, the general procedure required for the licensing of the planned new nuclear power plant units and the current situation of environmental licensing.

2. Forecasts and strategies related to the planned project

In this chapter an overview is given of the forecasts related to the use of electricity in Hungary, and the main statements of the National Energy Strategy 2030, the National Climate Change Strategies and the National Environmental Programme.

3. A general guide to nuclear engineering

This chapter gives a general overview of the current state of nuclear power generation, pressurized water reactor (PWR) units, the benefits of III+ generation PWR type units against other types, the international organisations regulating and supervising nuclear energy use, the fundamental principles of nuclear safety and the various events.

4. Description of the planned installation site

This chapter describes the location of the installation area, its ownership, the infrastructure connections of the installation site, the Paks Nuclear Power Plant, its related facilities and monitoring systems located in the neighbourhood of the Paks Nuclear Power Plant, and summarizes the features and characteristics of the Paks site.

5. Possible methods of condenser cooling in the new nuclear power plant units

This chapter contains general information on the cooling requirements of condenser power plants used for electricity generation, describes the statutory framework applicable to the heat loading of aquatic environments, *and gives a general overview of the applicable limit values. This is followed by the description of the eligible cooling methods that have been taken into consideration on the Paks site.*

6. Characteristics and basic specifications of the Paks II Nuclear Power Plant planned to be built on the Paks site

This chapter gives a detailed description of the characteristic features and fuel of the Russian VVER units planned to be erected on the Paks site, the primary circuit, the secondary circuit, the planned cooling systems, the auxiliary systems and facilities, the control engineering technology, telecommunication, the power systems, the architectural solutions, the installation site plan, physical protection and the characteristic of nuclear safety. At the end of the chapter a summary is given of the characteristic features of the implementation, operation and decommissioning of Paks II.

7. Connection to the Hungarian power grid

This chapter describes the connectivity of the new units to the Hungarian power grid, the installation site of the new 400 / 120 kV Paks II substation, and the routing and parameters of the 400 kV unit line and 120 kV transmission line.

8. Potential impact factors and impact matrices of Paks II

This chapter summarizes the potential impact factors, the processes and impacts triggered by them, and the potentially affected parties. All these are included in a matrix of potential impacts.

9. Social and economic effects

This chapter presents the analysis of the area of a 30 km radius in terms of urban and rural development and zoning, characterizes the economy, transport routes and land use in the region, its spatial structure, the various regional development concepts and programs, and introduces and characterizes the population metrics and their expected changes. A brief summary is given of the regional impacts of the Paks development.

10. Climate Profile of Paks and its Environs Within a 30 km Radius

This chapter presents the features of the natural environment, analyzes the climate profile of Paks and its environs within a 30 km radius, and presents the findings of a climate modelling performed for the region.

11. Modeling the Danube bed morphology and heat load on the Danube

The purpose of the model analyses performed in the framework of the environmental impact assessment of Paks II was to determine and evaluate the extent to which the area of the Paks Nuclear Power Plant would be affected in the worst case and the morphodynamic changes in the Danube that may develop as a result of various hydrological events; to determine, under various climate change scenarios, the standard conditions related to the project and to analyze the characteristic parameters of the Danube heat tail of the warmed cooling water that is discharged to the Danube.

12. Assessment of water quality in the Danube and other surface waters according to the Water Framework Directive

A highly detailed analysis and evaluation is given of the characteristic physical and chemical parameters of the Danube, of the characteristic features of the fauna and flora in the Danube (phytoplankton, phytobenton, macrophyte, macrozoobenton, fish communities), of the status of the Danube sections upstream and downstream of the Paks Nuclear Power Plant site, and of changes in the Danube properties, especially those of water habitats, based on the parameters determined for the standard situations resulting from the findings of the modelling. The development and operation of an environmental monitoring system is proposed.

13. The geological formation and subsurface waters on the site and in its immediate environs

In this chapter the area subject to analysis is identified, the initial condition of the geological formation and the subsurface waters on the site and in its immediate environs are characterized, and then the impacts of the implementation, operation and decommissioning of Paks II on the geological formation and the subsurface waters are analysed and assessed. A proposal is presented for the implementation of a system for monitoring subsurface waters.

14. Geological formation and subsurface waters in the Danube valley downstream of Paks

In this chapter the area subject to the analysis is identified, its baseline condition is described, then the method of estimating the indirect impacts on subsurface waters in the Danube valley are specified and the indirect heat impact of the operation of Paks II is evaluated.

15. Noise and vibration

In this chapter the noise generated by the implementation and operation of Paks II are presented on the basis of the baseline noise and vibration condition of the surveyed area, and then the noise reduction options and the proposed ambient noise monitoring system are described.

The detailed data and calculations related to the measurements, and the data of the affected areas marked out as a result of noise modelling during the environmental impact assessment are attached for use by DdKTF.

The subfolder *Zaj_rezges_alapmeresek* in the folder *PaksII_KHT_Zaj_mellekletek* contains the detailed data of the 2012 and 2014 baseline measurements, and subfolder *KHV_zajhatasteruletek* contains the graphic displays of the defined impact areas, and the parcel numbers of the affected areas.

16. Ambient air

This chapter describes the air quality in the analysed area, the impacts of non-radioactive air pollutants emitted during the implementation and operation of Paks II, and the recommended ambient air monitoring system.

17. Non-radioactive wastes

This chapter tackles the issues related to the generation and management of waste during the implementation, operation and decommissioning of Paks II.

18. Wildlife and ecosystem

In this chapter the exemplary biomonitoring analyses of the environs of the Paks Nuclear Power Plant are outlined, the initial condition of the area is characterized and, based on this, estimates are given for the impacts of the implementation and operation of Paks II on the affected part of the Tolna Section of the Danube (HUDD20023) according to Natura 2000.

19. Radioactive wastes and spent fuels

This chapter tackles the issues related to the management of radioactive waste generated during the operation and decommissioning of Paks II and of the spent fuels.

20. Ambient radioactivity, and exposure of the population living in the vicinity of the site to radiation

This chapter gives a description of the current ambient radioactivity on the territory within a 30 km radius of the power plant, characterizes the health condition of the population living within 30 km from the power plant, and the exposure of the population living within 30 km of the power plant to radiation. Based on the relevant radiation protection requirements, the impacts of the implementation and operation of Paks II on the exposure of the population of the site environs to radiation are modelled and evaluated.

21. Exposure of wildlife to radiation in the vicinity of the site

Based on the international recommendations for the limitations of exposure of wildlife to radiation, this chapter presents the current and expected exposure of wildlife to radiation in the immediate surroundings of the site.

22. Summary impact matrices and aggregate impact areas

This chapter gives a summary of the findings of the Paks II environmental impact assessment, a summary impact matrix determining the processes triggered by the direct impact factors related to its implementation and operation, and the aggregated impact areas.

SUMMARY CONTENTS OF THE EIAS:

15. Noise and vibration

The detailed data and calculations related to the measurements, and the data of the affected areas marked out as a result of noise modelling during the environmental impact assessment are attached for use by DdKTF.

The sub-folder *Zaj_rezges_alapmeresek* in the folder *PaksII_KHT_Zaj_mellekletek* contains the detailed data of the measurements made about the 2012 and 2014 basic condition, graphic displays of the defined impact areas, and the parcel numbers of the affected areas.

16. Ambient air

17. Non-radioactive wastes

18. Wildlife and ecosystem

19. Radioactive wastes and spent fuels

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

Abbreviated name	Complete name
ÁNTSz OTH	National Public Health and Medical Officer Service, Chief Medical Officer
ATWS	Anticipated Transients Without Scram
BM	Ministry of the Interior
BME	Budapest University of Technology and Economics
CCS	Carbon Capture and Storage
CFR	Code of Federal Regulations (US)
DBC	Design Basis Conditions
DBT	Design Basis Threat (the level of threat, as determined by the state, against which effective physical protection must be provided by the party who uses the nuclear power.)
DdKTF	South-Transdanubian Environmental and Nature Conservation Supervisory Authority
DdKTVF	South-Transdanubian Environmental, Nature Conservation and Water Management Supervisory Authority
DDNPI	Danube–Drava National Park Directorate
DEC	Design Extension Conditions
DECC	Department of Energy and Climate Change of the United Kingdom
EEC	European Economic Community
PCD	Preliminary consultation documentation
UN	United Nations
ERBE	MVM ERBE ENERGETIKA Mérnökiroda Zártkörűen Működő Részvénytársaság; MVM ERBE Zrt.
ESzCsM	Ministry of Health, Social and Family Affairs
EUR	European Utility Requirements
Euratom	European Atomic Energy Community
EüM	Ministry of Health
rkm	river kilometer, rkm

Abbreviated name	Complete name
MCP	Main circulating pump
GCR	Gas-Cooled, Graphite-Moderated Reactor
GM	Ministry of the Economy
HLCR	Hungarian Low-Carbon Roadmap
LBR	Local Building Regulations
HVAC	Heating, Ventilation, Air Conditioning
IBSS	International Basic Safety Standards
ICRP	International Commission on Radiological Protection
IKIM	Ministry of Industry and Commerce
MI	Ministry of Industry
INES	International Nuclear Event Scale
IRG	Inert radioactive gas
IRM	Ministry of Justice and Law Enforcement
KHEM	Minister of Transport, Telecommunication and Energy
EIAA – EIAS	Environmental Impact Assessment Analysis – Environmental Impact Assessment Study
KHVM	Ministry of Transport, Telecommunications and Water Management
SFIS	Spent Fuel Interim Storage
KöM	Ministry for Environmental Protection
KPM	Ministry of Transport and Post
KSH NKI	Central Statistical Office Population Research Institute
KvVM	Ministry of Environment Protection and Water Management
MWL	Minimum water level
LOCA	LOss of Coolant Accident
LOOP	Loss of Offsite Power
LWGR	Light-Water-Cooled, Graphite-Moderated Reactor
MAVIR	Hungarian Electricity Transmission system operator Private Company Limited by Shares
HOMG	Hungarian Office for Mining and Geology
MEKH	Hungarian Office of Energy and Public Utility Regulation
MIR	Modernized International Reactor
MKEH	Hungarian Trade Licensing Office
MKM	Ministry of Culture and Education
MVM Zrt.	MVM Magyar Villamos Művek Zártkörűen Működő Részvénytársaság
MVM Paks II. Zrt.	MVM Paks II Atomerőmű Fejlesztő Zártkörűen Működő Részvénytársaság
IAEA	International Atomic Energy Agency
NSR	Nuclear Safety Regulations
NREAP	National Renewable Energy Action Programme
NAS	National Climate Change Strategy
NAS 2	Second National Climate Change Strategy
MND	Ministry of National Development
NM	Ministry of Welfare
OAH NBI	Hungarian Atomic Energy Authority, Nuclear Safety Directorate
P	Parliament
OMSz	Hungarian Meteorological Service
ORFK	National Police Headquarters
OSSKI	Frédéric Joliot-Curie National Research Institute for Radiobiology and Radiohygiene
NZP	National Zoning Plan
ÖTM	Ministry of Local Governments and Regional Development
Paks Nuclear Power Plant	MVM Paksi Atomerőmű Zártkörűen Működő Részvénytársaság; MVM Paksi Atomerőmű Zrt.
Paks II	Paks II Nuclear power plant – planned new nuclear power plant units at the Paks Site
PHWR	Pressurized Heavy-Water-Moderated and Cooled Reactor
PSA	Probabilistic Safety Assessment
PWR	Pressurized Light-Water-Moderated and Cooled Reactor
reactor year	One reactor's one-year operation corresponds to a reactor year, in other words, the simultaneous operation of the currently operative approximately 440 reactors represents 440 reactor years (in one calendar year).
RHK Kft.	Radioaktív Hulladékokat Kezelő Közhasznú Nonprofit Kft. (Not for profit Public LTD Company for the Handling of Radioactive Wastes)
SWOT	Strengths, Weaknesses, Opportunities, Threats
NCIS	Nature Conservation Information System
TRU	trans-uranium element (with an atomic number higher than 92, i.e. that of uranium)
GHG	Greenhouse gases
VÁTI	VÁTI Magyar Regionális Fejlesztési és Urbanisztikai Nonprofit Kft
FSR	Final Safety Report

Abbreviated name	Complete name
HPS	The Hungarian Power Grid System
DH	Department of Hydrography
VVER	ВВЭР (Водо-Водяной Энергетический Реактор) - Water-Water Power Reactor
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association
ZMCS	zone emergency cooling systems

1 BASIC INFORMATION ON THE PLANNED PROJECT

The age of large power plants, which provide the overwhelming majority of the supply-side capacity in Hungarian electricity generation, is approaching, or in certain cases have already exceeded, the end of their design life-cycles. In order to manage part of the supply-side capacity shortage and in view of the planned life of the existing nuclear power plant units, Hungary has started making preparations for building new nuclear power plant units.

The purpose of the project in preparation is to build two modern, III^+ generation, pressurized water nuclear power plant units, each having 1200 MW_e capacity and an expected life of no less than 60 years, next to the Paks Nuclear Power Plant, for the generation of electricity for public use, **according to the time schedule determined in the National Energy Strategy,** starting commercial operation in 2025 and 2030, respectively, in order to maintain the supply-side share of about 40% of nuclear power in electricity generation over the long term.

The planned project consists of the following main elements:

- power plant technology,
- cooling water system for the power plant,
- connection to the Hungarian power grid.

1.1 ACTIVITIES IN PREPARATION FOR THE PLANNED PROJECT

1.1.1 TELLER PROJECT

Pursuant to Article 7 (2) of Act CXVI of 1996 on Nuclear Energy, Parliament's preliminary provisional consent is required to start preparations for the building of any new nuclear facility. In Article 12. f. of its Decision No. 40/2008. (IV. 17.) on energy policy between 2008-2020, Hungary’s Parliament requested the Government to “start preparatory work to support decision making about the new nuclear power plant units. Following the laying down of the professional, environmental and social foundations, it should submit its proposals for the need, conditions, type and installation of the power plant to Parliament in due time.”

The Teller Project set up by MVM Zrt has prepared expert studies, analyzing the relevant technical, economic, commercial, legal and social considerations. The feasibility of various implementation options were examined, a preliminary environmental assessment was prepared, and the issues related to the disposal of spent fuels and radioactive waste were scrutinized. The findings of these studies were summed up in three decision support documents, which state that the best choice is a modern pressurized water nuclear power plant, which is not a prototype, has already been licensed somewhere in the world, and has a useful life of at least 60 years, to be built at the Paks site.

Relying on the specialists’ analyses, Parliament approved with a 95.4% Yes vote on March 30, 2009 the launching of activities to support preparations for the building of new nuclear power plant units at the Paks site.

1.1.2 LÉVAI PROJECT

For the purpose of performing the preparatory activities prescribed in Parliament’s decision, MVM Zrt set up the Lévai Project in June 2009. The following main activities were performed in the framework of the Lévai Project:

- ordering the preparation of strategic analyses and inquiries to clarify financing options;
- ordering the preparation of the first draft of a supplier tender documentation;
- examining the connectivity of the new units to the power grid;
- assessing the various cooling water supply options;
- launching the compilation of a preliminary consultation documentation;
- launching inquiries required for the preparation of an environmental impact analysis;
- preparing the compilation of an application for a site permit;
- assessing the workforce requirements;
- surveying the range of potential domestic suppliers and regional businesses.

1.1.3 MVM PAKS II. ATOMERŐMŰ FEJLESZTŐ ZRT - PROJECT COMPANY

In order to prepare for the building of the new nuclear power plant units, the MVM Group founded MVM Paks II. Atomerőmű Fejlesztő Zártkörűen Működő Részvénytársaságot (MVM Paks II. Zrt) on June 26, 2012.

The most important tasks of the project company comprise determining the frameworks of the future implementation, working out the financing details, and laying down the technical conditions (cooling options, environmental impacts). As an important element of the project, the licences required for environmental protection, for site use, for the use of water resources and for construction must be obtained. The project company is engaged in legal harmonisation matters as well as the analysis of regional economic and social impacts. A further especially important task is to make sure that building the new nuclear power plant units will boost Hungary's economy as much as possible.

1.1.4 REGULATORY SUPPORT

As a result of the above outlined preparatory activities, several elements supporting the implementation of the new nuclear power plant units have been introduced into the Hungarian regulatory environment.

On 3 October 3, 2011, Parliament adopted the **National Energy Strategy**, which identifies the directions of development and operation in the next decades up to 2050, and declares that – in order to facilitate the achievement of its long-term economic and environmental objectives – the state wishes to maintain the current approximately 40% share of nuclear power in Hungary's power generation.

In order to ensure a balanced development in nuclear power engineering in Hungary over the next thirty years, in its Decree No. 1195/2012. (VI. 18.) the Government established the **Government Commission for Nuclear Energy** chaired by the Prime Minister, for the analysis of strategic questions related to the use and development of nuclear power in Hungary.

In view of the strategic role played by nuclear energy in Hungary's power supply and in guaranteeing supply safety, and with regard to the provisions of the National Energy Strategy adopted by Parliament, in its Decree No. 1196/2012. (VI. 18.), the Government declared the installation of new nuclear power plant units at the site of the Paks Nuclear Power Plant as a **high-priority project for the national economy**, which is **essential for the safe supply of electrical energy**.

1.1.5 SELECTION OF THE UNITS TO BE BUILT

1.1.5.1 Hungarian–Russian intergovernmental convention

On 14 January 2014, the Hungarian Government entered into an agreement with the Government of the Russian Federation on the renewal of the nuclear cooperation agreement, which was concluded by the two countries several decades earlier. Based on the agreement, two additional 1200 MW units will be built at the site of the Paks Nuclear Power Plant with the Russian Competent Authority acting as the main contractor, for which the Hungarian Government will be granted an intergovernmental loan from Russia.

1.1.5.2 Act II of 2014

During its 6 February, 2014 session Parliament approved the agreement concluded between the two governments in ***Act II of 2014*** on the promulgation of the treaty on cooperation between the Government of Hungary and the Government of the Russian Federation in the field of the peaceful use of nuclear energy. Here are the relevant provisions of the act:

Article 1 – Object of the cooperation

The Parties shall cooperate in the maintenance of the output of the Paks Nuclear Power Plant, located in Hungary, and in its development, including the design, erection, commissioning and decommissioning of two new units with reactors of the VVER (water cooling, water moderator) type, each having at least 1000 MW built-in capacity, as provided in this Treaty below, in order to replace units 1 through 4, which will be shut down in the future.

Article 5 – Obligations of the Russian Party

(1) Prepare the feasibility study about the maintenance and improvement of the output of the Paks Nuclear Power Plant, and conduct an onsite inspection;
(2) prepare the design and technical documentation of the core and auxiliary facilities of the power plant with the help of computer-aided design software (CAD) and documentation tools, and manage the changes between the design documentation and actual building;
(3) prepare a safety report about the power plant in view of the safety requirements set forth by the statutory regulations of the Russian Federation and Hungary and by IAEA's recommendations, and of the environmental impact assessment study of the power plant;
(4) implement building and installation works in the various facilities of the power plant;
(5) provide onsite design inspection and oversight of compliance with the power plant building requirements in every stage of the power plant construction;
(6) prepare a quality assurance programme for each stage of power plant building;
(7) supply the main equipment required for the nuclear island and the technical, electrical, automation systems, devices, tools and materials in the amount required for the commissioning of the power plant units, according to the required time schedule and safety classification;
(8) provide technical maintenance services for the supplied equipment, including consultations, the supply of spare parts, and the presentation of methods for preserving their condition and for storing these items;
(9) assist in organizing the repair activities required in power plant;
(10) organize and run test runs, ramp up and commission the new nuclear power plant units;
(11) provide engineering and consultation services for the development of programs and actions for physical security;
(12) assist the competent Hungarian authority and/or the designated Hungarian organisation in obtaining the special licences required for the project to be implemented on the basis of this Treaty, including the transfer of the necessary information and documentation, as well as the required modifications made in the interest of compliance with the requirements set by the regulatory authorities;
(13) organize training and re-training courses for the nuclear power plant staff and the experts of the Hungarian Party;
(14) assist the development of the scientific, technical and technological development programme of the nuclear power sector, including the localisation of the elements of nuclear power, nuclear and radiation safety through the application of Russian experience and the appropriate developed technologies;
(15) compile the operational, technical maintenance and repair documentation;
(16) provide technical assistance to the Hungarian Designated Organisation in the operation, modernisation and reconstruction of units 1 to 4 of the Paks Nuclear Power Plant, and in decommissioning the units of the Paks Nuclear Power Plant when their design life is over;
(17) participate in basic research and development aimed at the provision of fundamental scientific support to applications and facilities related to the operation of the Paks Nuclear Power Plant;
(18) participate in the training of Hungarian and Russian students and/or scientists for the operation of the Paks Nuclear Power Plant, in technical matters related to the peaceful use of nuclear power;
(19) provide nuclear fuel supply, manage the spent fuel (including recycling), and handle nuclear waste based on the provisions of Article 7 of this Treaty.

Article 6 – Obligations of the Hungarian Party

(1) Furnish accurate initial data required for designing and building the new units of the Paks Nuclear Power Plant;
(2) hand over the construction site required for the new units of the Paks Nuclear Power Plant to the Russian Designated Organisation, provide access to the area for the Russian Designated Organisation and the Subcontractors;
(3) submit the design documentation relating to the development of the Paks Nuclear Power Plant for analysis by government specialists, and obtain the subsequent expert opinions;
(4) obtain the appropriate special permits and licences prescribed in the relevant Hungarian and EU regulations, required for implementing the project;
(5) assist the Russian Competent Authority and/or the Russian Designated Organisation and/or the Subcontractors in obtaining the special permits and licences required for the performance of their obligations stipulated in the Implementation Agreements;
(6) prepare its part of the design documentation in the subject areas and within the time frame agreed with the Russian Designated Organisation;
(7) participate in the preparation of the safety report and the environmental impact assessment study for the Paks Nuclear Power Plant with the help of the Russian Designated Organisation;
(8) prepare the technical documentation and manufacture the equipment according to the Implementation Agreements;
(9) supply items and materials of the equipment in compliance with the Implementation Agreements and the technical specifications given in them;
(10) manufacture and deliver the consumables and repair instruments for the equipment in compliance with the Implementation Agreements and the technical specifications provided in them;

(11) inspect and accept the equipment, devices, tools and materials as per the Implementation Agreements;
(12) design and build the infrastructure facilities at the site of the Paks Nuclear Power Plant, including water and electricity supply, access roads and auxiliary facilities, in compliance with the Implementation Agreements;
(13) provide water and electricity supply to the infrastructure facilities in every stage of the implementation of the various projects relating to the Paks Nuclear Power Plant;
(14) prepare and coordinate with the Russian Designated Organisation the quality assurance programs which the Hungarian Designated Organisation is required to perform, in every stage of the implementation of the various projects relating to the Paks Nuclear Power Plant;
(15) ensure that the persons acting for the benefit of the Russian Designated Organisation and the Subcontractors can stay and work in Hungary in compliance with the relevant Hungarian regulations in the periods required for their work;
(16) obtain the import licences for the equipment, materials, works and services required for the implementation of the projects stipulated in this Treaty, and organize customs clearance for the goods in accordance with the approved procedural rules;
(17) provide the workforce required for the implementation of the projects included in this Treaty;
(18) participate in the work preceding commissioning and putting into operation the new units of the Paks Nuclear Power Plant, according to the Implementation Agreements;
(19) coordinate work related to the manufacturing and delivery of equipment manufactured on the territory of Hungary; (the Competent Authorities agree on the list of such equipment and the conditions of their manufacturing and delivery);
(20) develop and implement the safety measures required for the physical security of the construction area of the new units of the Paks Nuclear Power Plant;
(21) guard the equipment, instruments and materials at the site of the Paks Nuclear Power Plant;
(22) provide uninterrupted financing as required for all work, transport and services required for the implementation of the projects included in this Treaty;
(23) consult with the Russian Party about training and re-training the staff required for the Paks Nuclear Power Plant;
(24) participate in basic research and development aimed at the provision of fundamental scientific support to applications and facilities related to the operation of the Paks Nuclear Power Plant;
(25) participate in the training of Hungarian and Russian students and/or scientists for the operation of the Paks Nuclear Power Plant, in technical matters related to the peaceful use of nuclear power.

Article 7 – Fuel supply and the management of spent fuel

1 The Parties shall ensure that their respective Authorized Organisations conclude agreements (contracts) for supplying fuel to the new units of the Paks Nuclear Power Plant, in the form of fresh fuels, in the amount required for the initial fill-up and for subsequent replenishments, and the provision of control rods in the amount required for operation. The supply obligation shall be valid and enforceable for at least twenty (20) years and may be extended.

2 The Parties shall ensure that their respective Authorized Organisations conclude agreements (contracts) for the management of the spent fuels handed over (together with all their components) on the basis of the Implementation Agreement. Management shall mean that the spent fuels are transported to the territory of the Russian Federation for temporary technological storage or technological storage and reprocessing. The spent fuels, or in the case of reprocessing, the nuclear waste shall be stored on the territory of the Russian Federation for a length of time prescribed in the agreement (contract) mentioned in Article 7 paragraph 1 for the purpose of nuclear fuel supply, and subsequently they shall be returned to Hungary.

1.2 GENERAL DESCRIPTION OF LICENSING THE PLANNED NUCLEAR POWER PLANT UNITS

The licensing procedures of the new nuclear power plant units can be divided into the following topics:

1. Radiation protection
2. Environmental protection
3. Water law
4. Nuclear safety
5. Power engineering
6. Technical supervision
7. Architecture
8. Additional licensing and other procedures

As several thousand permits and licences need to be obtained for the complete licensing for the planned nuclear power plant, only the most important permits and licences are listed below.

Radiation protection – *National Public Health and Medical Officer Service (ÁNTSZ) , Chief Medical Officer*

Dose limitation permit

Environmental protection – *South-Transdanubian Environmental and Nature Conservation Supervisory Authority (DdKTF)*

Environmental permit

Water rights –*Fejér County Disaster Control Directorate*

Preliminary water rights license

Water rights implementation permit

Operating license under water rights

Nuclear safety *– Hungarian Atomic Energy Authority*

Site inspection and assessment permit

Site permit

Implementation permit

Construction permit

Occupancy permit for buildings and building structures

System-level permits

Manufacturing permit
Procurement permit
Installation permit
Type permit

Commissioning license

Operation license

Power engineering

Power Plant *– Hungarian Office of Power Engineering and Public Utility Regulation*

Preliminary license for power plants having a significant impact on the operation of the power grid

Implementation permit by the Hungarian Office of Power Engineering and Public Utility Regulation (MEKH)

Electricity generation license issued by MEKH

Grid connection (transmission line) **-** *Baranya County Government Office, Pécs Office of Measures, Standards and Technical Safety*

Permit for preliminary works
Line permit
Operation license

Technical supervision – *Hungarian Trade Licensing Office*

Building permits falling within the competence of the Hungarian Trade Licensing Office (MKEH)

The licences to be obtained from MKEH during implementation (e.g. for pressure vessels, district heating pipes, hazardous waste stores)

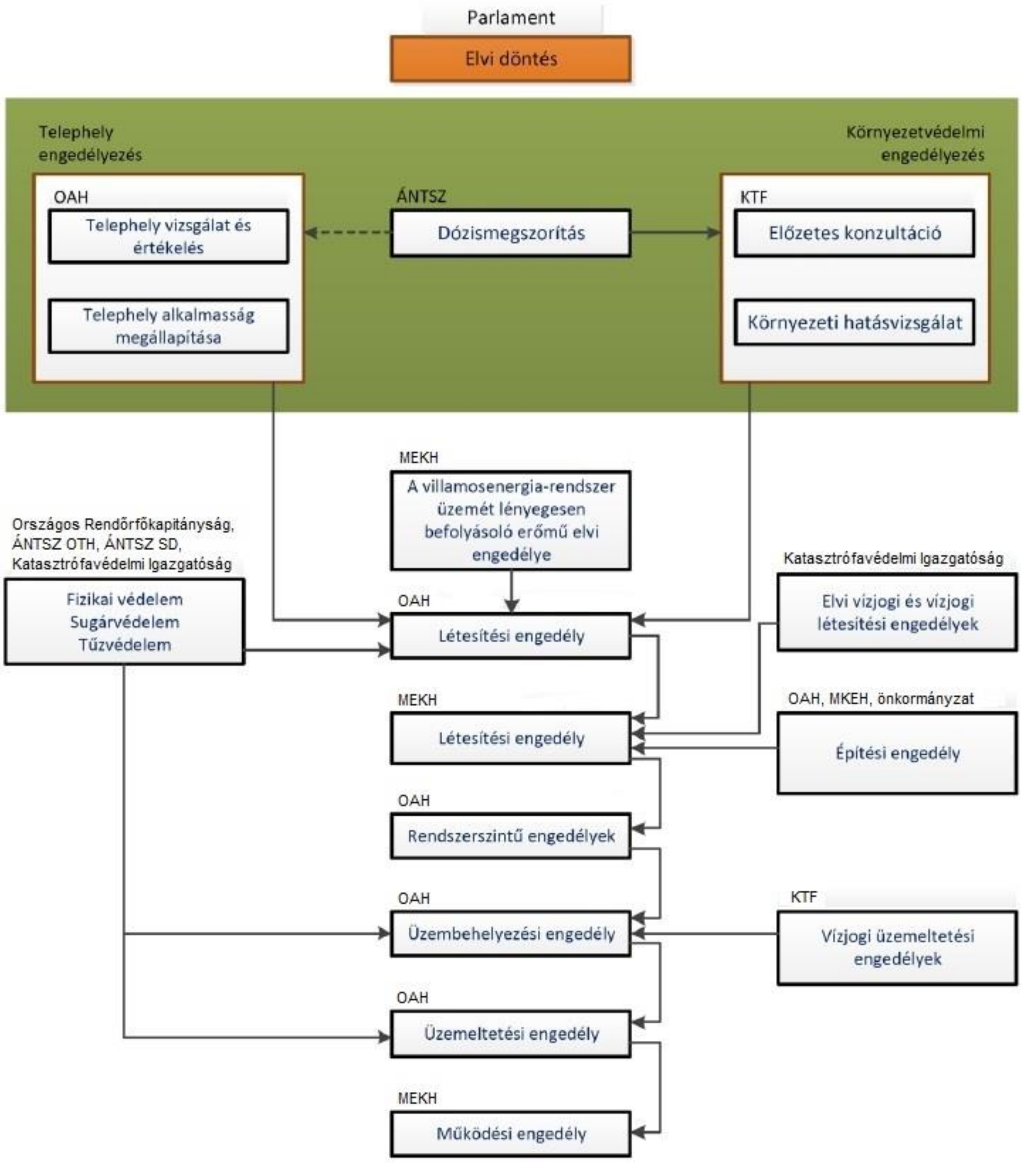
Occupancy permits falling within the competence of MKEH

Architecture – *Municipalities*

Building permits falling within the competence of municipalities

Additional licensing and other procedures

Physical security
Procedure as regulated in Article 37 of EURATOM
Procedure as regulated in Article 41 of EURATOM



Parlament–Parliament
Elvi döntés–Preliminary decision
Telephely engedélyezés–Site permit
Környezetvédelmi engedélyezés–Environmental licence
OAH - Telephely vizsgálat és értékelés– OAH Site inspection and assessment
Dózismegszorítás–Dosage limit
KTF Előzetes konzultáció– KTF Preliminary consultation
Telephely alkalmasság megállapítása–Implementation of site suitability
Környezeti hatásvizsgálat–Environmental Impact Assessment
Országos Rendőrfőkapitányság–National Police Headquarters
ÁNTSZ OTH, ÁNTSZ SD,
Katasztrófavédelmi Igazgatóság–Disaster Control Directorate
MEKH Villamosenergia-rendszer üzemét lényegesen befolyásoló erőmű elvi engedélye–MEKH Preliminary licence for power plants having a significant impact on the operation of the power system
Katasztrófavédelmi Igazgatóság–Disaster Control Directorate
Elvi vízjogi és vízjogi létesítési engedélyek–Preliminary water rights licence and water rights implementation permit
Fizikai védelem, sugárvédelem, tűzvédelem–Physical protection, radiation protection, fire protection
MEKH Létesítési engedély–MEKH Implementation permit
OAH, MKEH, önkormányzat– OAH, MKEH, municipalities
Építési engedély– Building permit
OAH rendszerszintű engedélyek–OAH system level permits/licences
OAH üzembehelyezési engedély–OAH commissioning licence
KTF vízjogi üzemeltetési engedélyek–Water rights operating licences
OAH üzemeltetési engedély– OAH management licence
MEKH működési engedély–MEKH operating licence

Figure 1.2.1–1: Nuclear power plant licensing procedure

1.3 CURRENT STATE OF ENVIRONMENTAL LICENSING FOR THE NEW NUCLEAR POWER PLANT UNITS

Based on Article 66 (1) of Act LIII of 1995 on the general rules of environmental protection, any activity subject to environmental impact assessment can only be started in possession of the relevant final and non-appealable environmental license issued by the environmental authority of the affected region.

The activities subject to environmental impact assessment are listed in Annex 1 to Government Decree No. 314/2005. (XII. 25.) on environmental impact assessment and on the unified procedure of licensing the use of the environment. Section 31 of this Decree deals nuclear power plants without any size limitation.

Thus, as a precondition of implementing the two nuclear power plant units of 1200 MW_e electrical output each, the environmental impact assessment prescribed in Government Decree No. 314/2005. (XII.25.) must be conducted, the findings must be summed up in an environmental impact assessment study, an environmental licensing procedure must be conducted on their basis, and as a result of this procedure, an environmental license must be obtained.

During the environmental licensing of the new nuclear power plant units planned to be erected at the Paks site, the licensing authority as the competent body appointed to deal with matters related to the site of the Paks Nuclear Power Plant is the South-Transdanubian Environmental and Nature Conservation Supervisory Authority (hereinafter: DdKTF).

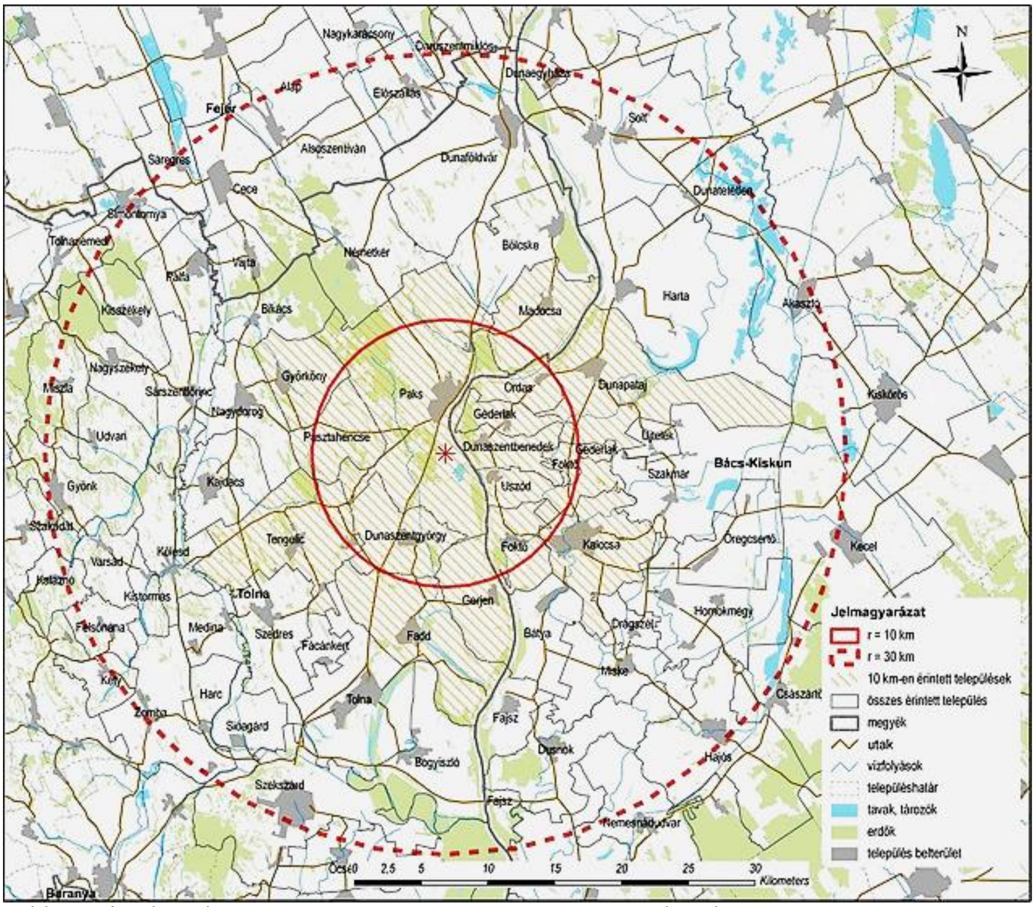
1.3.1 PRELIMINARY CONSULTATION DOCUMENTATION ON THE POTENTIAL 5 UNIT TYPES (PCD)

The environmental licensing procedure started on November 10, 2012 by the submission of preliminary consultation documentation No. 6F111121, entitled “MVM Magyar Villamos Művek Zrt, Implementation of New Nuclear Power Plant Units”, compiled by PÖYRY ERŐTERV Energetikai Tervező és Vállalkozó Zrt. [1-1] [1]

The PCD was prepared on the basis of the specification of the 5 unit types that may be installed on the Paks site.

Areas within a radius of 10 km and 30 km were studied in the PCD.

[1] *Download the PCD from the website of MVM PAKS II. Zrt at:*
http://www.mvmpaks2.hu/hu/Dokumentumtarolo/EKD-HUN.pdf
http://www.mvmpaks2.hu/hu/Dokumentumtarolo/EKD-ENG.pdf



Jelmagyarázat–*Legend*
r = 10 km
r = 30 km
10 km-en érintett települések –communities affected within 10 km
összes érintett település–all affected locations
megyék–counties
utak–roads
vízfolyások–water streams
településhatár–location border
tavak, tározók–lakes, reservoirs
erdők–forests
residential area–település belterület

Figure 1.3.1–1: Areas studied in the PCD (10 km, 30 km)[1-1]

In the course of the procedure conducted by the South-Transdanubian Environmental, Nature Conservation and Water Management Supervisory Authority, the following public administrative authorities made comments:

Public administration agency	file number
Tolna County Government Office, Public Health Administration	XVII-R-084/01550-2/2012
Tolna County Government Office, Public Services Department, Cultural Heritage Protection Department, Szekszárd	II-P-18/184-2/2012
Tolna County Government Office, Plant and Soil Protection Directorate	26.2/1271-2/2012
Baranya County Government Office, Forestry Directorate	II-G-033/8061/1/2012
Baranya County Government Office, Construction Office, State Chief Architect	II-D-15/157-2/2012
Pécs District Mining Inspectorate	PBK/3519-2/2012
District administrator of Pusztahencse – Györköny	629/2012
District administrator of Dunaszentgyörgy - Németkér - Gerjen	625-5/2012
Administrator of Bölcske	1985-2/2012
District administrator of Zomba, Harc and Medina, representative office at Medina	819-2/2012
City administrator of Kalocsa	8350-1/2012/H

Table 1.3.1–1: Public administration organisations that commented on the PCD:

The following parties had not made any comment up to the publication date of the Opinion:

Tolna County Government Office, Paks District Land Registrar
Hungarian Atomic Energy Authority
Titular city administrator of Paks
District administrator of the communities Nagydorog, Bikács and Sárszentlőrinc
District administrator of Kölesd, Kistormás, Kajdacs
District administrator of Foktő and Dunaszentbenedek
District administrator of Géderlak, Ordas and Uszód
District administrator of Harta and Dunatetétlen
District administrator of Homokmégy and Öregcsertő
District administrator of Szakmár and Újtelek
District administrator of Miske and Drágszél
District administrator of Sióagárd and Fácánkert
District administrator of Bogyiszló, Tengelic, Szedres, Fadd, Pálfa, Madocsa, Dusnok, Dunapataj, Bátya, Fajsz, Vajta, Tolna, Cece, Dunaföldvár, Előszállás

DdKTVF requested legal aid from the Road, Rail and Waterways Office of the National Transport Authority for reasons of these having competence; the opinion of the Central Transdanubian Environmental, Nature Conservation and Water Management Supervisory Authority, for reasons of having jurisdiction, and a declaration from the Danube-Dráva National Park Directorate. The affected organisations had not made any comment or given any declaration up to the publication of the Opinion.

Publicity

In the course of the procedure, the Energiaklub Climate Policy Institute and Applied Communications requested acknowledgement of its customer status, and on this basis it requested access to the PCD for inspection and formulating an opinion. Based on the statutes of the club, DdKTVF approved its customer status, and provided the Club with access to the electronic version of the consultation application. Up to the publication of the Opinion, Energiaklub had not expressed its opinion on the PCD.

During the procedure, neither DdKTVF nor the administrators of the affected communities received any comment from the public in relation to the preliminary consultation.

In view of all these, DdKTVF published its Opinion under file No. 8588-32/2012 on December 21, 2012, stating the following:

- implementation of the planned nuclear power plant is an activity subject to environmental impact assessment
- based on the available information, in the course of the preliminary consultation, DdKTVF sees **no condition that would prevent** the environmental licensing procedure in relation to the planned project
- the environmental impact assessment study must be prepared in accordance with the content requirements set forth by DdKTVF and in Annexes 6 and 7 to Government Decree 314/2005. (XII.)
- the specialized parts of the environmental impact assessment study may be prepared by licensed experts.

DdKTVF emphasized that the statements made in the Opinion reflect their position and the observations made by the public administrative organisations may differ.

International procedure

The implementation of a nuclear power plant is subject to the provisions of Government Decree 148/1999. (X. 13.) on the promulgation of the Espoo (Finland) Convention on Environmental Impact Assessment in a Transboundary Context, signed on February 26, 1991, and to Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment, as amended by Council Directives 97/11/EC, 2003/35/EC and 2009/31/EC of the European Community.

In order to start the international procedure, under the Espoo Convention, DdKTVF sent the PCD and its foreign language versions to the Environment Preservation Department of the Ministry of Rural Development, which informed 30 countries of the procedure. The contacted countries and their positions on the procedure are summed up in the following table:

Notified potential participant	Participation	Statement of intention to participate	Observations
Austria	Yes	**wished to participate**	sent comment
Belgium	N/A		
Bulgaria	N/A		
Cyprus	No	did not wish to participate	
Czech Republic	Yes	**wished to participate**	sent comment
Denmark	N/A		
Estonia	No	did not wish to participate	
Finland	N/A		
France	N/A		
Greece	Yes	**wished to participate**	sent comment
Netherlands	N/A		
Croatia	Yes	**wished to participate**	sent comment
Ireland	N/A		
Poland	No	did not wish to participate	
Latvia	N/A		
Lithuania	N/A		
Luxembourg	N/A		
Malta	Yes	**wished to participate**	sent comment
Germany	Yes	**wished to participate**	sent comment
Italy	N/A		
Portugal	N/A		
Romania	Yes	**wished to participate**	sent comment
Spain	No	did not wish to participate	
Switzerland	N/A		
Sweden	N/A		
Serbia	N/A		
Slovakia	Yes	**wished to participate**	sent comment
Slovenia	Yes	**wished to participate**	did not send comment
United Kingdom	N/A		
Ukraine	Yes	**wished to participate**	did not send comment

Table 1.3.1–2: Countries contacted in the course of the international procedure

A total of approximately 15 thousand letters were received from the other countries, which included questions and comments that may be classified into the following 10 topics:

	Topics
1	Comments related to the energy strategy
2	Comments on serious accidents and malfunctions
3	Questions regarding nuclear safety
4	Remarks related to nuclear damage liability
5	Presentation of the effects of the full fuel cycle on the environment
6	Comments on the management of radioactive waste
7	The aggregate impacts of the two power plants, and the effects of the new power plant on the old one
8	Comments on the content of the environmental impact assessment study
9	Economic considerations
10	Comments on other matters

Table 1.3.1–3: Questions asked in the course of the international procedure

The responses given in writing to the individual groups of questions are included in the chapter on international affairs.

1.3.2 Environmental Impact Assessment Study (EIAS) of the Paks II Nuclear Power Plant

The purpose of the environmental impact assessment analysis (EIAS) performed before erecting the Paks II Nuclear Power Plant on the Paks site is to identify and evaluate the environmental impacts of the planned nuclear power plant technology on the individual elements and systems of the environment depending on the condition and load capacity of the design area.

If based on the legislative background and the professional positions, the impact assessment conducted in this system of conditions does not identify any inadmissible use or exposure for any environmental element or system, then *no environmental consideration prevents the installation and operation of the two 1200 MW units.*

1.3.2.1 Design basis condition surveys

In order to provide a baseline for the environmental impact assessment analysis (EIAA), surveys and analyses have been made from 1 March, 2012 on the study areas in the following topics in order to assess the current state of the environment and characterize and appraise the baseline condition on this basis.

I. **Characterisation of the site**

II. **Weather conditions**
   a) Meteorology
   b) Micro- and mezo-climate in the vicinity of the site

III. **Description of the geological formation and the ground and underground aquatic environment**
   a) Description and characteristics of the geological formation
   b) Description and characteristics of the subsurface aquatic environment
   c) Hydrological characterisation of the site
   d) Condition of the Danube and other surface waters
   e) Condition of the river bed and the embankment wall of the Danube

IV. **General characteristics of the ambient radioactivity**

V. **Assessment of noise and vibration exposure**

VI. **Assessment of air quality**

VII. **Wildlife health status**
   a) Exposure of the wildlife to radiation (with human exposure excluded)
   b) Model biomonitoring surveys

VIII. **Population health status**
   a) Definition of the population’s exposure to radiation
   b) Health status of the population living in the surroundings of the site

The baseline measurements, tests and analyses providing the input data for the environmental impact assessment analyses were completed in 2012, thus the relevant closing date is 2012. The closing date of data collection for meteorological analyses differs from this, as it is 2010.

The year 2012 was extremely dry. The findings of biomonitoring surveys reflected the extreme drought recorded in the year reviewed. In order not to record the baseline status of the wildlife under such extremely dry weather conditions, the biomonitoring surveys were repeated in 2013. For this reason high water measurements on the Danube were also carried out in 2013.

In all cases when subsequent onsite surveys were made in 2013 or when analyses were prepared with later dates (e.g. high water measurements on the Danube, analyses of the data from groundwater monitoring wells), the closing date of the affected data is shown for the specialist fields involved.

Study areas

In the course of the baseline surveys conducted during 2012-2013, the area marked by a circle of a 30 km radius from the installation site of the new units was taken as the area for the general status survey of the site environs.

The majority of the surveys conducted by the various specialist fields were conducted within this boundary. The Danube study areas fundamentally differ in various extent in the individual topics, and in certain cases the full length of the Danube in Hungary was surveyed.

As the hypothetical impact is expected to occur within a circle of a 10-km radius, more detailed analyses were conducted on this territory. Hence the baseline status of the Natura 2000 areas outside the Danube was also surveyed on this part of the area.

The detailed biomonitoring surveys and flora mapping were also performed on the hypothetical direct impact area, i.e. within a circle of 3 km radius.

The one-year survey of the baseline air pollution was conducted on the expected direct impact area, adjusted to the location of the points to be protected. The noise and vibration measurements were also performed on these areas.

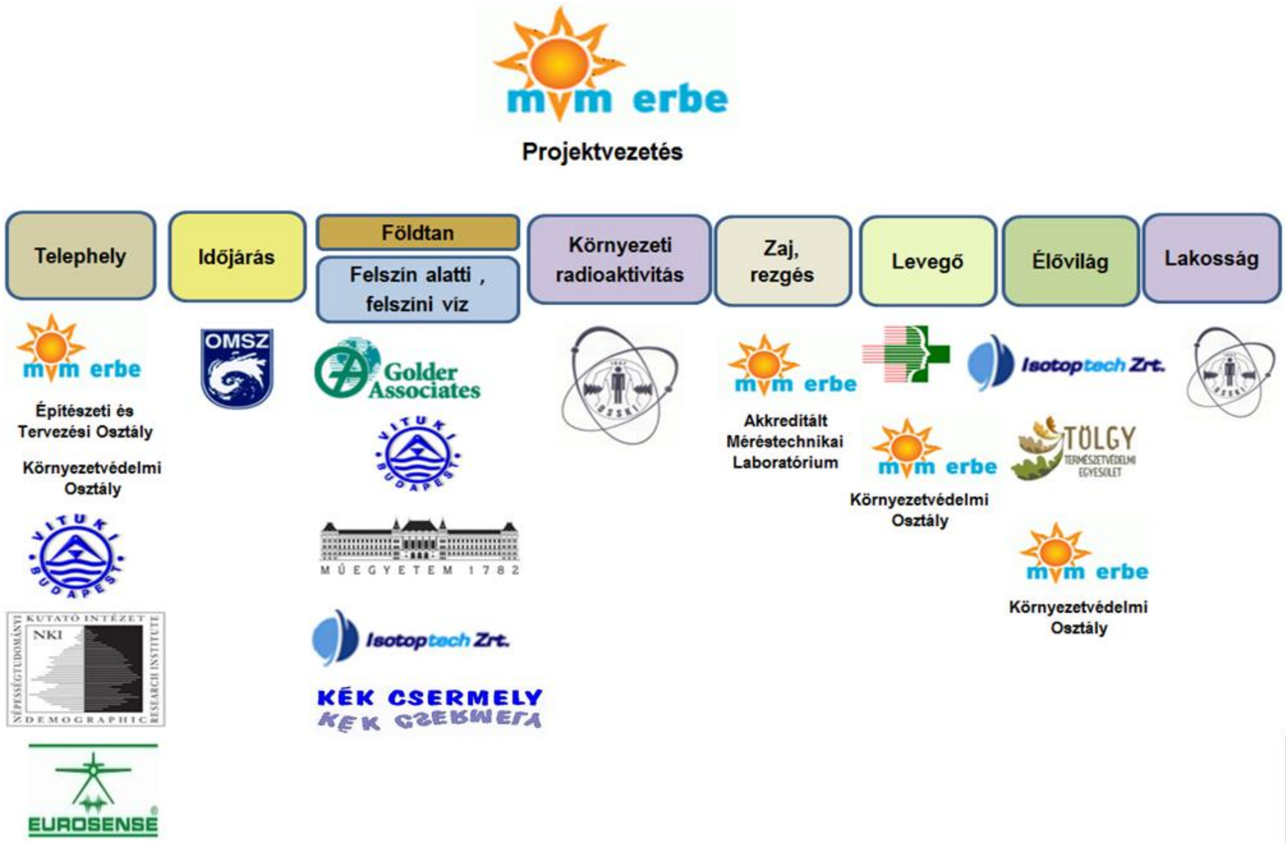
The field surveys aimed at determining the properties of the area, including those for characterizing geological formations and subsurface waters, were also conducted on the planned installation areas and their immediate vicinities.

The various study areas included the following:

	Area surveyed for general characterisation	**Largest estimated impact areas**	
		indirect impact area	**direct impact area**
Designation of the area	r = 30 km	r = 10 km	r = 3 km
Area of the territory	2,826 km^2	314 km^2	28.3 km^2

Table 1.3.2-1: Areas surveyed for the baseline report and their dimensions

The following professional organisations contributed to the elaboration and execution of the survey and evaluation programs that provided the basis of the environmental impact assessment analysis:



Projektvezetés–Project management
Telephely–Site
Időjárás–Weather
Földtan–Geology
Felszín alatti víz–Subsurface water
Felszíni víz–Surface water
Környezeti radioaktivitás–Ambient radioactivity
Zaj, rezgés–Noise, vibration
Levegő–Air
Élővilág–Wildlife
Lakosság–Population
Építészeti és Tervezési Osztály–Department of Architechture and Design
Akkreditált Méréstechnikai Labor–Accredited Metrological Laboratory
Környezetvédelmi Osztály–Environmental Department

	MVM ERBE Zrt. o Department of Environmental Protection o Accredited Metrological Laboratory
	EUROSENSE Légi Térképészeti Kft. (Aerial Mapping Ltd.)
	Central Statistical Office, Population Research Institute
	Hungarian Meteorological Service o Climate Department o Observations Department o Surface Observations Department o Methodology Development Department
	Golder Associates (Magyarország) Zrt.
	VITUKI Környezetvédelmi és Vízgazdálkodási Kutató Intézet Nonprofit Kft.
	VITUKI Hungary Kft.
	Budapest University of Technology and Economics o Department of Sanitary and Environmental Engineering
	Isotoptech Zrt.
	Kék Csermely Kft
	SCIAP Kutatás-Fejlesztési és Tanácsadó Kft
	Frédéric Joliot-Curie National Research Institute for Radiobiology and Radiohygiene o Department of Radiohygiene I o Department of Occupational Radiohygiene o Department of Environmental Public Hygiene o Division of Cellular and Immune-radiobiology
	National Institute of Environmental Health o Environmental Health Department • Air Hygiene Department
	Tölgy Természetvédelmi Egyesület (Oak Nature Conservation Association)

1.3.2.2 Technical conditions and installation site plan for the environmental impact assessment analysis

The Hungarian-Russian intergovernmental convention concluded on 14 January 2014 specified that two new Russian 1200 MW capacity units will be built on the territory of the Paks Nuclear Power Plant with VVER-1200 reactors.

Paks II. Considering data from the already operating Paks Nuclear Power Plant, MVM ERBE Zrt. prepared and laid out the framework of technical conditions and the installation site plan, which makes it possible to assess the environmental impacts of Paks II Nuclear Power Plant and fits the present stage of planning in the depth of its details, based on the data that the supplier of the units provided in advance, data already published from power plants that are being constructed as well as reference data from public databases, presentations and units that have been completed so far, using the figures of highest environmental emissions causing the biggest environmental impact.

On the installation site plan the buildings and structures were arranged on the basis of technological considerations, taking into account the technological units with the known maximum spatial requirement. The specifications for buildings were also given on the basis of data reported by the supplier and taking into consideration the structures of the existing nuclear power plant.

In conformity with procedure presented in the PCD, fresh water cooling was analysed in detail as the applicable cooling method. The points where water is taken from the Danube and where hot water is discharged into the Danube and the methods applied during these operations differ from those presented in the PCD.

In order to identify the appropriate foundation construction technology, the successive layers obtained by drilling performed in recent years for environmental protection purposes provided the starting data for estimating the expected foundation depths. Later on, all the buildings and structures located on the construction site will have to be dimensioned with a view to fire protection and earthquake resistance. For certain buildings other special sizing considerations also need to be taken into consideration, such as sizing to minimize the impact of aircraft crash, sizing for radiation, noise and vibration protection and the creation of salvage facilities to protect the geological formation and subsurface waters.

The construction licensing documentation, including the structural and architectural design of the buildings and structures will be based on the results of drillings performed during the geological exploration programme and during various geological surveys, as well as specific soil mechanical analyses.

Based on the above, as the work proceeds, changes may be made in the arrangement and in the sizes due to functional, building physics, building structure, earthquake resistance and fire protection considerations and the as yet unknown considerations of the supplier of the units.

The volume of the necessary supplies was determined on the basis of the technical solutions, basic specifications and the installation site plan prepared for the completion of the EIAA. The sources of the supplies are not yet known; a specific organisational plan will be prepared when the implementation is planned. The sources and volumes of the supplies and the parameters of movements within the area will be specified in that stage of the planning procedure. In the course of preparing the EIAA, calculations were made for every conceivable route within the circle with a radius of 25 km specified by law.

The process and the circumstances for shutdown, decommissioning, and dismantling Paks II – considering the units' expected life of at least 60 years – cannot be defined at the moment.

1.3.2.3 Environmental Impact Assessment Analysis (EIAA) – Environmental Impact Assessment Study (EIAS)

The several months' long process of environmental impact assessment analysis was performed on the basis of the framework of technical conditions and the installation site plan valid in March 2014.

Thus, from among the versions taken into consideration in the Preliminary Consultation Documentation (PCD), the Environmental Impact Assessment Study (EIAS), which describes and sums up the results of the Paks II environmental impact assessment, analysed the assessability of significant environmental impacts of the Russian nuclear power plant technology selected for implementation, its main connections, cooling water intake, discharge of the heated water into the Danube, and the unit line that carries the electricity generated in the power plant, also taking into account the opinions given on PCD.

The environmental impact assessment study did not address any economic or financial matters related to the installation of the planned units.

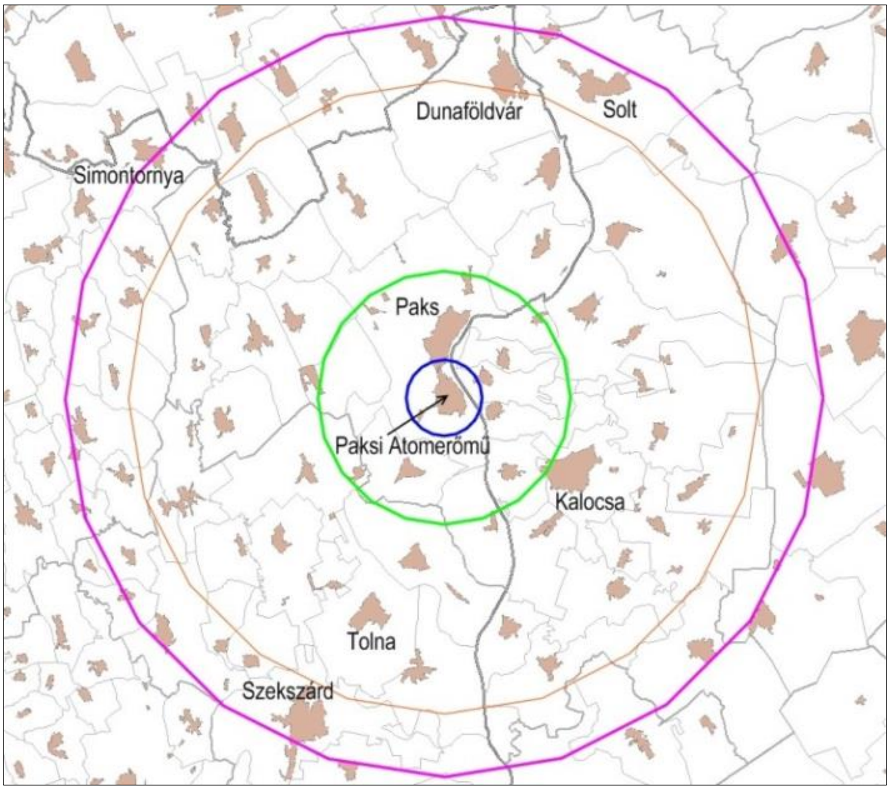
The content of the EIAS is structured on the basis of the general descriptions given in Annexes 6 and 7 of Government Decree 314/2005. (XII. 25.).

 # 6. - on the general requirements for the content the environmental impact assessment study analysis
 # 7. – defining the impact area for the completion of the environmental impact assessment study

Based on the completion of the EIAA and its findings the EIAS was compiled for those parameters that exert the greatest environmental impact on the individual environmental elements and systems – taking into consideration the given basic condition of the Paks site.

The purpose of the Environmental Impact Assessment Analysis is to identify and evaluate the environmental impacts of the power plant technology on the individual elements and systems of the environment depending on the condition and load capacity of the design area, defining the areas affected by the planned project.

If based on the legislative background and the professional positions, the impact assessment conducted in this system of conditions does not identify any inadmissible use or exposure for any environmental element or system, then *no environmental consideration prevents the installation and operation of the two 1200 MW units.*



blue circle: estimated area of directly affected territories
green circle: estimated area of indirectly affected territories
purple circle: area surveyed for general characterisation
orange circle: area of a 25 km radius surveyed to meet a statutory obligation for the impacts of supplies

Figure 1.3.2-1: Various areas surveyed in the EIA [1-2], [1-3]

Areas surveyed in the framework of the EIA and their dimensions

	General description	**Deliveries**	**Largest estimated impact areas**	
	impact area		**indirect impact area**	**direct impact area**
Designation of the area	r = 30 km	r = 25 km	r = 10 km	r = 3 km
Area of the territory	2826 km2	-	314 km2	28.3 km2

Table 1.3.2-2: Areas surveyed during the EIA and their dimensions

1.3.3 OFFICIAL CONSULTATIONS PRECEDING THE ENVIRONMENTAL LICENSING PROCEDURE FOR THE PAKS II NUCLEAR POWER PLANT

In order to clarify the detailed content of the PCD Opinion (DdKTVF: 8588-32/2012) and the impact assessment analysis, a professional consultation took place on 28 January 2014 with the South-Transdanubian Environmental and Nature Conservation Supervisory Authority (DdKTF).

Here are the main conclusions of the consultation:

- The EIAS was prepared for a power of 2 x 1200 MW, without specifying the type of units, taking the most disadvantageous environmental impacts into consideration.
- Concerning surface water the decision issued on PCD contains the following:

  “Base the worst case cooling water sourcing scenario on the actually observed lowest flow values, instead of the average minimum stream flow values.”

  However, analysis of the data available for recent years has made it clear that the highest temperature of water in the Danube does not coincide with the minimum stream flow, therefore the EIAS should be based on the appraisal of real-life, actual circumstances.
- In respect of modelling the exposure of the Danube to heat, the provisions of Decree 15/2001. (VI. 6.) of the Minister for the Environment on radioactive emissions to the air and to waters and on their control shall apply.
- Due to the change in the route of the coolant to be discharged into the Danube, Natura 2000 areas that would have been affected according to earlier plans are no longer affected by the project, consequently, a separate Natura 2000 impact assessment study is no longer needed. A chapter in the EIAS currently being prepared will include the examination of the Natura 2000 territory concerned, in compliance with the requirements for the content of the Government Decree 275/2004 (X. 8.) on areas designated for environmental protection of European significance.
- Other projects that necessitate independent environmental licensing procedures are only mentioned in the EIAS, just as the new M6 highway exit, the port and the roads; their impacts do not need to be evaluated.

1.4 REFERENCES

[1-1] MVM Magyar Villamos Művek Zrt. Implementation of new nuclear power plant units, Preliminary consultation documentation, PÖYRY ERŐTERV Zrt., 01/31/2011

http://gis.teir.hu/arcgis/services/TeIR_GIS/teirgis_corine2006/MapServer/WMSServer

[1-3] http://gis.teir.hu/arcgis/services/TeIR_GIS/teirgis_kozigazgatas/MapServer/WMSServer

2 FORECASTS AND STRATEGIES RELATED TO THE PLANNED PROJECT

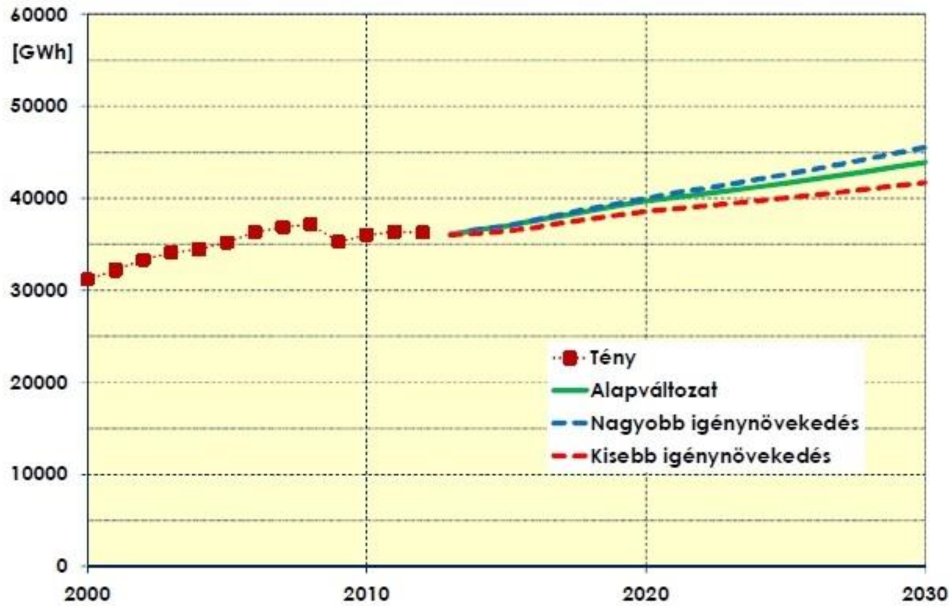
2.1 FORECASTING ELECTRICITY CONSUMPTION IN HUNGARY

Forecasting long-term developments in the electric power system in Hungary is one of the important statutory tasks of MAVIR Zrt. (MAVIR Hungarian Independent Transmission Operator Company Ltd), the system operator. The system operator must assess the expected future electricity consumption, and must monitor changes in the system-level energy balance, power plant capacity, the public electricity network and consumption.

2.1.1 FORECASTING ELECTRICITY CONSUMPTION IN HUNGARY UP TO 2030

Since 2012 forecasts on consumer demand and the presentation of medium and long-term capacity development of the Hungarian electric power system have been published in a separate study, based on the electricity consumption and system load data of the past few years and on the economic growth predictions of various economic research institutes. The short-term forecast for the period up to 2018 relies on MAVIR's short and medium-term forecasts, while the period up to 2030 is forecast on the basis of the predictions made in the National Energy Strategy 2030.

The analysis of the period to 2030, included in MAVIR's 2013 consumer demand forecast contains three different scenarios, as illustrated in Figure 2.1.1-1.



Tény – *Fact*
Alapváltozat – Baseline version
Nagyobb igénynövekedés – Faster increase in demand
Kisebb igénynövekedés – Slower increase in demand

Figure 2.1.1-1: Expected net electricity consumption up to 2030[2-3]

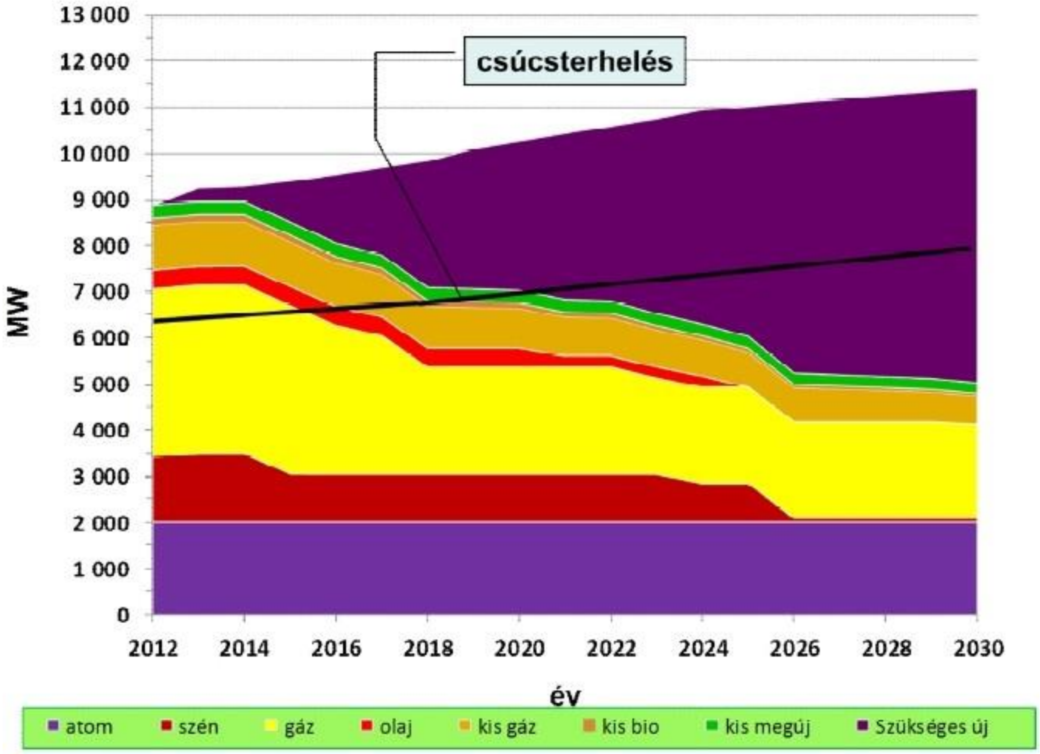
The **baseline version** compliant with the strategic objectives (marked by a green line in the figure) reckons with an annual 1.5% average increase in the net electricity consumption for the period to follow 2014, and then after 2020 this pace will decline slightly. In addition to the baseline version, as an alternative a **faster demand increase version** *(***marked by a blue line)** is also given, with an annual demand growth rate between 1.4–1.7% between 2014 and 2020, slowing to 1.4% by 2030. A **demand course slower** than the baseline version *(***marked by a red line)** expects demand to grow at 1% p.a. between 2014 and 2020, and a gradual decline to 0.8% p.a. by 2030.

The net electric power consumption is expected (according to the baseline version) to be about 40 TW_h and may increase to 44 TW_h by 2030.

The total electric power consumption (including consumption by the Hungarian power plants as well as system loss) may reach 47.6 TW_h in 2020 and – according to the baseline version – 54.7 TW_h in 2030.

From among system loads, peak load has a key significance in terms of supply-side capacity development.

Figure 2.1.1-2 illustrates demand for the expected new electricity generation capacity on the basis of MAVIR's forecast, also taking into consideration the peak load increment and the reserve capacity required on a system level.



Csúcsterhelés–Peak load
atom–nuclear
szén–coal
gáz–gas
olaj–oil
kis gáz–small gas
kis bio–small biomass
kis megúj–small renewable
szükséges új–required new

Figure 2.1.1-2: Required new power generation capacity [2-2]

Based on the forecast, the installed capacity of large power plants will decrease by about 3,500 MW by 2030, comp.ared to 2013 (Table 2.1.1-1). Such a dramatic drop will be caused by the shut-down and scrapping of aging Hungarian power plants. This means that the primary factor driving the construction of new power plants is the shutdown of old power plants, and consumption increase is only a secondary trigger.

	Installed power				
	Year:	2013	2018	2023	2030
Large power plants	MW	7,621	5,712	5,542	4,111
Small power plants	MW	1,458	1,299	1,144	1,009
Total existing power plants	MW	9,079	7,011	6,686	5,120

Table 2.1.1-1: Future installed electric power capacity of all the remaining power plants[2-2]

Renewable energy sources and small power plants can cover only a part of the forecast capacity shortage (nearly 6500 MW in 2030), since the conditions for their installation and use have gradually worsened, and so in the future new projects can only be completed under less favourable conditions, and their competitiveness is doubtful.

The total requirement cannot be met by increasing the import capacity, primarily as this would jeopardize the safety of power supply, and secondly because technical feasibility of building such a cross-border capacity is questionable, and the practical availability of import opportunities is also doubtful, as they depend on regional power plant developments and the current market conditions.

A capacity shortage of this size should be reduced by newly built power plants with a high unit capacity. The construction of a new nuclear power plant is a favourable solution for obtaining a part of the missing resources, as the generation of electric power by a power plant is economically efficient, allows safe power supply over the long term, and the required fuel can be purchased from several sources on a safe basis and at a calculable price.

2.2 NATIONAL ENERGY STRATEGY 2030

The main purpose of the National Energy Strategy approved by Parliament in the autumn of 2011 (Decision No. 77/2011. (X. 14) of Parliament on the National Energy Strategy) is “to make Hungary self-sufficient with regard to energy“.

The document entitled “National Energy Strategy 2030” was published as Annex 1 to Decision No. 77/2011. (X. 14) of Parliament, and contains recommendations for the stakeholders and decision-makers of the Hungarian energy sector for the period up to 2030 and puts the measures recommended for this period in a longer term perspective leading to 2050.

The purpose of the Energy Strategy is to guarantee safe energy supply in Hungary at any time, to increase the competitiveness and sustainable growth of the Hungarian economy in a way that takes account of environmental sustainability, the accessibility of services and prices that are affordable for a broad range of consumers.

The following objectives should be achieved in the course of the power industry’s structural change:

(i) introducing energy efficiency measures encompassing the entire supply and consumption chain;
(ii) increasing the share of low-carbon electric power generation;
(iii) promoting renewable and alternative heat generation;
(iv) increasing the share of low-carbon transport modes.

In order to achieve these goals, according to the document the following tasks must be completed:

- increasing energy saving and energy efficiency,
- boosting the proportion of renewable energy in power consumption as much as possible,
- promoting safe nuclear energy and the electrification of transport using such energy,
- integration of the Central European transmission network and building the required cross-border capacities,
- using Hungary’s coal and lignite stocks in electricity generation in an environmentally friendly manner.

The National Energy Strategy analyses the following scenarios:

Scenario	Assumptions up to 2050			
	New base load power plants		Ratio of electric power from renewables	
	Nuclear	Coal	2030	2050
nuclear – green	2000 MW	0 MW	15%	20%
anti-nuclear – green	0 MW	0 MW	15%	20%
nuclear – green (+)	2000 MW	0 MW	20%	35%
nuclear (+) – green	4000 MW	0 MW	15%	20%
nuclear – coal – green	2000 MW	440 MW	15%	20%
anti-nuclear – green (+)	0 MW	0 MW	20%	35%

Table 2.2-1: Scenarios analysed in the National Energy Strategy

In the interest of developing a competitive, safe and sustainable energy sector, the implementation of the *nuclear* **–** *coal* **–** *green scenario* is preferred in electric power generation, based on the analysis of the possible scenarios. This scenario consists of the following components:

- *long-term maintenance of nuclear power in the energy mix;*
- *sustenance of coal-based power generation for two reasons:*

(i) in an energy crisis (e.g. a sharp natural gas price increase, nuclear accident) this is Hungary's only quickly harnessable reserve;
(ii) in order to prevent the ultimate loss of the relevant valuable professional culture and to maintain the opportunities of increased future use, while complying with the sustainability and GHG emission criteria (the full application of carbon capture and storage as well as clean carbon technologies);

- *in respect of renewable energy, linear extension of the National Renewable Energy Action Program after 2020 with the proviso that efforts must be made at increasing the targeted ratio depending on the load-bearing capacity of the economy, system regulability and technological developments.*

In the framework of the economic impact analysis of the various scenarios formulated in the National Energy Strategy ("Impact Analysis under the National Energy Strategy 2030", Regional Energy Economy Research Centre, 2011), the opportunities of decarbonisation in the Hungarian power generation industry were analysed.

The main conclusions included the following:

- ✓ Decarbonisation of the Hungarian electricity industry is highly capital intensive (while ensuring low-cost operation at the same time), requires production capacities (nuclear and renewable), and the application of carbon capture and storage.
- ✓ Development of the carbon capture and storage technology is a critical factor in the creation of a zero emission energy sector, and in the long term its application needs to be studied for both coal and natural gas fuelled power plants.
- ✓ If the Paks Nuclear Power Plant is implemented, two scenarios – the massive development of renewables – green (+) scenario, and the new nuclear power plant – nuclear (+) scenario – can support a nearly 100% emission reduction after 2030.

2.3 NATIONAL CLIMATE CHANGE STRATEGIES

The relevant international obligations are formulated in the UN Framework Convention for Climate Change, signed in 1992, and its Kyoto Protocol, which was adopted in 1997 and entered into effect in 2005. Preparation of the National Climate Change Strategies (NAS) is required by Article 3 of Act LX of 2007 (V. 28.) on the execution of the UN United Nations Framework Convention on Climate Change and its Kyoto Protocol.

2.3.1 NATIONAL CLIMATE CHANGE STRATEGY, 2008–2025

The strategic framework of Hungarian climate policy was set up by the National Climate Change Strategy (NÉS/NCCS) in line with the National Framework Strategy on Sustainable Development. NCCS has set directions and objectives for the period between 2008-2025.

The core statement of the strategy is the following: „Climate change is a compelling risk threatening Hungarian society and national economy. Based on comprehensive analyses, the expected significant changes of temperature and precipitation, the possible shift of seasons, as well as the increased intensity and frequency of certain extreme weather phenomena are endangering our natural resources, our waters, our biosphere, our forests, and agricultural yields, as well as our built and inhabited environments and the health and quality of life of our population."[2-3]

The scientific basis for NÉS/NCCS was provided by the VAHAVA2 (VÁltozás – HAtás – VÁlaszok, Change–Effect–Responses) research project studying the changes of climate in Hungary.

[2] *VAHAVA ("change – effect – response") Project: Effects of the Global Climate Change on Hungary and Our Responses. Hungarian Academy of Sciences, 2003-2006*

2.3.2 SECOND NATIONAL CLIMATE CHANGE STRATEGY, 2014-2025

Despite the scientific efforts made in the past 30 years, there is a great deal of uncertainty in modelling future climate developments. Various impacts of climate change do not occur at the same time and in a uniform manner in all regions. Recognition of the supposed change trends is also hindered by the natural variability of climate.

The VAHAVA project shed light on the fact that in terms of climate, Hungary's vulnerability is significant even in a European context. The Carpathian Basin is straddling three climate regions: the wet oceanic, the dry continental, and the dry summer/wet winter Mediterranean ones. In this borderline zone, a small but lasting change may result in a significant modification of the annual temperature and precipitation pattern which, on the other hand, may only be estimated with great uncertainty. Based on international and domestic research conducted in the past 10-15 years, the intensification of the greenhouse effect is expected to result in greater temperature increase in Hungary than globally. At the same time, Hungary can expect to see extremes in water levels, including severe droughts and devastating floods within the same year. Growing seasons are expected to be hotter and dryer, aggravated by increased evaporation due to reduced cloud coverage.

Plans in various fields and industries, regardless whether we face natural climate change or one induced by human activity, must take into account the system of conditions shaped by these changes.

Both the probable inducing factors (the emission of greenhouse gases), their probable impacts (the changed climate) and their socio-economic and environmental consequences are transnational, and therefore this complex set of problems can only be addressed by proper international cooperation. The relevant international obligations are formulated in the UN Framework Convention for Climate Change, signed in 1992, and its Kyoto Protocol, which was adopted in 1997 and entered into effect in 2005. Even though efforts made so far have laid the basis for such cooperation in climate policy, in practice they have had little success in moderating the growing risk of global climate change. [2-4]

The European Union pays special attention to climate change management, marked by initiatives like the European Climate Change Program; the Community level regulation of trading with emission quotas; the EU's Emissions Trading System; the system of coordinated efforts introduced in 2013; as well as the ever growing number of climate protection regulations, and increased institutionalisation. These international documents set forth the most important tasks for the domestic climate strategy as well as for the various strategies of the affected industries.

In December 2012, the Parliament modified Act LX/2007 on implementing the UN Framework Convention on Climate Change and its Kyoto Protocol.

The Second National Climate Change Strategy (NCCS-2) was prepared for the period between 2014-2025, with an outlook to 2050. The directions of activities are specified in the Strategy for three different periods:

- *short term: specific tasks scheduled for the period between 2014-2017*
- *medium term: strategic directions scheduled for the period 2018-2025*
- *long term: intervention opportunities in the period between 2025 and 2050.*

2.3.3 HUNGARIAN LOW-CARBON ROADMAP

NCCS-2 includes the Hungarian Low-Carbon Roadmap (HDÚ/HLCR) setting the targets, priorities and courses of action for reducing the emission of greenhouse gases, until 2050. As envisioned by the low-carbon plan of NCCS-2, Hungary will strive to ensure economic competitiveness and growth, social welfare, fighting poverty, as well as to protect our climate, and follow a course of action that gradually leads to implementing an economy with a low carbon emission.

2.3.3.1 Theoretical extreme scenarios

The future emission scenarios of the individual sectors were analysed with the help of a carbon calculator [3] developed by the Department of Energy and Climate Change (DECC) of the United Kingdom. The Hungarian version of the carbon calculator has been developed in a bilateral British-Hungarian cooperation, with the participation of the Department of

[3] *The carbon calculator developed by the Department of Energy and Climate Change of the United Kingdom is an internationally accepted tool used for the flexible modelling of GHG emission in any sector or in all sectors responsible for emission.*

Energy and Climate Change of the United Kingdom, the Hungarian Geological and Geophysical Institute as well as the Embassy of the United Kingdom in Hungary. The model was developed in several phases with the involvement of hundreds of experts. The Ministry of National Development, in cooperation with the National Climate change Centre of the Hungarian Geological and Geophysical Institute, started an open planning process for the Low-Carbon Roadmap in the summer of 2012. For this purpose, 5 working groups were created involving almost 150 experts in the field of energy production, building energetics, industry, transport and agriculture. These working groups cooperated with numerous experts of governmental organisations, professional associations, higher academic institutions, professional civilian organisations and professional background organisations.

In order to be able to estimate the future GHG emission of electric power production, two scenarios have been examined with the help of the carbon calculator.

These scenarios represent the extreme values of emission trends (that is why they are called the minimum and maximum scenarios, respectively), i.e. the scenarios show the theoretical emission reduction potentials.

- Minimum GHG emission scenario = the scenario of highest reduction of GHG emission (min. emission – max. reduction)
- Maximum GHG emission scenario = the scenario of lowest reduction of GHG emission (max. emission – min. reduction)

Factors determining the GHG emission of electric power generation:

- *structure of electric power generation*
- *volume of used electric power*
- *the balance of exports and imports*

Electric power generation methods that have outstanding significance in reducing GHG emission:

- renewables
- nuclear energy
- application of CO2 capture and storage technology

The minimum GHG emission trajectory fundamentally contains the green (+) and atom (+) scenarios of the National Energy Strategy, while in respect of CCS, continuous increase is assumed after 2030 with a total of 1600 MW carbon capture and storage capacity to be build by 2050, of which 500 MW will be based on coal and the rest on natural gas (100 MW being demonstration and 1000 MW generation capacity). The maximum GHG scenario takes only one 100 MW natural gas facility into consideration for demonstration purposes up to 2050.

For the minimum GHG emission scenario, the change in electric power needs at the level of national economy was recorded at the lowest value, and did not take into account the significant electrification of other sectors (transportation, industry), whereas for the maximum scenario this was also included.

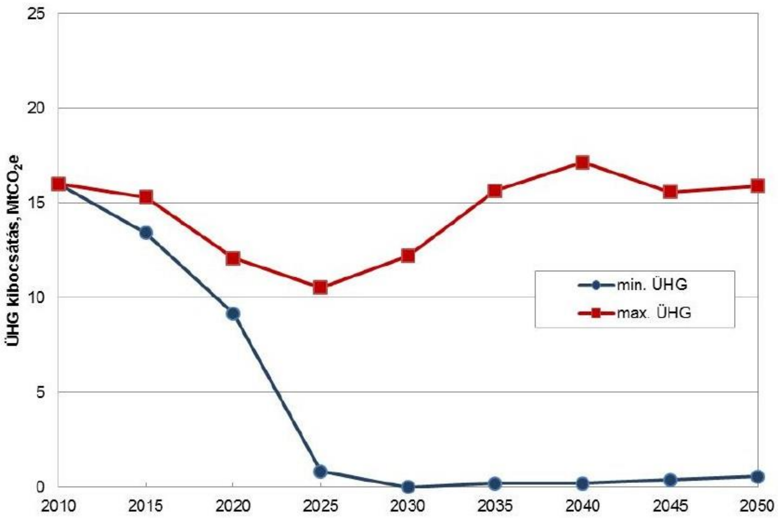
With regard to imported power, the minimum GHG emission scenario assumes growing imports, based on present processes, whereas the maximum GHG emission scenario does not include any import and therefore represents a state of self-sufficiency in terms of energy.

The following table contains the results of summarizing these basic hypotheses.

Scenario	2010	Minimum GHG emission		Maximum GHG emission	
		2030	2050	2030	2050
	GW				
Biomass	0.37	1.4	2.0	0.8	1.2
Coal, CCS	0	0	0.5	0	0
Natural gas, CCS	0	0	1.1	0	0
Coal, without CCS	1.5	0	0	0	0
Nuclear power plant	*2*	*4*	*4*	*2*	*0*
Wind power	0.33	1.2	4.0	1.0	1.4
Water power	0.06	0.07	0.07	0.07	0.07
Geothermic	0	0.22	0.77	0.08	0.14
Solar power	0	0.73	4.70	0.23	0.38
Natural gas	4.6	0	0	10.2	13.2
Mineral oil	0.4	0	0	0	0
Import (TW_h)	5.2	7.0	9.0	0	0

Table 2.3.3-1: Structure of electric power generation according to the individual theoretical extreme emission scenarios[2-4]

Figure 2.3.3-1 illustrates the emission tendencies of the GHG emission scenarios taking into account the above factors.



ÜHG kibocsátás–*GHG emission*
min.ÜHG–min.GHG
max.ÜHG–max. GHG

Figure 2.3.3-1: GHG emissions according to the individual theoretical extreme emission scenarios[2-4]

Major conclusions of NCCS-2

If the minimum GHG emission scenario is achieved, emissions will drop radically already in the short run, primarily due to the increase of renewables and import.

The expansion of the Paks Nuclear Power Plant may be a decisive step in the medium term, resulting in significant reduction in emissions between 2020-30. Due to the temporary parallel operation of the old and new units (as well as to the further increasing import ratio), zero emission could be reached as early as 2030. Without the new units, however, emissions will increase as described in the maximum emission scenario.

The theoretical character of these scenarios is revealed by the fact that such a composition is economically unrealistic. An achieved, but "oversized" total decarbonisation in the case of the minimum scenario is based on several factors:

- the grid connection of the new 2000 MW nuclear power plant
- the application of carbon capture and storage technology
- further massive adoption of renewables
- (imports).

NCCS-2 states that the results and conclusions of the minimum GHG emission scenario harbour energy policy and safety risk, since they rely on the use of a certain technology as well as on imports. Even though imports indeed result in reduced GHG emission, they also involve energy policy risks.

In the maximum GHG emission scenario, two of the three technologies of producing electric power (namely, nuclear technology and CO2 capture and storage) are missing, and the proportion of renewables is also significantly lower. This production structure, however, is only sufficient for maintaining the current level of emission in the long run.

Based on these results, as well as on considerations of energy policy, the study concludes that the decarbonisation of electricity production in Hungary cannot be achieved by using a single technology, but should be built on a production structure using multiple technologies. [2-4]

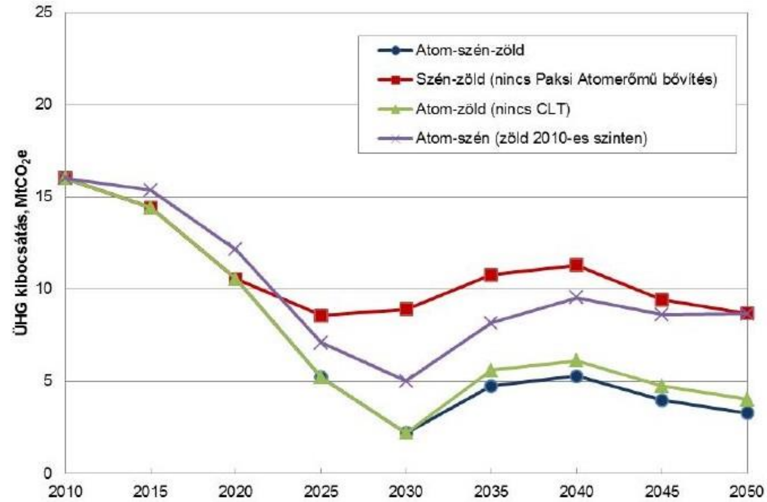
2.3.3.2 Nuclear–coal–green scenario in the National Energy Strategy

As NCCS-2 states: "The National Energy Strategy is the only official strategy of the industry that includes decarbonisation in its vision of the future of energetics."

As concluded by NCCS-2, the structure of electricity production set forth in the National Energy Strategy will result in an emission reduction of about 70% by 2050 (Figure 2.3.3-2).

If the new, modern coal power plant equipped with CO2 capture and storage technology is excluded from production, this will result in only a minor increase of emissions. The two scenarios diverge from 2030, indicating that the coal power plant is supposed to be commissioned after this period. Freezing the volumes of renewables at the 2010 level and excluding the nuclear option basically removes half of the 70% reduction. Without renewables, the effect of nuclear expansion becomes strikingly clear, as the old and the new units operate parallel to each other until 2030, after which the closure of the old units leads to an increase again.

The document declares that the long-term use of nuclear energy in Hungary's energy sector is a basic pillar of decarbonisation.



ÜHG kibocsátás–*GHG emission*
Atom-szén-zöld–Nuclear –coal – green
Szén-zöld (nincs Paksi Atomerőmű bővítés) – Coal-green (no extension of Paks)
Atom-zöld (nincs CLT) – green (no CLT)
Atom-szén (zöld 2010-es szinten) – Nuclear – coal (2010 level green)

Figure 2.3.3-2: GHG emissions based on the various scenarios of the National Energy Strategy[2-4]

2.4 NATIONAL ENVIRONMENTAL PROGRAM

Environmental planning is based on the National Environmental Program. Hungary's National Environmental Program, accepted in 2009 for the period between 2009-2014 (Parliamentary Decree No. 96/2009. (XII. 9.) on the National Environmental Program) describes the general state of the environment, and specifies the goals to be reached, as well as the sequence, timeframe and tools of their achievement.

The National Environmental Program must be reviewed once every six years. Elaboration of the Fourth Environmental Program started in 2012. As stated in the third program related to this period between 2009-2014, the emission of greenhouse gases decreased in Hungary, and so did the amount of waste generated and the volume of water used. Forest coverage increased to 20%, but habitats have split further and soil degradation continued.

The goal of the program for the next six years is going to be the creation of environmental conditions needed for sustainable development. The National Nature Conservation Curriculum is also included in the National Environmental Program. After its public discussion and corresponding modifications, the Program shall be accepted by Parliament.

Regional, county-level and local municipal programs shall be prepared in line with the accepted National Environmental Program The major topics of these will include the following items: the condition and cleanliness of the environment, drinking water supply, energy management, management of green surfaces, rainwater drainage, communal waste water and waste management, protection against noise, vibration and air pollution generated by the population as well as the public services, organisation of local transport facilities, and the issues of countering environmental emergencies.

2.5 REFERENCES

[2-1] Forecast of Consumer Demand in the Hungarian Electric Power System, 2013. MAVIR RTO - 6 -MAVIR-RTO-DOK-0009-00-2013-09-30

[2-2] Medium and long-term supply-side capacity development of the Hungarian Power System, 2013, MAVIR

[2-3] National Climate Change Strategy, 2008-2025

[2-4] Second National Climate Change Strategy 2014-2025, with prospects in the period up to 2050: Hungarian Low-Carbon Roadmap; National Climate Change Strategy; “Partnership for Climate” Awareness Raising Plan; policy discussion material, September 2013

3 A GENERAL GUIDE TO NUCLEAR ENGINEERING

3.1 NUCLEAR ELECTRICITY PRODUCTION IN THE WORLD

In 2012 the total electricity generated in the world was 22,668 TW_h, of which nuclear generation shared 2,461 TW_h, in other words, 10.9% of the electric power was generated by nuclear plants (Source: IEA: Key World Energy Statistics 2014). Nuclear power plants typically have a more pronounced role in the electric power generation systems of developed regions, such as Europe, North-America and Japan.

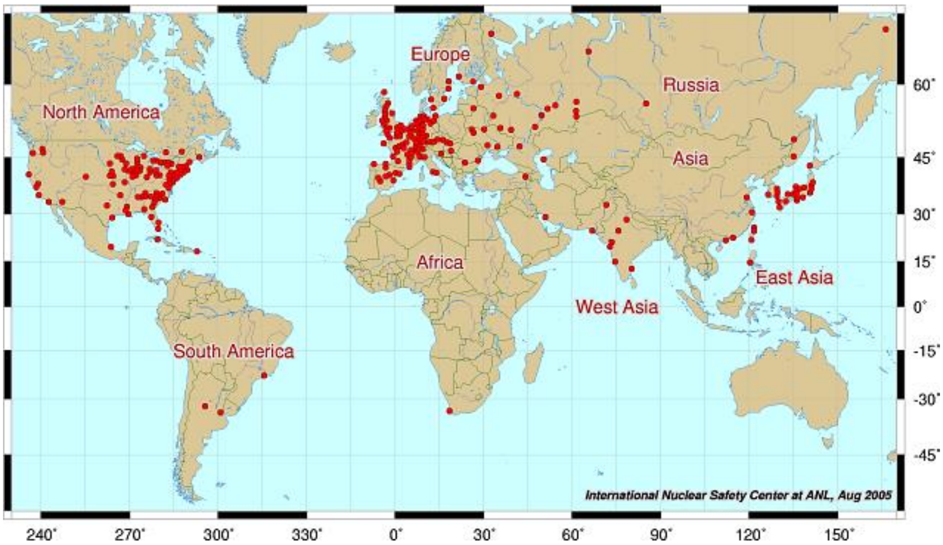


Figure 3.1-1: Geographical location of the nuclear power plants of the world[3-1]

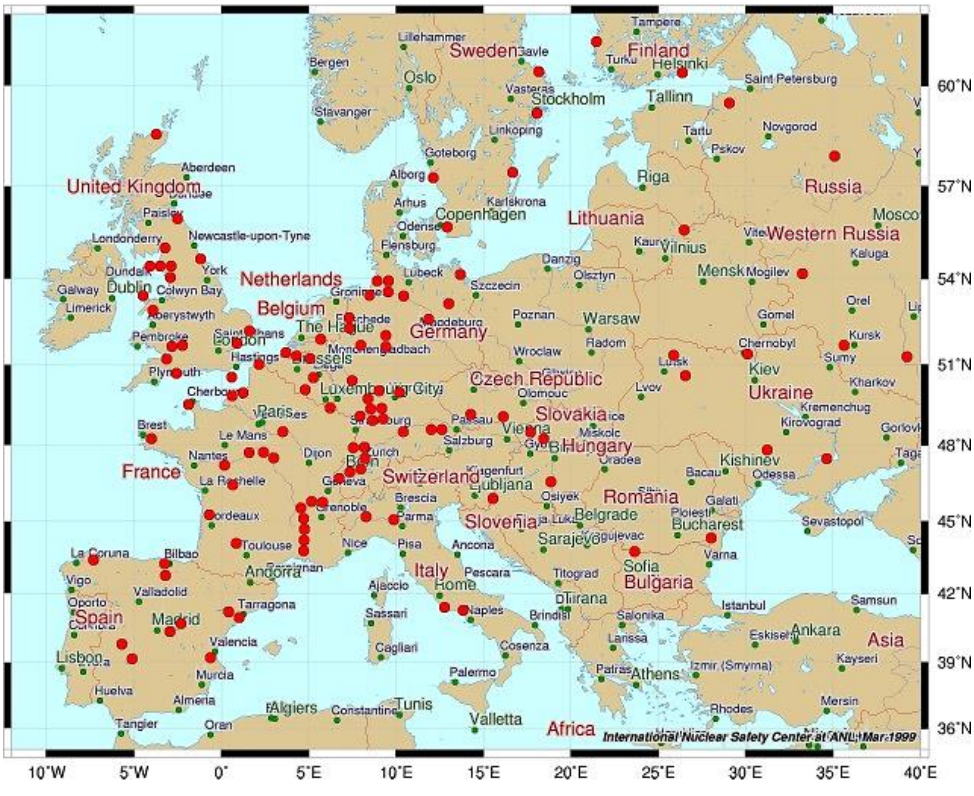


Figure 3.1-2-2: Geographical location of the nuclear power plants of the world[3-2]

3.1.1 OPERATING NUCLEAR POWER PLANTS

The majority (62.2%) of the currently operating 434 nuclear power plant units use pressurized water reactors.

Reactor type		Number of reactors	Total deliverable power [MW]
PWR	Pressurized Light-Water-Moderated and Cooled Reactor	270	249,621
BWR	Boiling water, Light-Water-Moderated and Cooled Reactor	84	78,122
PHWR	Pressurized Heavy-Water-Moderated and Cooled Reactor	48	23,961
LWGR	Light-Water-Cooled, Graphite-Moderated Reactor	15	10,219
GCR	Gas-Cooled, Graphite-Moderated Reactor	15	8,040
FBR	Fast Breeder Reactor	2	580
Total		434	370,543

Table 3.1.1-1: Breakdown of currently operating reactors by type [3-3]

3.1.2 ONGOING PROJECTS

The overwhelming majority of power plants being built are also pressurized water reactors (82.6%).

Reactor type		Number of reactors	Planned total deliverable power [MW]
PWR	Pressurized Light-Water-Moderated and Cooled Reactor	57	57,275
PHWR	Pressurized Heavy-Water-Moderated and Cooled Reactor	5	3,212
BWR	Boiling water, Light-Water-Moderated and Cooled Reactor	4	5,250
FBR	Fast Breeder Reactor	2	1,259
HTGC	Gas-Cooled, Graphite-Moderated Reactor	1	200
Total		69	67,196

Table 3.1.2-1: Breakdown of currently built reactors by type [3-4]

3.2 A GENERAL INTRODUCTION OF PRESSURIZED WATER REACTOR (PWR) UNITS

3.2.1 POWER PRODUCTION PROCESS IN UNITS OPERATING WITH PWR REACTORS

The basis of nuclear energy generation is the regulated and self-sustaining chain reaction based on the fission of atomic nuclei. The power released during the chain reaction is carried away by the coolant and used for the generation of electricity.

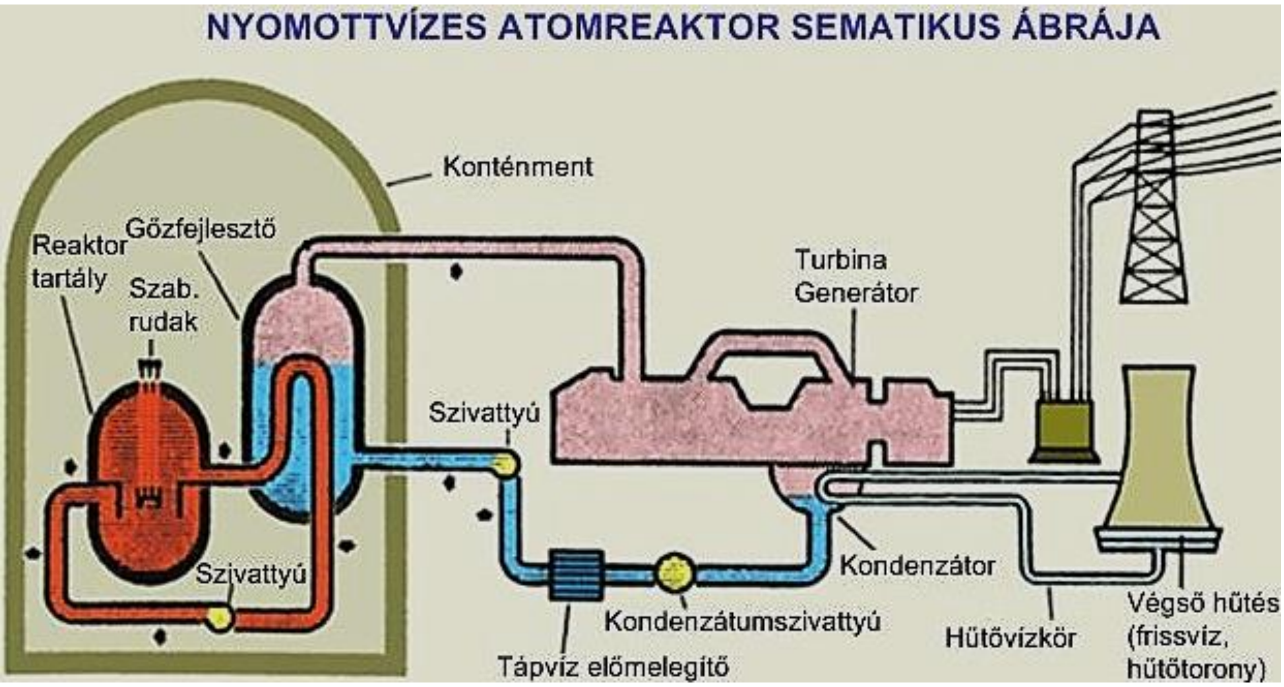
Pressurized water reactors comprise two closed circuits: the primary and the secondary.

The **primary circuit** consists of a pressurized water, light-water cooled and moderated nuclear reactor, the circulating loops (main water circuit), the main circulating pumps, the heat transfer tubes of the steam generators and the expansion tank. The reactor vessel is a cylindrical pressure tank with a hemispheric bottom and a removable hemispheric top, which contains the active zone. In addition to these, the nuclear steam generator, called reactor, connects to numerous other auxiliary systems that have safety functions, improve power plant efficiency and constantly clean the water circuits.

The main water circuit absorbs the heat released in the active zone of the reactor, carries it away and transfers it to the secondary circuit in the steam generators. The main function of the steam generator is to use the heat transferred by the primary circuit and generate steam with the parameters suitable for driving the turbines. This equipment is a cylindrical, vertically or horizontally positioned vessel in an airtight space called containment structure, and contains heat exchanger pipes and a built-in steam separator.

The **secondary circuit** is fundamentally the feedwater-side part of the steam generators, and consists of the main steam system, the various high and low pressure parts of the turbine, the condenser and the feedwater system. The function of the secondary circuit is to transform the energy of the steam produced in the steam generator into rotational motion to drive the generator.

The bled “exhaust” steam is turned back into water (condensed) by the final heat absorber using sea water, river water or, in the case of tower cooling, air.



Nyomottvizes atomreaktor sematikus ábrája–General schematic structure of a PWER reactor
Konténment–Containment
Reaktor tartály–Reactor vessel
Szab. rudak–Control rods
Gőzfejlesztő–Steam generator
Szivattyú–Pump
Turbina generátor–Turbine generator
Tápvíz előmelegítő–Feedwater pre-heater
Kondenzátumszivattyú–Condensate pump
Kondenzátor–Condenser
Hűtővízkör–Coolant circuit
Végső hűtés (frissvíz, hűtőtorony) – Final cooling (fresh water, cooling tower)

Figure 3.2.1-1: General schematic structure of a PWR reactor[3-5]

3.2.1.1 Fuel

The nuclear fuel is located in the active zone[4].

Natural uranium typically consists of two isotopes: ^{235}U, which splits as a result of the low-energy (or “thermal”) neutrons (natural uranium contains only 0.72% ^{235}U), and the isotope ^{238}U, which splits as a result of high-energy (or “fast”) neutrons (99.275% of natural uranium is of this kind). No self-regulating chain reaction can be achieved in a reactor fuelled purely by ^{238}U.

The PWR units fundamentally use enriched uranium-based fuel (UO_2), and the Paks Nuclear Power Plant currently uses this type. This fuel is made by processing and enriching raw uranium.

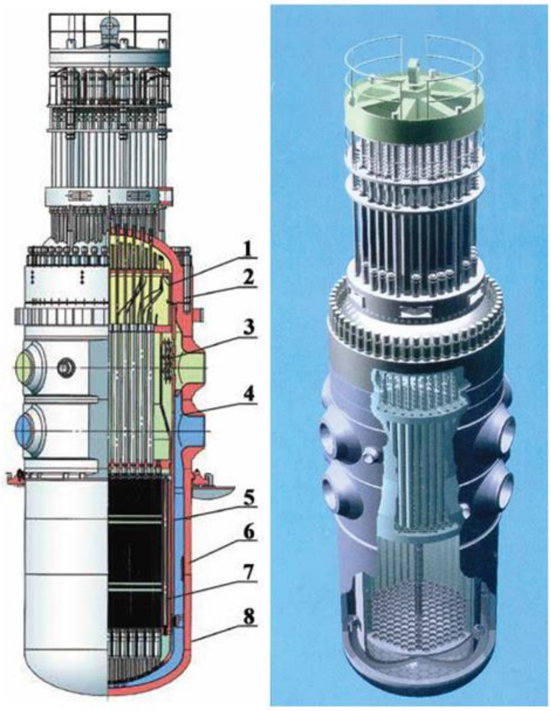
3.2.1.2 Primary circuit

The function of the primary circuit is to absorb the heat generated during the nuclear chain reaction regulated in the active zone of the reactor, to transfer it to the secondary circuit water, and to evaporate the latter in the steam generators in order to produce the dry, saturated steam required to drive the turbines. The primary circuit contains the equipment that are in direct contact with the radioactive substances, i.e. in the case of PWR reactors, the reactor vessel, including the active zone, the circulating pumps, the steam generator, the connection pipes and the required auxiliary systems.

In the active zone of the reactor, heat generation results from several processes:

4 *The area where every condition required for fuel fission and energy generation is met.*

- [5]Fission fragments gradually lose their initially high kinetic energy when colliding with each other, and a significant part of their kinetic energy is transformed into heat power.
- the various kinds of radiations generated during fission are absorbed and their energy is partly turned into heat,
- in the course of radioactive decay, the fragments generate heat.

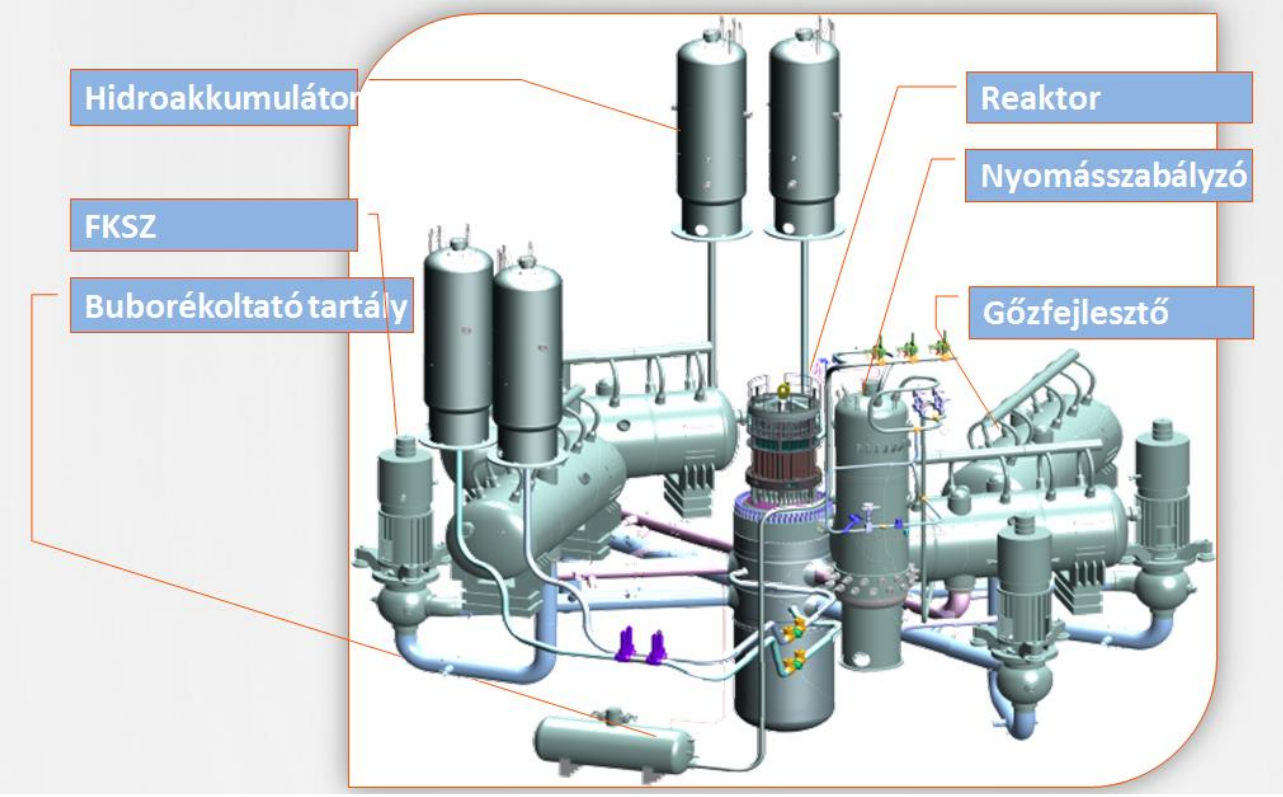


Numbers
1 Instrumentation; 2 Upper unit; 3 Perforation, outlet nozzle; 4 Inlet flange; 5 Reactor pit; 6 Samples 7 Reactor core 8 Reactor vessel

Figure 3.2.1-2: Overview of a nuclear reactor[3-6]

In the case of pressurized water reactors, overpressure is maintained in the primary circuit in order to significantly increase the temperature of the coolant without phase change.

[5]*When a neutron strikes the nucleus of a ^{235}U, it splits the latter into two smaller nuclei (one of the fragments is typically lighter and the other is heavier). During this process, several free neutrons (fission neutrons) are also generated. At their birth, the fragments, e.g. ^{144}Ba and ^{89}Kr, are very fast, however, they transfer their kinetic energy to their immediate environment quickly and warm it up. 80% of the energy released during fission are carried by the fragments. Fragments are radioactive and decay fast.*



Hidroakkumulátor–Hydrological battery
FKSZ–MAP
Buboréktartály–Bubble chamber
Reaktor–reactor
Nyomásszabályozó–Pressurizer
Steam generator–gőzfejlesztő

Figure 3.2.1-3: Theoretical arrangement of a nuclear island [3-6]

3.2.1.3 Secondary circuit

In the secondary circuit the heat generated in the reactor is transformed into kinetic and then electric energy.

The secondary circuit contains those equipment of the power plant which participate in energy transformation and conveyance, but do not contact radioactive substances.

As a significant element of radiation safety, there is a barrier between the two circuits, i.e. the primary circuit is hermetically separated from the secondary one.

As the primary circuit's heat transfer agent flows in the steam generator pipes (heat pipes), steam is generated within the jacket on the secondary side. A part of the heat of the steam generator at the border of the primary and the secondary circuits is transferred to the secondary circuit's working fluid (water), turning the secondary circuit's water into steam. The steam expands in the turbine, i.e. the inherent energy (temperature, pressure, kinetic energy) of the steam diminishes as it moves the turbine. The turbine's rotational energy is then transferred through a drive shaft (with an optional clutch) to the generator, where the driven rotor induces electricity in the stator frame, which in turn generates three-phase electric power. The electric power generated by the generator is transformed by the power plant's transformers into voltage identical with the electricity carried in the connected electric power grid.

The steam leaving the turbine enters the condenser, where an external coolant turns it back to water again. The resulting condensate is then returned by circulating pumps to the place of evaporation. On the other side of the steam generator, the agent in the primary circuit is returned to the reactor vessel, passes the zone and reheats.

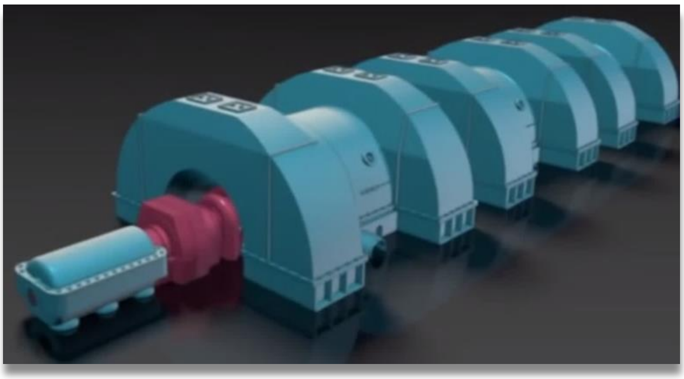


Figure 3.2.1-4: View of a steam turbine unit [3-6]

3.2.2 CHARACTERISTIC FACILITIES OF PWR-TYPE UNITS

3.2.2.1 Facilities in the main building

NUCLEAR ISLAND

Containment: In the interest of safe operation, the primary circuit systems typically (e.g. in the case of the EPR-1600 and the VVER-1200 types) are placed in a double-walled containment. The function of the internal containment is to retain the radioactive substances that escape in the course of any malfunctions foreseen during design, and to transfer the released heat.

The internal containment is surrounded by an external screening building to ensure increased protection against external impacts (e.g. a major earthquake, aircraft, flood).

Safety system buildings: for the sake of multiple redundancy, there are several safety systems in nuclear power plants (e.g. malfunction zone cooler), and the appropriate operation of any single one of them is sufficient for handling malfunctions. In order to provide for an appropriate spatial separation, they are usually placed in separate buildings or building parts.

Auxiliary building: it houses the auxiliary systems of the primary circuit.

Nuclear maintenance facility: a building used for the performance of maintenance related to the primary circuit, and for decontamination.

Waste management building: the liquid and solid radioactive waste generated during unit operation is treated in this building.

Fuel building: used for the management and storage of fresh and spent nuclear fuel

TURBINE ISLAND

Turbine building: The turbine building contains the secondary circuit equipment that transform the heat transferred from the steam generator into mechanical and then electric power, condense the steam that leaves the turbine, and return it to the steam generator.

Water treatment plant: a facility used for the generation of extra water in the quality and quantity appropriate and required for the primary and secondary circuits.

Electric switchboard room: *a building that houses electrical switchboards, control engineering equipment and communication devices.*

Transformer area: *this is the outdoor place of unit transformers and other power plant transformers.*

3.2.2.2 Connected facilities

- ✓ *Spent fuel interim storage:* a building used for the interim storage of the spent fuel generated during the operation of the nuclear power plant (prior to any further processing or final placement without processing)

- ✓ *Diesel generators:* Diesel generators to ensure continued power feed in the case of malfunctions (for an appropriate physical separation, they are placed in different buildings).
- ✓ *Healthcare facility:* a facility that contains the healthcare centre, the primary access system, and the offices required for work with the primary circuit.
- ✓ *Water intake plant:* supplies the industrial water required for the power plant. Most of the water taken from the Danube is used for cooling.
- ✓ *Chemical* depository*:* a building in which the chemicals required for operation are kept.
- ✓ *Storage room for industrial gases:* a building that contains the gases required for operation.
- ✓ *Nuclear maintenance facility:* A building used for the performance of maintenance on the secondary circuit.
- ✓ *Fire service facilities:* a building within the boundaries of the power plant, serving as a branch office of the fire service, and containing the fire water and fire fighting systems.
- ✓ *Electric substation:* ensures transfer of the electric power produced by the generators to Hungary's national grid.
- ✓ *Waste storage: stores the non-radioactive waste generated in the nuclear power plant.*
- ✓ *Civil defence shelters:* protect the operating and hazard control staff during emergencies.
- ✓ *Protected control point* (with reserves): provides a working environment for emergency control in the event of emergencies, and protects the troubleshooting and clean-up staff.
- ✓ *Environmental monitoring systems:* include the system of environmental sampling and measurements.
- ✓ *Infrastructure:* access roads and railway rails to the power plant, drinking water and sewage systems, etc.
- ✓ *Physical security systems: reception desks, access systems, perimeter fences etc.*

3.3 INTERNATIONAL ORGANISATIONS REGULATING AND SUPERVISING NUCLEAR POWER USE

3.3.1 INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

The International Atomic Energy Agency (IAEA) was established on July 29, 1957 to promote the peaceful use of nuclear energy, as well as to control and prevent the military use of nuclear fuels.

IAEA is a specialized institution of the UN, is not directly controlled by any other organisation and reports to the General Assembly as well as to the Security Council of the UN.

Today, IAEA serves as the international platform of scientific and technical cooperation for the peaceful use of nuclear energy. Programmes supported by the IAEA promote research related to the peaceful use and safety of nuclear energy (such as protection from radiation, or materials research). IAEA prepares recommendations on nuclear power and radiological protection. [3-7]

Its publications include the following:

Safety Standards,
Safety Guidelines,
Safety Recommendations,
Safety Requirements

3.3.2 EUROPEAN ATOMIC ENERGY COMMUNITY (EURATOM)

The European Atomic Energy Community (Euratom) was founded in 1958, at the same time when the Treaty establishing the European Economic Community (EEC) was signed. The signatories of the treaty agreed on the peaceful use of nuclear energy as well as on cooperating in the development of the nuclear industry. This meant the coordination of research in the field, as well as the joint formulation of safety regulations and the creation of a common market in all fields related to the use of nuclear energy, including that of the free moving of capital and professional people.[3-8]

3.3.3 NUCLEAR ENERGY AGENCY (NEA)

The European Nuclear Energy Agency (ENEA) was established in 1958, in order to meet the steadily increasing energy needs of post-World War II Europe with nuclear energy. The organisation's name was shortened to Nuclear Energy Agency (NEA) in 1972, in view of the growing number of members from outside Europe. Nuclear Energy Agency (NEA) is a specialized agency of the intergovernmental Organisation of Economic and Cooperation and Development (OECD) set up by industrialized countries.

At present NEA consists of 31 countries from Europe, North-America and Asia. NEA member countries represent 90% of the nuclear capacity installed throughout the world. About one fifth of electric energy produced in member countries comes from nuclear power plants.

NEA maintains close cooperation with the International Atomic Energy Agency (IAEA) and the Environment Directorate-General of the European Committee. [3-9]

Fields of work of the NEA:

Nuclear safety and regulation
Nuclear energy development
Handling of radioactive waste
Radiological protection and health of the population
Nuclear law and responsibility
Nuclear science
Data bank
Public information

3.3.4 INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP)

Ever since its establishment in 1928, the goal of the International Commission on Radiological Protection has been to prevent the harmful effects of and diseases, such as cancer, caused by ionizing radiation, as well as to protect the environment.

ICRP is an independent international organisation with more than two hundred volunteer members from thirty countries of six continents. These members represent the leading scientists and decision makers of radiological protection.

The international system of radiological protection used throughout the world as the basis for radiological standards, legal regulations, programmes and practices, has been developed by ICRP.

This international system of radiological protection is based on the following:

(i) *radiological exposure levels and their impacts according to current scientific knowledge*
(ii) *evaluation*
Evaluation take into account both experience gained during the use of the radiological protection system, and the expectations of society.

ICRP monitors the development of radiological protection and prepares recommendations concerning its basic principles as well as the rules of radiological safety. [3-10]

3.3.5 WORLD ASSOCIATION OF NUCLEAR OPERATORS (WANO)

The World Association of Nuclear Operators (WANO) is a global organisation comprising all companies and countries operating commercial nuclear power plants.

It was established in 1989 in London, and has regional centres in Moscow, Atlanta, Tokyo and Paris.

For its members, WANO promotes access to the best safety and reliability solutions. Understanding the fact that the nuclear industry is as strong as its weakest player, the organisation provides help to its members. WANO is a not-for-profit organisation.

Even though WANO cooperates directly with its members, it is not a regulatory organisation and does not advise them on the selection of the types of reactors to be used. Its highest priority is to ensure safety, therefore WANO promotes effective communication among operators as well as the open and free sharing of information. [3-11]

3.3.6 ORGANISATION OF EUROPEAN NUCLEAR POWER PRODUCERS (EUR)

In Europe, the development and design of power plants equipped with light water reactors used to be national endeavor, complemented by a certain degree of international cooperation. In 1992, 5 European nuclear energy producers (the German and Spanish ones, plus Tractebel, EDF and British Energy / Nuclear Electric) joined forces and established EUR. The organisation is steadily growing and has 17 members at present.

The primary goal of EUR is to lay down the conditions and requirements concerning the development of light water reactors; to promote their harmonisation with relevant international regulations and standards; and to provide solutions for a unified electricity market in Europe. [3-12]

3.3.7 WESTERN EUROPEAN NUCLEAR REGULATORS' ASSOCIATION (WENRA)

The Western European Nuclear Regulators' Association (WENRA) was established in February 1999 by the countries of the European Union using nuclear energy, and Switzerland. The establishment had two reasons:

- nuclear safety became a priority for the expansion criteria of the European Union, and
- each country interpreted the safety requirements of the International Atomic Energy Agency (IAEA) and the treaty of nuclear safety in its own way.

WENRA's main aim is to provide a unified European interpretation of nuclear safety, and to independently supervise the status of nuclear safety in candidate states. With respect to reactor safety, 218 recommendations have been prepared in 18 topics (reference levels), and 81+77 recommendations deal with dismantling and waste management. [3-13]

3.4 NUCLEAR SAFETY

In designing, installing and operating the new nuclear power plant units, the first and foremost priority is to ensure nuclear safety.

3.4.1 BASIC PRINCIPLES OF NUCLEAR SAFETY

Nuclear safety is a key aspect of nuclear power.

Nuclear power plants must comply with three basic safety requirements:

I. The nuclear chain reaction must stop in the case of abnormal operation.
II. When the chain reaction is stopped, the stable and safe cooling of fuel cells must be ensured.
III. The amount of radioactive pollutants released into the environment must stay below allowed levels.

The safety of a nuclear power plant is ensured by applying the principle of defence in depth, with an emphasis on the prevention of emergencies.

The basic principles for and the five levels of such a multi-level protection were developed by the International Atomic Energy Agency. National nuclear safety authorities strive to apply these principles in their own regulations to the maximum possible extent. Multi-level protection is applied in each facility according to its local characteristics.

The following are the basic goals of defence in depth:

- preventing accidents through conservative engineering,
- preventing abnormal operation through constant monitoring,
- preventing the escalation of any abnormal operation and reducing its consequences through *integrated defence devices*,
- ensuring that proper tools and predefined procedures are in place for the management of design extension conditions and for reducing their consequences.

The safety of nuclear power plants is ensured by the complex system of engineering solutions and operating requirements.

Defence in depth defines five hierarchic levels of safety related events, equipment and procedures. Each level is aimed at preventing the occurrence of the next one.

Level	Objective	Implementation
Level I	Preventing abnormal operation	High quality, conservative planning
Level II	Detecting abnormal conditions and preventing abnormal operation	Proper operation of supervisory and control systems
Level III	Management of design-basis emergencies	Safety systems and procedures
Level IV	Management of serious accidents, moderating their severity and easing their consequences	Complementary tools, measurements, actions as well as accident management guides
Level V	Reducing the consequences of radioactive emissions outside the facility	Accident prevention action plans

Table 3.4.1-1: The five hierarchic levels of protection

- ✓ Level I is related to the engineering process, where the power plant must be designed in a conservative manner, with operation and safety reserves, using solutions that minimize the possibility of human error (automation, easy-to-understand and intuitive handling). In this phase, all external events must be defined that should not be able to endanger the operation of the nuclear power plant (earthquakes, extreme weather etc.).
- ✓ Level II is about having those tools and procedures at hand through which the power plant can be kept within the designed operating envelope, so that safety barriers are not crossed. These include continuous measurements (of pressure, temperature, circulation etc.), as well as periodical tests and trials, maintenance work and inspections.
- ✓ Level III involves systems and measures that ensure the operation of safety functions in emergencies included in the design basis conditions). Some events (such as inherent material faults or natural disasters) cannot be prevented even by the most careful engineering, installation and operation. This level involves the automatic stoppage of the chain reaction, while ensuring the continued cooling of the fuel and keeping radioactive emissions below the limit values, for all of which the corresponding safety systems must be set up.
- ✓ Level IV represents very low probability events extending beyond designed-for emergencies. At this level, safety systems cannot completely fulfil their role and there is a risk of zone meltdown and radioactive pollution. Despite their low probability, the severity of possible consequences makes it necessary for nuclear power plants to have the tools that hinder the escalation of such accidents, reduce their impacts and provide time for other measures to be taken (such as delivering additional equipment to the site, helping the population shutter up or move away).
- ✓ Level V kicks in when all previous levels have failed. This involves the escape of significant amounts of radioactive pollutants into the environment, which, in turn, requires the intervention of authorities in accordance with emergency scenarios developed for such events.

BASIC DESIGN PRINCIPLES

- Criteria for choosing the geographical location of the site
- Evaluating the potential dangers of operation
- Defining the design basis and analysing its events

  Fundamental requirements include the following:
  - *Ability to be driven to subcritical state*
  - *Removal of residual heat*
  - *Keeping radioactive emissions under the limit values*
- Minimizing anomalies beyond the design base
- Keeping radiological exposure at the lowest reasonable level

SYSTEM OF ENGINEERED BARRIERS

The ***system of engineered barriers*** serves to prevent radioactive pollutants from getting out into the environment, or reduce their escape. These barriers set up one after the other are designed to block pollutants from spreading further once they escaped from the previous level. The four physical barriers are:

1. the fuel matrix (UO_2),
2. the fuel casing (the airtight casing of the fuel cells),
3. the pressure barrier of the primary circuit (of the reactor vessel and other systems included in the primary circuit),
4. the safety mantle called containment structure (airtight, usually with a double wall).

Üzemanyag mátrix–Fuel matrix
Üzemanyag burkolat–Fuel casing
Primerköri nyomáshatár–Primary circuit pressure limit
Konténment–Containment structure

Figure 3.4.1-1: Engineered barriers in the case of nuclear power plant units [3-6]

DOUBLE-WALLED CONTAINMENT STRUCTURE

The containment structure is a component of outstanding significance for defence in depth, as this is the last barrier in the internal space of the nuclear power plant between radioactive substances and the environment.

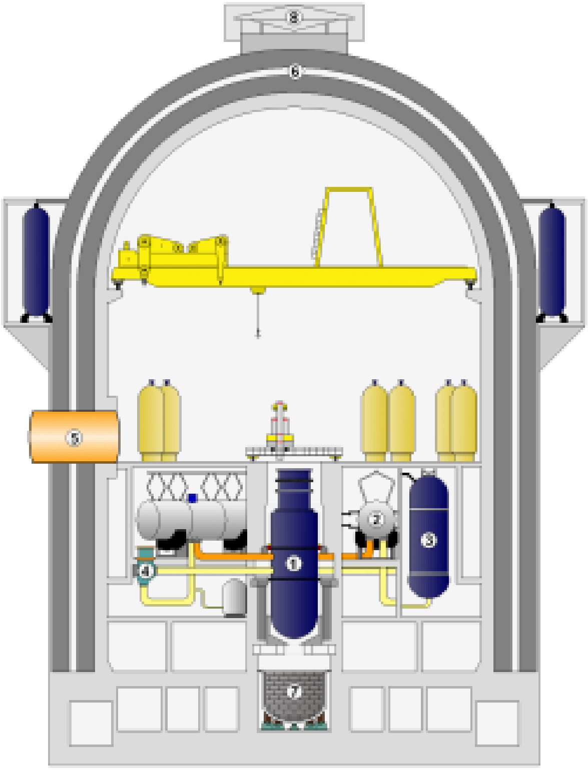


Figure 3.4.1-2: Cross-section of the double-walled containment structure [3-6]

Continuous and safe cooling of the reactor fuel must be ensured under all conditions. In the case of any pipe burst, cooling is ensured by the emergency cooling system, in a passive or active manner. If the pressure falls, the passive cooling system feeds water into the reactor and ensures cooling until the pumps start operation. The active emergency cooling system consists of a high-pressure and a low-pressure part, and reserve coolant is stored in large tanks to replace evaporated water.

Most safety systems need electric power to operate. These systems must remain serviceable in the case of a power loss. This is ensured by emergency Diesel generators, which automatically start when needed and provide uninterrupted power to consumers which are of key importance for the safety of the nuclear power plant.

One structure used widely for handling meltdowns in the course of serious accidents is the “core catcher”: the melting of the concrete below the reactor vessel is prevented by rooms built at the bottom of the core that facilitate the spread of the melt, or by substances are placed under the vessel which the core melt cannot penetrate.

Reinforcement of the containment and maintenance of its structural integrity over the long term are of outstanding significance. Containment integrity is also protected by the procedures applied for the treatment of the hydrogen gas – explosive when it reaches certain concentration if mixed with the containment air – generated in the course of hypothetical grave accidents. In the passive process, the hydrogen released to the air is continuously transformed into water steam by catalytic recombination systems, while in the active process, “hydrogen igniters” are applied, which deliberately ignite the hydrogen gas accumulated in the containment before the hazardous concentration is reached to prevent reaching the explosive concentration.

In most countries current requirements demand that the containment structure withstand even a direct hit by a large passenger airplane.

The most important guarantee for the safety of the nuclear power plant is called ***inherent safety.*** In certain accident situations, inherent physical and heat engineering processes and barriers operate in the reactor which slow down and finally stop unfavourable developments. This inherent safety ***is always ensured irrespectively of the operability of***

the safety and protection systems. This reactor feature is type-specific. Pressurized water reactors, currently the most wide-spread type in the world, fall into this category. The VVER-440 reactors of the Paks Nuclear Power Plant are also of this type. (The other type, developed and built in the former Soviet Union, is the RBMK type, which does not meet all the conditions for inherent safety. The reactors of the nuclear power plant at Chernobyl, where an accident happened on April 26, 1986, belong to this type. It was proven that one of the fundamental reasons of the accident was the lack of inherent safety. For this reason, the disaster of the Chernobyl nuclear power plant does not mean that other types of reactors are unsafe. Due to of the lack of inherent safety, Chernobyl type reactors have been shut down nearly everywhere in the world.)

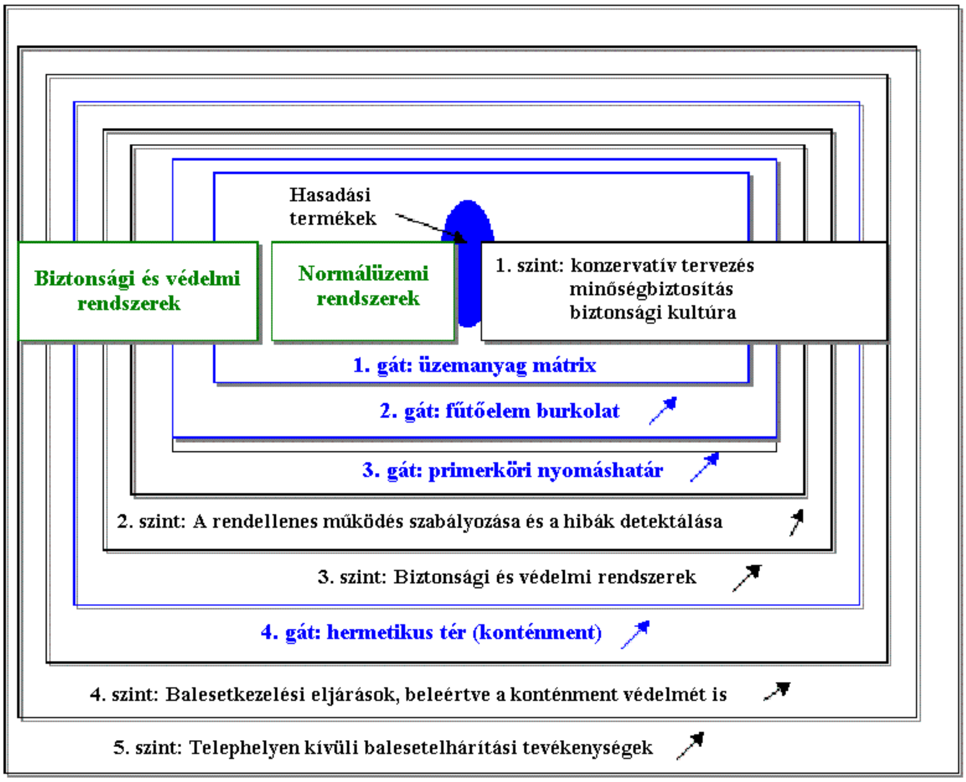
Another important guarantee of protection against nuclear power plant accidents is the application of ***external safety devices***, which prevent the progress and deterioration of various accident situations, and complement inherent safety. Within the framework of these external safety devices, an increasing role is played by the ***passive defence systems***, which can operate without any external power supply.

As a result of the above, nuclear power plants can be built today with a probability of grave accidents affecting the environment being less than 10^{-6} per reactor year. The probability of a potential risk must be kept at the lowest possible level in accordance with the ALARA (As Low as Reasonably Achievable) principle, to guarantee the best reasonably achievable safety.

The fundamental goal of defence in depth is to maintain the integrity of the physical barriers with the help of automatic or manual safety and protection systems against inherent or external events which jeopardize their integrity.

HIERARCHY OF SAFETY AND PROTECTION SYSTEMS

The five levels of defence in depth, applicable to new units, the four physical barriers and the relationship between automatic and manual interventions are plotted in Figure 3.4.1-3.



Hasadási termékek–Fission products
Biztonsági és védelmi rendszerek–Safety and defence systems
Normálüzemi rendszerek–Normal operation systems
1.szint: konzervatív tervezés, minőségbiztosítás, biztonsági kultúra–Level 1: conservative design, quality assurance, security culture
1. gát: üzemanyag mátrix–Barrier 1: fuel matrix
2. gát: fűtőelem burkolat–Barrier 2: fuel casing
3. gát: biztonsági és védelmi rendszerek–Barrier 3: Safety and defence systems
4. gát: hermetikus tér (konténment) –Barrier 4: Containment (airtight area)
4. szint: balesetkezelési eljárások, beleértve a konténment védelmét is–Accident management procedures, including containment defence
5. szint: telephelyen kívüli balesetelhárítási tevékenységek–Accident prevention activities outside the site

Figure 3.4.1-3: Protection barriers, defence in depth levels and the hierarchy of interventions [3-14]

In the case of new units, breakdowns that were previously classified as “design extension conditions” (such as multiple failures) are now part of the design basis. For this reason, the content of the “design extension” category differs between current and new reactors. In the case of the currently operating reactors, in depth protection deals with nuclear fuel mainly in those operational states when the fuel is in the reactor. In the case of new units, it includes all the possible states of the nuclear fuel (including those situations where the fuels are stored in the spent fuel pool).

In the course of developing III^{+} generation reactors, key design objectives included preventing serious accidents and reducing the consequences of extremely low probability accidents. The applied design and technological solutions ensure that no radioactive substances are released to the environment even if serious accidents happen, and thus III^{+} generation units do not have any significant impacts on the population and the environment of the power plant even in the case of serious accidents.

STRESS TEST

Following the accident caused by an earthquake and an unprecedented tidal wave in the Fukushima nuclear power plant, in March 2011 the European Council called for a targeted safety survey in all nuclear power plants of the European Union. In the course of the survey the safety of nuclear power plants and their ability to withstand extreme natural impacts, such as floods, earthquakes and extreme weather conditions were assessed. The operators of the nuclear power plants carried out self-assessment against the specified criteria, and submitted the results to their respective national nuclear authorities for approval. The national authorities prepared national reports, which were assessed by international expert groups, holding on-site consultations in several cases.

Besides those member states of the EU where nuclear power plants are in operation, Lithuania, Ukraine and Switzerland also took part in the surveys. This safety review, which was conducted in 17 countries, ended with the conclusion that European nuclear power plants had sufficient safety reserves and that no deficiencies were found in any of the nuclear power plants that would make it necessary to shut them down. At the same time, the report by the European Commission included several recommendations concerning increased safety, for the implementation of which the member states developed programmes.

The targeted safety survey of the European Union concerning the Paks Nuclear Power Plant also ended with positive findings. The report emphasized good practices that should be modelled by others in several areas. No critical or significant deficiencies were found and some of the recommendations concerned developments in progress.

Based on the recommendations of the stress test, Paks Power Plant developed a programme to enhance safety, with periodic reports on its implementation. Similar programmes are implemented in other power plants of the EU and the relevant reports will be summarized for EU level assessment [3-15], [3-16], [3-17].

SAFETY ANALYSES

Safety analyses using *deterministic* and *probabilistic* methods as well as ***safety reports*** prepared on their basis are of basic importance in nuclear safety licensing.

The most serious consequence of a breakdown in a nuclear power plant is contaminating the environment with radioactive material, which can mainly happen in the wake of serious damage done to the active zone, especially in a meltdown, if the contamination is not held back by the containment structure. Therefore ***Probabilistic Safety Analyses*** (PSA) primarily deal with the probability of ***zone damage***. This requires the examination of all the possible chains of events that can lead to zone damage with the help of deterministic analyses and calculating their probability individually. Their sum total characterizes the safety of the nuclear power plant. This analysis also reveals the weak points of the nuclear power plant from the point of view of safety. The results make it possible to create means and equipment to enhance safety. Safety analyses are conducted at various levels.

The purpose of probabilistic safety analyses is the calculation of the probable frequency of level 1 events (involving zone damage) and level 2 events (involving heavy release of radioactive material). For the requirements applicable to the new units please refer to Chapter 6.13.5.

3.4.2 NUCLEAR SAFETY REQUIREMENTS

Article 2 of Act CXVI of 1996 on Atomic Energy (as effective on July 16, 2014) stipulates:

> *"No. 29 nuclear safety: "Ensuring proper operating conditions, preventing accidents and mitigating the consequences of accidents in every phase of the life cycle of the nuclear facility, to protect employees and the public against the hazards resulting from the ionizing radiation of nuclear facilities."*

Act CXVI of 1996 on Atomic Energy specifies the general requirements for the peaceful use of nuclear energy, and lays down the rights and obligations of the parties involved in nuclear energy use.

The regulations on the execution of the Atomic Energy Act assign the matters related to nuclear safety and nuclear safety licensing to the competence of the Hungarian Atomic Energy Authority.

During the licensing of new nuclear power plant technology, special attention shall be paid to checking whether the planned nuclear power plant to be established meets the nuclear safety requirements.

Nuclear power plants are engineered, and their equipment and safety systems are designed so that even in the case of an accident, the safety of the power plant's surroundings should be guaranteed as much as possible. The continuous supervision of safe operation and the development of measures aimed at increasing safety are basic requirements for the operators. The supervisory authority allows the commissioning and operation of a reactor, or actions to be carried out on certain parts of the reactor only if there is proof that the safe operation of the reactors can be guaranteed.

Compliance with the geological and nuclear safety requirements must be confirmed in the framework of a site licensing procedure to be conducted by OAH on the basis of the Nuclear Safety Regulations (NSR) attached as annexes to Government Decree No. 118/2011. (VII.11.) on the nuclear safety requirements of nuclear facilities and the related activities of authorities.

The OAH determines the adequacy of the site and the geological base data related to the site according to the results of highly detailed assessments. The site assessment programme was developed to meet the latest international requirements (post-Fukushima). The site assessment programme was evaluated by the experts of the International Atomic Energy Agency (IAEA) within the framework of an independent supervisory procedure.

In accordance with the effective statutory regulations, the power plant units envisaged for Paks are to be safe against the impact of large civilian aircraft. There are very stringent quality control criteria in place regarding the equipment and buildings of the power plant units. The supplier of the units undertook to meet the European Utility Requirements (EUR); therefore, they will employ such architectural and other technical solutions during the construction that will ensure the integrity of the facility even against an aircraft impact.

Building and system-level permits are to be acquired for ABOS class buildings, structural parts, systems and system elements that affect the nuclear safety of the nuclear power plant.

Defence in depth

Article 7 (1) of Government Decree No. 118/211 (VII.11.) regulates defence in depth as follows:

(1) Through the application of defence in depth in the nuclear power plant, the exposure of the environment to radioactive materials or radiation must be prevented, and it must be ensured that the accidents involving significant radiation damage as a result of breakdowns or their combinations may only occur with a sufficiently low probability.

(2) Defence in depth ensures that

a) possible human errors or technical failures can be compensated for;
b) the effectiveness of successive embedded barriers is maintained; and
c) both the public and the environment are protected should the efficiency of the barriers not be fully effective.

(3) The 5 levels of defence in depth comprise the following:

a) prevention of abnormal operation and failures;
b) detection of abnormal operating conditions and preventing the expected operational events from turning into design breakdowns;
c) existence of procedures in place for the control of design basis conditions;
d) stopping beyond-design conditions and accidents from worsening, and mitigating their consequences;
e) mitigating the radiological consequences of significant off-site releases of radioactive materials.

(4) The most important elements of defence in depth of a nuclear facility comprise the following:

> *a) design solutions employing adequate safety reserves (this includes choosing the proper site, diversity and redundancy, as well as the application of tried and tested technologies and materials of high reliability), high quality construction and operation;*
> *b) application of control, limiting and protective systems and other surveillance / monitoring solutions, as well as documents controlling operation;*
> *c) safety system ensuring the control of design basis conditions, procedures and training for managing faults;*
> *d) application of complementary measures, tools and accident management guidelines, organisation of practice exercises; and*
> *e) preparation for on-site and off-site emergency response activities.*

(5) In order to maintain defence in depth, the Licensee operates an efficient control system in accordance with the rules defined in Appendix 2, and its management is firmly committed to maintaining nuclear safety and a strong safety culture.

The safety requirements applicable to the nuclear facilities to be installed in Hungary are fundamentally determined in Hungarian statutory regulations. However, it is also advisable to take into consideration the relevant international safety regulations, the IAEA safety directives, the American ASME standards, as well as the EUR recommendations in order to ensure a uniform level of nuclear safety conformance for the different reactor types built in different countries.

A requirement for the envisaged new power plant unit is that during the licensing procedure carried out before erection, the emission recommendations of the unit type for various breakdowns must conform to the domestic and international regulations in effect at the time of licensing.

3.4.3 NUCLEAR POWER PLANT OPERATIONAL STATES – CLASSIFICATION OF VARIOUS ORGANISATIONS

Below we present first the recommendations by the IAEA and the EUR, respectively, and then the recommendations worked out by OAH for the Hungarian statutory regulations environment.

3.4.3.1 International Atomic Energy Agency (IAEA)

Chapter 4 (Principal Technical Requirements), Section 9 of the document entitled "Safety of Nuclear Power Plants: Design, Specific Safety Requirements (SSR-2/1)" issued by the ***IAEA*** reads:

> *Items important for the safety of a nuclear power plant shall preferably be of a design that has previously been proven in equivalent applications, and if not, shall be items of high quality and of a technology that has been qualified and tested.*

Chapter 5 (General Plant Design) formulates the following recommendation regarding the operational states of the power plant:

Operational state		**Accidents**	
Normal operation	Expected operational events	Design Basis Conditions	Design Extension Conditions

Table 3.4.3-1: IAEA proposal for individual plant operational states [3-18]

3.4.3.2 Organisation of European Nuclear Power Producers (EUR)

EUR identifies the following operational states of nuclear power plants. [3-19 [3-20]

Design Basis Conditions				Design Extension Conditions	
Design Basis Condition (DBC)				**Design Extension Condition (DEC)**	
Operational state / Design Basis		Design basis failures			
Normal operation	Breakdown	Low probability design basis failure	Very low probability design basis failure	Complex processes	Serious accidents
DBC1	**DBC2**	**DBC3**	**DBC4**	**DEC1**	**DEC2**

Table 3.4.3-2: EUR classification of operational states [3-19]

Design Basis Conditions (DBC)

DBC1 *– Normal operation*

Normal operational states:

- Normal service, at various output levels.
- Shutdown:
    - Warm shutdown
    - Shutdown due to fuel treatment/transfer
    - Shutdown due to checks performed during servicing or operation, or due to parts replacement/repairs/treatment
- Transient states (transient periods between various output levels, including the time of reaching individual shutdowns)

DBC2 *– Breakdown*

The conditions for DBC2 are the same as for initial failures and equipment failures in the case of which the frequency of occurrence is lower than 10^{-2} per reactor year.

DBC3 **–** Low incidence design basis breakdown

The anticipated occurrence probability of DBC3 events is between 10^{-2} and 10^{-4} per reactor year. The power plant is capable of returning to normal operation once all necessary inspections, repairs and qualifications have been carried out.

DBC4 **–** Very low incidence design basis breakdown

DBC4 events are unexpected during the operational time of the power plant, although their consequences are still manageable. Their frequency is between 10^{-4} and 10^{-6} per reactor year.

Design Extension Conditions (DEC)

DEC1 *- Complex processes*

A DEC event is one that does not involve the meltdown of the fuel in the active zone or in the holding pool, with radioactive emissions remaining within the confines of limit values specified for accidents.

DEC2 - Serious accidents

DEC2 events involve a significant meltdown of the fuel, with processes leading to emission levels that exceed the limit values specified for accidents.

NSR, the domestic classification (Annex 10 to Government Decree No. (118/2011. (VII. 11.), Operational state 163) defines the individual operational states of new nuclear units as follows:

Design Basis (DB)				**Design Extension (DE)**	
Normal operation condition	**Design Basis Conditions***			**Design Extension Conditions***	
		Design basis failures			
Normal operation	Expected operational events	Low incidence service breakdowns	Very low incidence service breakdowns	Design Extension Conditions**	Serious accidents
DBC1	DBC2	DBC3	DBC4	DEC1	DEC2

The expected modification of the NSR in the near future will probably introduce the following changes:

* The term "conditions" will change to "operational states" after the modification.

** The designation of "Design extension conditions" is expected to be changed to: "Complex breakdowns".

Table 3.4.3-3: Breakdown of classification in Hungary, according to the currently effective (October 20th, 2014) NSR

Table 3.4.3-4 below summarizes the abbreviations applied by NSR for individual operational states and the relevant or appropriate EUR abbreviations:

Design Basis (DB)					Design Extension (DEC)	
Normal operation condition	**Design Basis Conditions**				**Design Extension Conditions**	
Normal operation	Expected operational events	Design basis failures			Design Extension Conditions	Serious accidents
		Low incidence service breakdowns	Very low incidence service breakdowns			
DBC1	**DBC2**	**DBC3**	**DBC4**		**DEC1**	**DEC2**
Design Basis Condition (DBC)					Design Extension Condition (DEC)	
DBC1	***DBC2***	***DBC3***	***DBC4***		***DEC1***	***DEC2***

Table 3.4.3-4: Comparison of operational states according to NSR and the EUR

Classification of individual operational states according to the probability of occurrence

Government Decree No. 118/2011. (VII. 11.) assigns frequencies of occurrence (probabilities) to individual operational states, as shown by Table 3.4.3-5 below.

Operational state	Description	Frequency (probability) (f [1/year])
DBC1	normal operation	1
DBC2	expected operational events	$1 > f > 10^{-2}$
DBC3	Low incidence service breakdowns	$10^{-2} > f \geq 10^{-4}$
DBC4	Very low incidence service breakdowns	$10^{-4} > f \geq 10^{-6}$

After the expected modification of NSR the header in the table will change from “Frequency (probability)” to “Event probability”.

Table 3.4.3-5: Classification of operational states according to their probability of occurrence, for new units

3.4.3.3 Normal operation

Normal operation is defined in Annex 10 to Government Decree No. 118/2011. (VII. 11.) (Nuclear Safety Regulations) as follows:

121 **Normal operation**

*"The **operation** of a nuclear facility by observing the Operational Conditions and Limits approved by the nuclear safety authority, including, in the case of nuclear reactors and nuclear power plants, **load changes, shutdown, start-up, fuel rod replacement, maintenance, tests, and other planned operations**.”*

3.4.3.4 Design Basis Condition

Annex 10 to Government Decree No. 118/2011. (VII. 11.) (Nuclear Safety Regulations) defines events falling under the category of design basis conditions as follows:

179 **Expected operational events**

“A process triggered by an initial event included among design basis conditions and analysed according to the principle of single failure, as well as covered by these analyses, which has a significant chance of occurring during the operating time of the nuclear power plant.”

(Note:
The expected modification of the NSR will change the term “nuclear power plant” to “nuclear facility”.)

Another group of operational states is that of service breakdowns. It is advisable to consolidate the notion of service breakdown, along with its associated group of events and conditions.

159 **Design basis breakdown**

"A process triggered by an initial event included among design basis conditions and analysed according to the principle of single failure, as well as covered by these analyses, which has a slight chance of occurring during the operating time of the nuclear power plant, and which results in fuel rod damage limited to the type and extent defined in the designs."

Note:
The expected modification of the NSR will replace the term "nuclear power plant" with "nuclear facility", and "process" with "operational state".

In Annex 3 to Government Decree No. 118/2011. (VII. 11.) (Engineering Requirements of Nuclear Power Plants), in the Chapter entitled "General Design Requirements", among others stipulations No. 3.2.2.3100 and 3.2.2.3300. must be taken into consideration.

Note:
With the expected modification of the NSR, the contents of Section 3.2.2.3100 are expected to change significantly.

The NSR requirement for abnormal operational states falling under the category of design basis condition is as follows:

3.2.2.3700. Design solutions must ensure that after TA2 to TA4 (DBC2 to DBC4) operational states, the nuclear unit achieves controlled state and then safe shutdown state within the shortest time reasonably possible. Controlled state must be achieved within 24 hours, and safe shutdown state within 72 hours at the latest.

3.4.3.5 Design Extension Conditions (DEC)

The relevant definitions given in Annex 10 of Government Decree 118/2011. (VII. 11.) are as follows:

155 **Design Extension Condition**

A process that falls outside the scope of expected operational events and service breakdowns, which cannot be excluded, but may only occur as a consequence of several unrelated failures, and which may have more serious consequences than the processes belonging to the design basis conditions, causing zone damage without meltdown.

Note:
After the expected modification of the NSR, the following section will replace "Design extension breakdown":
94/A. **Complex operating failure (DEC1)**
An operational state that in the case of new nuclear units, falls outside the scope of expected operational events and service breakdowns, which may only occur as a consequence of several, unrelated failures, and which may have more serious consequences than the operational states belonging to the design basis conditions, causing fuel rod damage without meltdown. In the case of existing nuclear facilities, this corresponds to a design extension breakdown.

145 **Serious accident (DEC2)**

A state of accident that involves significant damage to the reactor zone and includes meltdown, which has more serious external affects than design basis and design extension conditions.

Note:
After the expected modification of the NSR, the following section will replace the definition above:
"In the case of a nuclear power plant unit, an operational state that involves significant damage to the fuel rods and has more serious off-site affects than design basis conditions (DBC4) and design extension conditions (DEC1)."

In Annex 3 to Government Decree No. 118/2011. (VII. 11.) Section 3.2.2.3900 under the heading "General engineering requirements" lists the minimum requirements to be taken into consideration in the case of design extension conditions. According to Section 3.2.2.4000, in the case of a new nuclear unit, following a DEC1 operational state (design extension condition), controlled state must be achieved within 24 hours, and safe shutdown state within 72 hours at the latest.

Note:
The text "in the case of a new nuclear unit" will be deleted from the modified NSR version.

In addition, according to Section 3.2.4.0800: in the case of new nuclear units, the cumulative probability of the chain of events with high emissions for each initial operational state and effect – with the exclusion of sabotage – must not exceed the value of 10^{-6}/year. Compliance with the requirements must be verified by level 2 probability-based safety analyses.

3.4.3.5.1 Russian units

In the Russian Federation, the highest level regulation for the peaceful and safe use of nuclear energy is formulated in Act 170-FZ of 1995 (11.21.) on the "*Use of Atomic Energy",* and the highest level regulation applicable to the quality assurance of nuclear power plant equipment is set forth in Act 184 FZ of 2002 (12.07.) on *"Technical Regulations".*

Russian units are engineered in accordance with the normative documents forming a three-level hierarchical structure, issued by the Federal Nuclear and Radiation safety Authority of Russia (GOSZATOMNADZOR). The most relevant of these normative documents are the following:

- NP-001-97 (PNAE G-01-011-97) "General Regulation on Ensuring Safety of Nuclear Power Plants"
- NP 006-98 "Requirements to Contents of Safety Analysis Report of Nuclear Power Plant with VVER Reactors"
- NP-10-98 "Regulation on Establishing and Operating Localisation Systems of Nuclear Power Plants"
- NP-031-01 "Standards for Design of Seismic Resistant Nuclear Power Plant"
- NP-032-01 "Nuclear Power Plant Siting. General safety criteria and requirements."

The EUR summarizes the specifications concerning Russian units in a standalone publication: European Utility Requirements for LWR Nuclear Power Plants (EUR), Volume 3, AES 92 Subset, Chapter 1, AES 92 Plant Description, Part 2, General Safety Design Basis, Revision A, June 2006 Appendix A.

3.5 INTERNATIONAL NUCLEAR EVENT SCALE

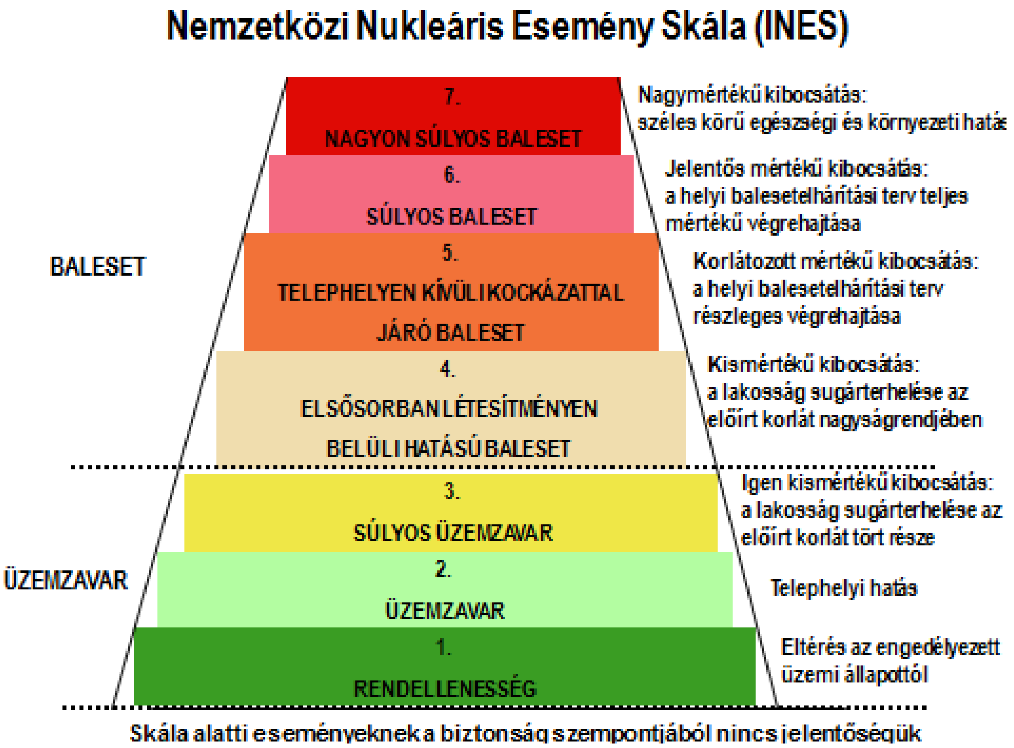
In order to facilitate the spread of information concerning nuclear events and to promptly and **adequately inform the public, the social and political organisations and the media,** the Nuclear Energy Agency (NEA) of OECD and the International Atomic Energy Agency (IAEA) developed the International Nuclear and Radiological Event Scale (INES).

The INES scale is intended to **inform and notify the public using a comparative scale** about the quality and the severity of the events, incidents and accidents and their impacts on safety in nuclear power plants or other nuclear facilities.

The INES scale rates the events on a scale of seven levels.

Deviations from normal operating level are rated by levels 1-7 of the INES scale. There are three levels for incidents and four levels for accidents.

The International Nuclear and Radiological Event Scale is shown in Figure 3.5-1.



Baleset– accident
7. Nagyon súlyos baleset – major accident
Nagymértékű kibocsátás: A helyi balesetelhárítási terv teljes mértékű végrehajtása–Significant emission: widespread health and environmental effects
6. Súlyos baleset –serious accident
Jelentős mértékű kibocsátás: A helyi balesetelhárítási terv teljes mértékű végrehajtása – Significant emission: full implementation of planned local countermeasures
5. Telephelyen kívüli kockázatokkal járó baleset – accident with wider consequences
Korlátozott mértékű kibocsátás: a helyi balesetelhárítási terv részleges végrehajtása – Limited emission: implementation of some planned local countermeasures
4. Elsősorban létesítményen belüli hatású baleset –accident with local conseuqences
Igen kismértékű kibocsátás:a lakosság sugárterhelése az előírt korlát tört része – Minor emission: radioactive exposure of population within specified limits
3. Súlyos üzemzavar –serious incident
Igen kismértékű kibocsátás: a lakosság sugárterhelése az előírt korlát tört része – Very small emission: radioactive exposure of population only a fraction of the specified limits
2. Üzemzavar – incident
Telephelyi hatás – Impact within the facility
1. Rendellenesség –anomaly
Eltérés az engedélyezett üzemállapottól – Diversion from the normal operating conditions
Skála alatti eseményeknek a biztosnág szempontjából nincs jelentőségük – Events under the scale have no safety-related significance.

Figure 3.5-1: International Nuclear and Radiological Event Scale (INES)

The accident that took place in the Chernobyl nuclear power plant in 1986 belongs to level 7 on the INES scale. The accident seriously impacted people’s health and the environment. One of the main considerations in developing the criteria for rating on the INES scale was to clearly distinguish less serious events with less extensive impacts from this very serious accident. Thus, they rated the accident that happened at Three Mile Island (TMI) nuclear power plant in 1979 as level 5 on the INES scale.

Events of any level on the scale have to be reported to the National Nuclear Energy Office (OAH) and the Vienna headquarters of the International Atomic Energy Agency (IAEA) and also to other organs designated by local and international treaties, within the specific timeframe required for the given level.

The events are rated in Hungary by the operative technical personnel of the Paks Nuclear Power Plant according to Guide no. 1.48. of the OAH and based on the Nuclear Safety Regulations (NSR), which is approved by the OAH. The Information and Visitor Centre of the Paks Nuclear Power Plant issues a short, clearly understandable public announcement about all event on the scale and forwards it to the Hungarian Press Agency.

The specific events related to nuclear facilities, categorized on the basis of Article 163 of Appendix 10 of NSR are rated on the INES scale according to a complex set of criteria.

Table 3.5-1 shows the general criteria of the rating of nuclear events and Table 3.5-2 gives examples that illustrate the INES criteria that are used to rate the events at nuclear facilities.

Description and INES level	People and environment	Engineering control in the facility and radiological barriers	Defence-in-depth
Major accident INES 7	Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures		
Serious accident INES 6	Significant release of radioactive material likely to require implementation of planned countermeasures.		
Accident with wider consequences INES 5	Limited release of radioactive material likely to require implementation of some planned countermeasures. Several deaths from radiation.	Severe damage to reactor core. Release of large quantities of radioactive material within an installation with possible exposure of (one or more members of) the population. This could arise from a major criticality accident or fire.	
Accident with local consequences INES 4	Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. At least one death from radiation.	Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	
Serious incident INES 3	Exposure in excess of ten times the statutory annual limit for workers. Non-lethal deterministic health effect (e.g., burns) from radiation.	Exposure rates of more than 1 Sv/h in an operating area. Severe contamination in an area not expected by design, with a low probability of significant public exposure.	Near accident at a nuclear power plant with no safety provisions remaining. Lost or stolen highly radioactive sealed source. Misdelivered highly radioactive sealed source without adequate procedures in place to handle it.
Incident INES 2	Exposure of a member of the public in excess of 10 mSv. Exposure of a worker in excess of the statutory annual limits.	Radiation levels in an operating area of more than 50 mSv/h. Significant contamination within the facility into an area not expected by design.	Significant failures in safety provisions but with no actual consequences. Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. Inadequate packaging of a highly radioactive sealed source.
Anomaly INES 1			Overexposure of a member of the public in excess of statutory annual limits. Minor problems with safety components with significant defence-in-depth remaining. Low activity lost or stolen radioactive source, device or transport package.
No safety significance (Below scale/INES 0)			

Table 3.5-1: General criteria of rating nuclear events [3-21]

Description and INES level	People and environment	Engineering control in the facility and radiological barriers	Defence-in-depth
Major accident Level 7	Chernobyl 1986 Widespread health and environmental effects. Environmental release on a significant part of the zone inventory.		
Serious accident Level 6	Kyshtym, Russia, 1957 Significant release of radioactive material to the environment after the explosion of a high-activity waste container.		
Accident with wider consequences Level 5	Windscale Pile, UK, 1957 Release of radioactive material to the environment, after the reactor zone caught fire.	Three Mile Island, USA, 1979 Severe damage to the reactor zone.	
Accident with local consequences Level 4	Tokaimura, Japan, 1999 Lethal exposure of workers owing to a critical event in the nuclear facility .	Saint-Laurent des Eaux, France, 1969 Melting of one of the fuel channels in the reactor, without release outside the facility.	
Serious incident Level 3	No precedent.	Sellafield, UK, 2005 Release of significant amount of radioactive material contained within the facility.	Vandellos, Spain, 1989 Near-accident due to fire, which stopped the safety system in the reactor.
Incident Level 2	Alucha, Argentine, 2005 Exposure of a worker in excess of the statutory annual limits in an energetic reactor.	Cadarche, France, 1993 Radioactive contamination within the facility into an area not expected by design.	Forsmark, Sweden, 2006 Impaired safety functions and the failure of the emergency power supply system with a common cause in the nuclear power plant.
Anomaly Level 1			Damage done to the operation limits in a nuclear facility.

Table 3.5-2: Examples used for rating events in nuclear facilities to illustrate the INES criteria [3-21]

Table 3.5-1 and Table 3.5-2 do not contain the level 3 incident that took place on 10 April 2003 in unit 2 of the Paks Nuclear Power Plant and the very serious level 7 accident that took place on 11 March 2011 in units 1, 2 and 3 of the Nuclear Power Plant of Fukushima Daiichi in Japan.

.

3.6 REFERENCES

[3-1] http://nuclearinfo.net/Nuclearpower/CurrentReactors

[3-2] http://theresilientearth.com/files/images/european_nuc_plants.jpg

[3-3] http://www.iaea.org/PRIS/WorldStatistics/OperationalReactorsByType.aspx

[3-4] http://www.iaea.org/PRIS/WorldStatistics/UnderConstructionReactorsByType.aspx

[3-5] http://www.animatedsoftware.com/hotwords/nuclear_reactor/nuclear_reactor.htm

[3-6] Sándor Nagy, Nuclear capacity maintenance, licensing duties, Budapest, 04/23/2014

[3-7] http://www.iaea.org/About

[3-8] http://www.euratom.org

[3-9] http://www.oecd-nea.org

[3-10] http://www.icrp.org

[3-11] http://www.wano.info

[3-12] http://www.europeanutilityrequirements.org

[3-13] http://www.wenra.org

[3-14] MVM Magyar Villamos Művek Zrt. Implementation of new nuclear power plant units, Preliminary consultation documentation, PÖYRY ERŐTERV, 04/15/2010

[3-15] Dr László Czibolya, Hungarian Nuclear Forum Association, Paks Nuclear Power Plant III. Safety of nuclear power plants, 2013

[3-16] Dr János Gadó, The concept and measurability of safety

[3-17] Dr Iván Lux, Hungarian Atomic Energy Authority, Legislative system for the regulation of nuclear energy use

[3-18] Safety of Nuclear Power Plants: Design, Specific Safety Requirements (No. SSR-2/1), 2012.02.14. IAEA

[3-19] European Utility Requirements for LWR Nuclear Power Plants (EUR), April 2001

[3-20] Normal, transient and accidental operational modes: control and protection functions identification, CIRTEN, 2012.10.31.

[3-21] Hungarian Atomic Energy Authority, Guide No. 1.48, Guide for the INES rating of nuclear and radiological events. Version number: April 2, 2013

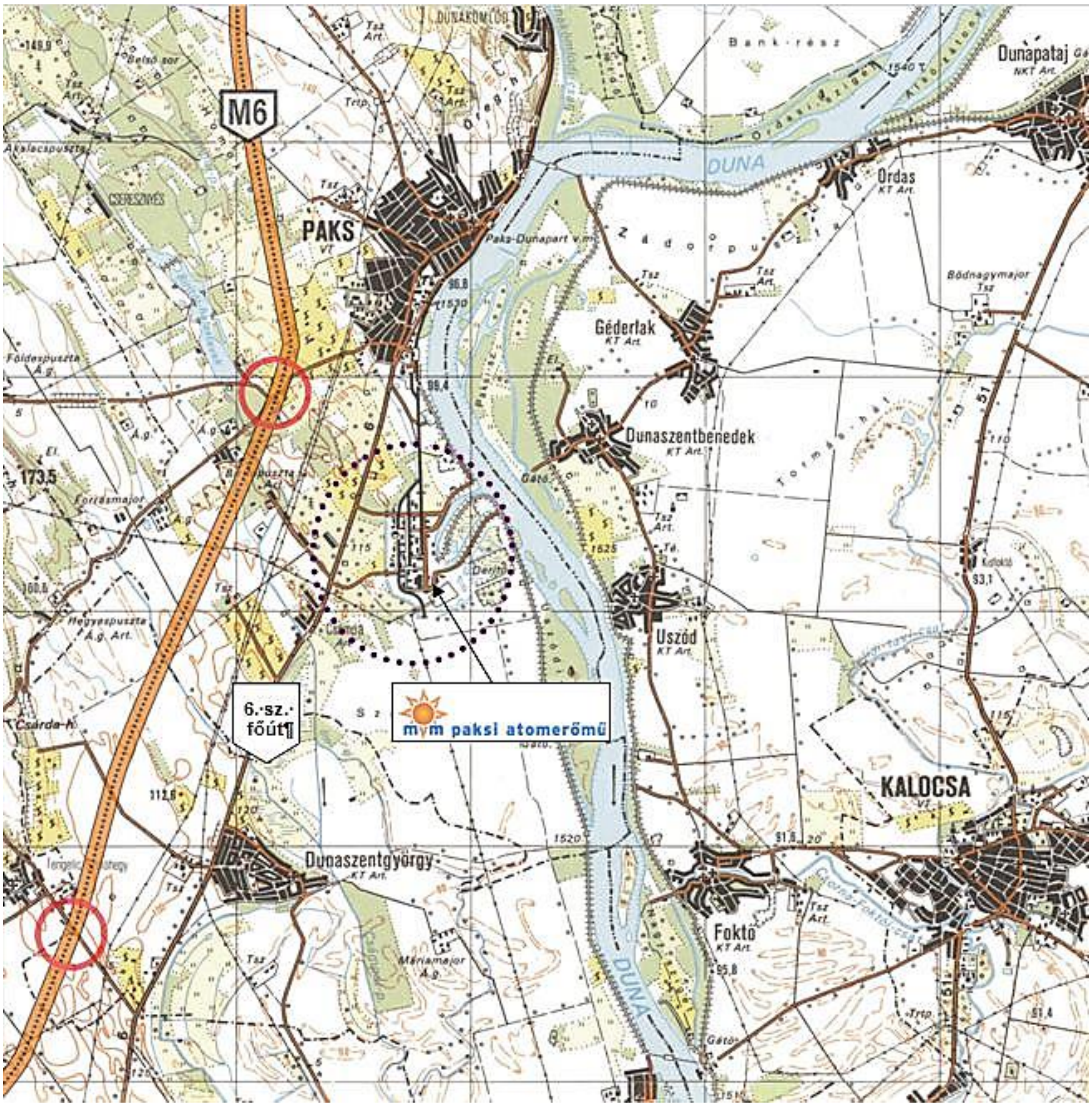
4 DESCRIPTION OF THE PLANNED INSTALLATION SITE

4.1 LOCATION AND OWNERSHIP OF THE PLANNED INSTALLATION SITE

4.1.1 SITE OF THE PAKS NUCLEAR POWER PLANT

The site of the Paks Nuclear Power Plant is located in Tolna County, 118 km south of Budapest.

The plant lies 5 km south of the centre of Paks, 1 km west of the River Danube and 1.5 km east of Main Road No. 6. Figure 4.1.1-1 shows the plant and its immediate environs.



MVM Paksi Atomerőmű – MVM Paks Nuclear Power Plant

Figure 4.1.1-1: Overview map of the Paks Plant [4-1]

The southern border of Hungary lies 75 km as the crow flies from the plant.

The approximately 5,5 km^2 area of the plant can be divided into two parts in terms of its functions and security and protection.

The ***operating area of the Paks Nuclear Power Plant*** accommodates the four units of the current power plant and the related water intake plant and warm water channel as well as the ancillary equipment and systems, the offices and the maintenance and storage facilities providing services for them.

There is a temporary storage facility for spent fuel owned by Radioaktív Hulladékokat Kezelő Közhasznú Nonprofit Kft. (RHK Kft.) on the area adjacent to the operating area.

The maintenance workshops, storage facilities and offices of the contractor institutions and companies needed for the operation of the power plant are located on the ***project area of the Paks Nuclear Power Plant***.

4.1.2 THE AREA OF THE NUCLEAR POWER PLANT AS ENTERED INTO THE LAND REGISTRY RECORDS

According to the map extract dated 22 November 2012 scaled M=1:10 000 containing certified data issued by the Paks District Land Registry Office (Figure 4.1.2-1), the Paks Nuclear Power Plant is registered under a shared topographical lot number (8803/15).

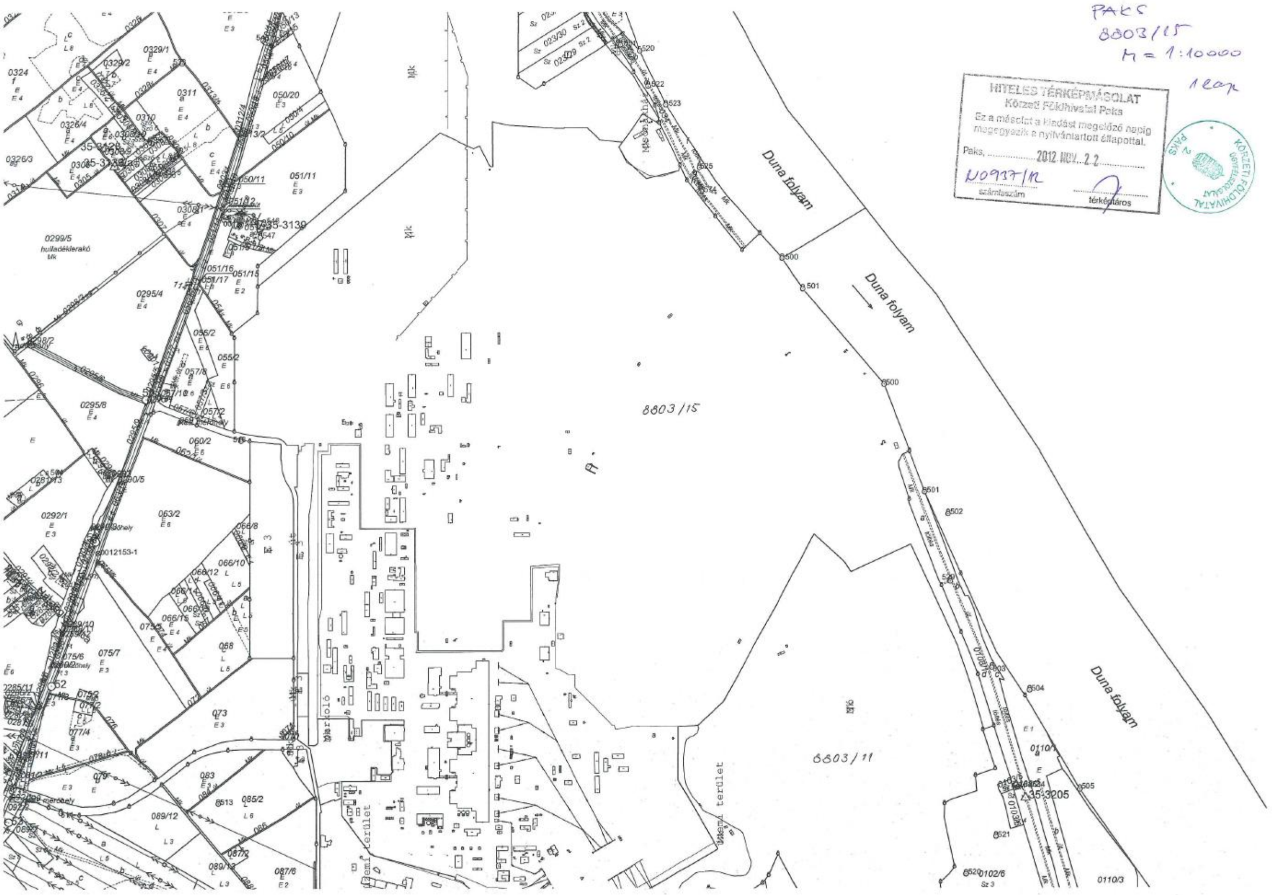
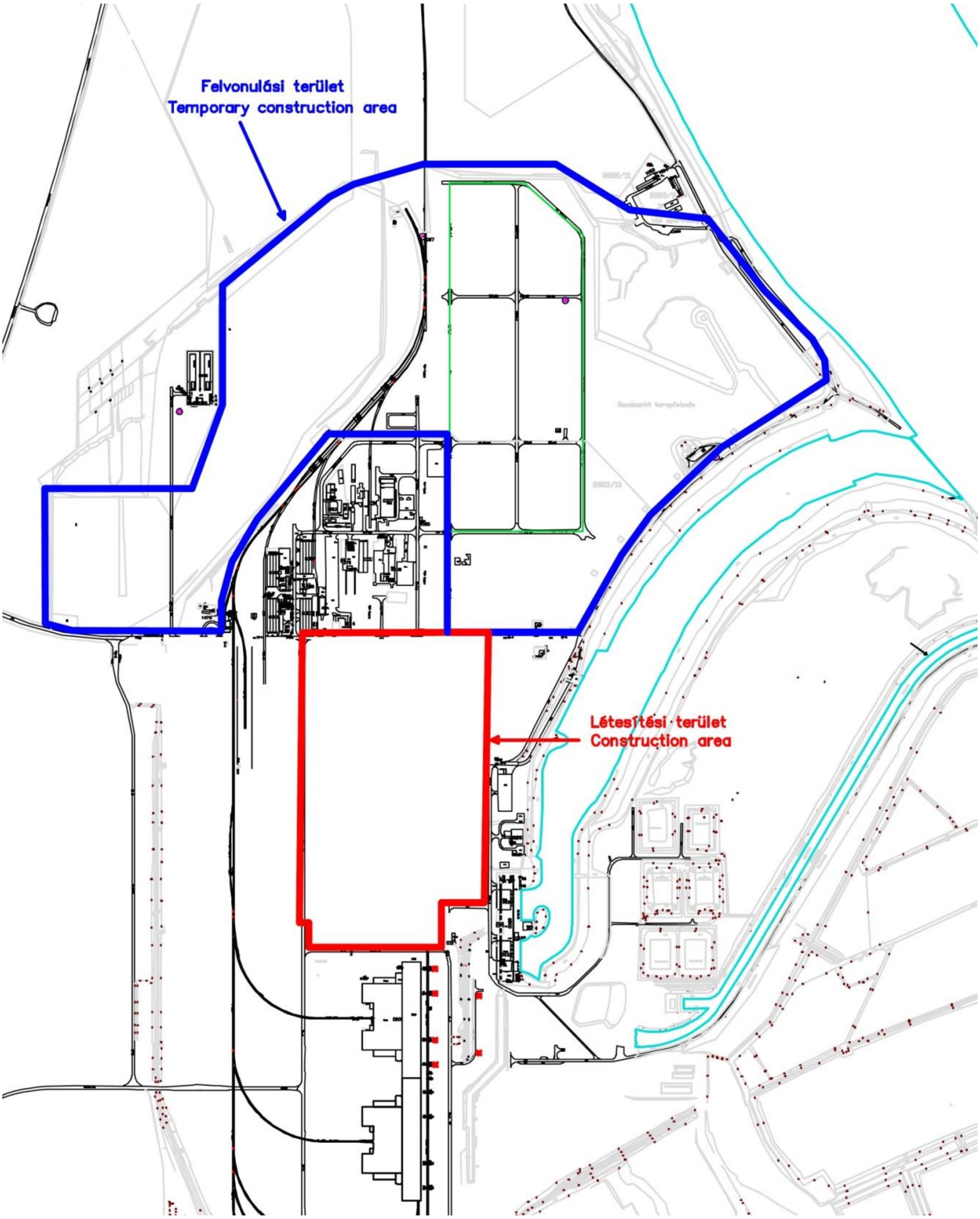


Figure 4.1.2-1: Certified copy as of 22 November 2012 of the map of the area of the Paks Nuclear Plant (the Paks District Land Registry Office) [4-2] [4-2]

4.1.3 INSTALLATION SITE OF PAKS II ON THE SITE OF THE PAKS NUCLEAR POWER PLANT

The areas envisaged for the new units are those north of the current units; the area delineated by the red line will be the operating area of the new units and the one delineated by the blue line will serve as a temporary construction site.



Legend
Red line: operating geographical scope
Blue line: preparatory area

Figure 4.1.3-1: The Paks site with the location of the planned new nuclear power plant

The total area is 105.8 ha, of which operating facilities and the temporary construction will occupy 29.5 ha and 76.3 ha, respectively. The operating area will accommodate the power plant units, the auxiliary equipment and systems providing support as well as other buildings, and the temporary construction site will offer a suitable location for construction in the implementation phase.

Figure 4.1.3-2: Site of the planned units [4-3]

4.2 INFRASTRUCTURAL CONNECTIONS OF THE INSTALLATION SITE[4-4]

4.2.1 TRANSPORT AND ACCESSIBILITY

A task of major importance in the preparatory phase of the investment is studying the accessibility of the designated development area and the feasibility of the supply of a large amount of equipment. The area earmarked for the construction of the new units is accessible by road, rail and water; however, the physical condition of the current infrastructure does not make or only partially makes daily commuting or the supply of a large amount of equipment possible in the installation period. The upgrade (development) of the infrastructure is of key importance among the other upgrades related to the investment and is slated for implementation during the preparatory phase of the investment.

4.2.1.1 Road connections

Both the operating and the temporary construction sites of the new nuclear plant described in the previous section are accessible via the M6 motorway (Paks southern exit) and Main Road No. 6. There are separate driveways leading to the northern gate and the southern gate of the nuclear power plant. However, it is inevitable that the current infrastructure be developed. Towards this end, the following opportunities are available:

Several options for accessibility by road have been studied in advance:

- ✓ implementation of a new access road branching off the exit of the M6 motorway;
- ✓ upgrading the road network connecting the neighboring settlements (Tengelic, Kölesd, Nagydorog, Németkér and Bölcske) with Main Road 6, to 2 x 1 lane of standard width;
- ✓ widening and upgrading the current dirt road to Gerjen.

The Gerjen-Paks Nuclear Plant road and a boat or ferry service on the River Danube can plug the city of Kalocsa and its surroundings into the construction project.

4.2.1.2 Railway connections

Regarding rail links, the current railroad runs along the area mentioned in the direction of Pusztaszabolcs (Pusztaszabolcs-Dunaújváros-Paks, Hungarian Rails' partially electrified 79 km single-track railroad). The original section was upgraded during the construction of the Paks Nuclear Power Plant and is suitable for engines with an axle load of 20 tons; nevertheless, the section needs further upgrading. Alternatively, a new track needs to be implemented.

4.2.1.3 Waterway an nautical connections

Regarding access by water, the Paks Nuclear Power Plant already has a port, however, it needs to be upgraded with a portal jib-crane and perhaps extended.

4.2.2 WATER SUPPLY AND WASTE WATER DISPOSAL

The operating and temporary construction sites of the new nuclear plant will be located north of the current units of the Paks Nuclear Plant. Currently, no direct water supply or waste water disposal is available. Therefore, this issue needs to be addressed.

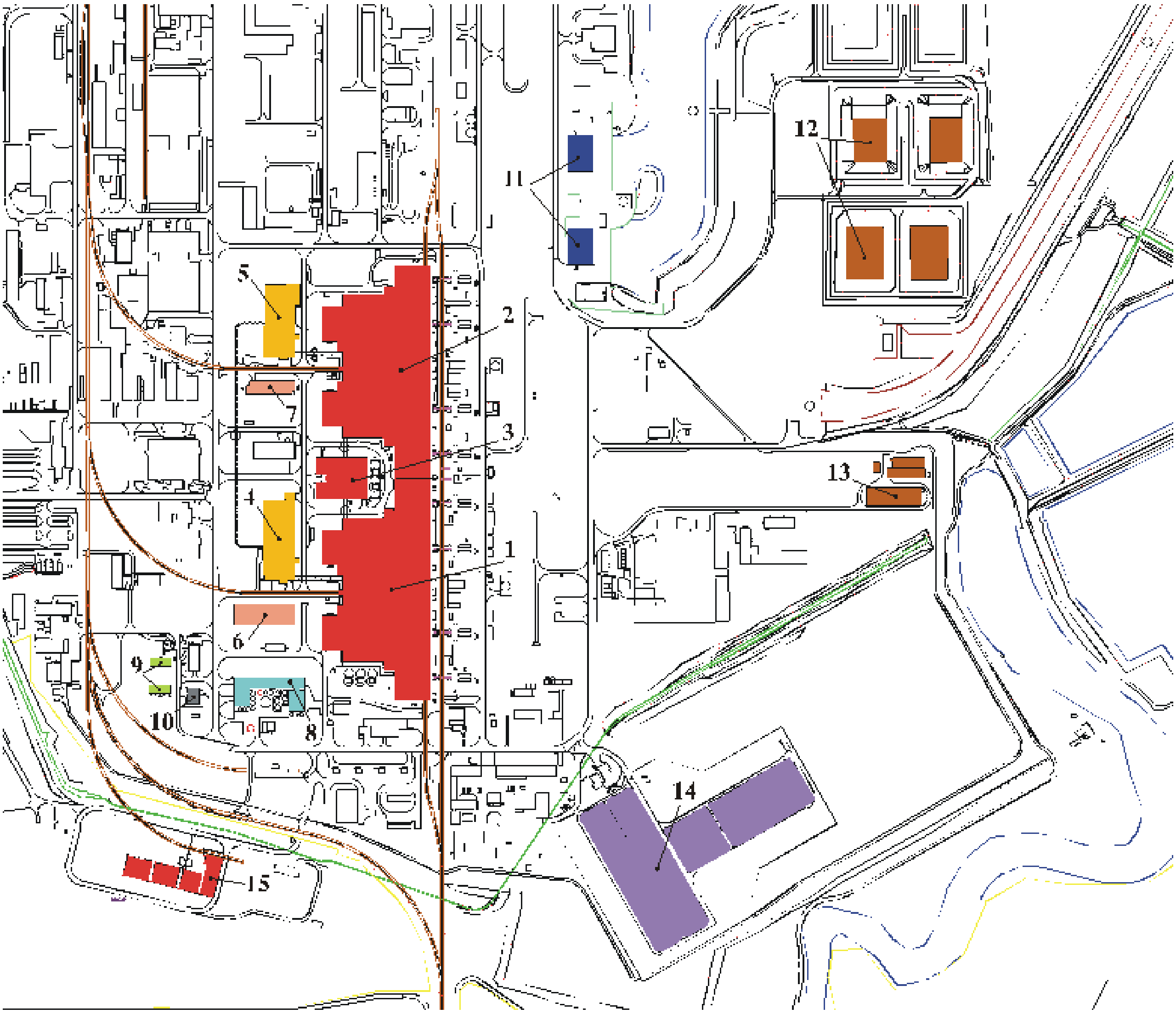
4.2.3 GRID CONNECTION

In order for the envisaged new nuclear power plant units to be connected to the power grid, a new 400 / 120 kV transformer station (Paks II substation) needs to be built. The electricity generated in the new units is transmitted to the new substation via a 400 kV overhead electrical power line; a dual 120 kV back-up supply will be connected to the spare house-service transformers of the units first via a parallel overhead line and then a cable on the premises of the plant.

In order to be able to feed the electricity generated by the new nuclear power plant units from the Paks II substation to the grid, a two-way Paks–Albertirsa line needs to be built.

Electricity needed for the construction of the new units must also be provided. Such temporary power can be supplied via feed cables from a 6 kV ring connected to the external network (outside the Paks Nuclear Power Plant) and/or the internal network of the Paks Nuclear Power Plant. The feed cables would connect the ring to mobile 6/0.4 kV containerized transformer stations, feeding distribution or sub-distribution networks supplying the users. [4-5]

4.3 THE PAKS NUCLEAR POWER PLANT AND ITS ASSOCIATED FACILITIES



Legend:

1 Main operating building I
2 Main operating building II
3 Sanitary facility and laboratory
4 Auxiliary building I
5 Auxiliary building II
6. Diesel engine room I
7 Diesel engine room II
8 Chemical water pre-treatment room
9 Hydrogen – nitrogen tanks
10 Hydrogen plant
11 I - II Water abstraction structures
12 Sludge tanks
13 Waste water treatment plant
14 Transformer station
15. Spent Fuel Interim Storage (SFIS)

Figure 4.2.3-1: The Paks Nuclear Power Plant and its associated facilities at the Paks site[4-6]

4.3.1 PAKS NUCLEAR POWER PLANT

The Paks Nuclear Power Plant has a dominant role in Hungary's supply of power. Its four units were commissioned between 1982 and 1987, with one pressurized, water-cooled and water-moderated VVER-440 reactor of the V-123 type in each unit. The initial nominal capacity of the units was 440 MW_e. This was increased to 500 MW_e in a capacity boosting program, as a result of which the total nominal capacity of Paks increased to 2000 MW_e. The heat output of each unit is 1485 MW_{th} and the total heat output of plant is 5940 MW_{th}.

The Paks Nuclear Plant operates as a base load power plant with an output load kept as steady as reasonably possible. In 2013 it generated 15,369.6 GWh electricity accounting for 50.7% of Hungary's gross domestic electricity output.

Figure 4.3.1-1 shows the electricity output of the Paks Nuclear Power plant between 1983 and 2013.

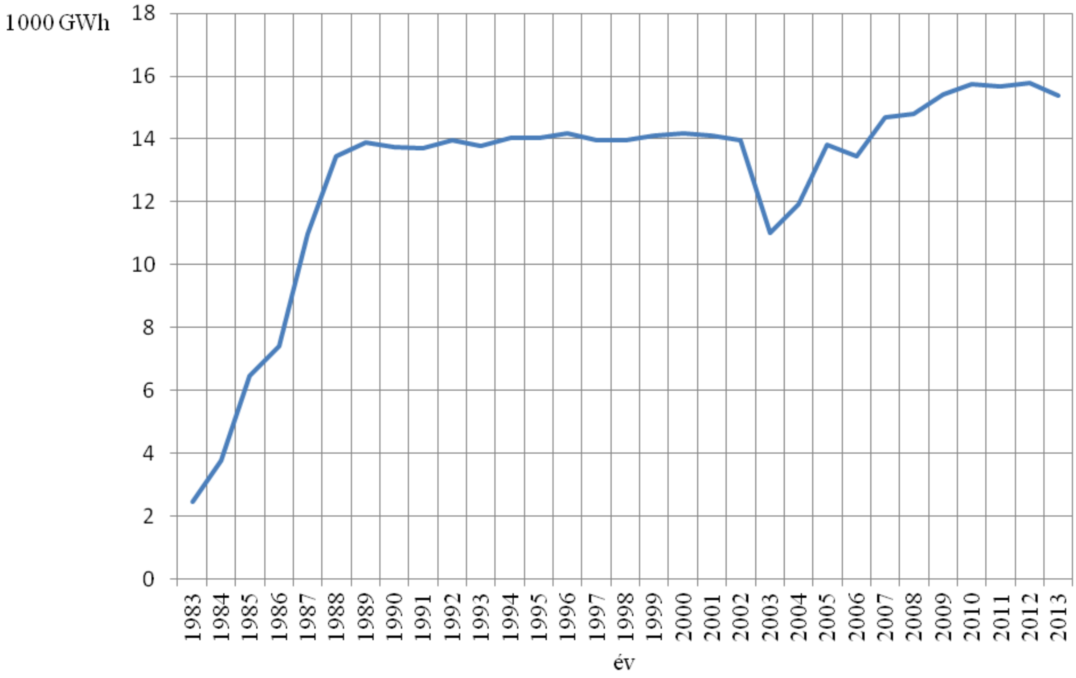
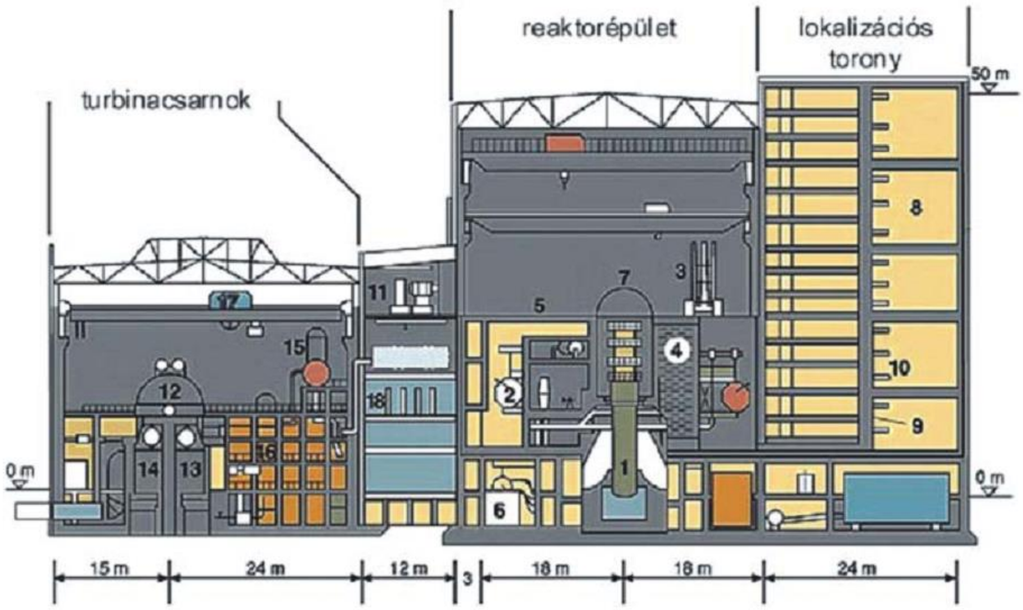


Figure 4.3.1-1: Electricity generation by the Paks Nuclear Power Plant, 1983 to 2013

The technology used within the nuclear power plant can be divided into a primary and a secondary circuit. The primary circuit comprises the core with the main water circuit and the related primary circuit systems and other auxiliary systems. The main equipment of the primary circuit is a vertical cylindrical reactor, housing the active zone. The reactor is fueled by 42 tons of uranium-dioxide. The pressurized nuclear reactor is moderated and cooled by light water (H_2O). High pressure and high temperature primary circuit water transmits heat from the reactor to the secondary circuit via the heat transmission pipes of a steam generator. In the secondary circuit the heat generated in the reactor is transformed into kinetic and then electrical energy. In the steam generator water evaporates and reaches the turbines via the main steam system. The steam exiting the turbines condenses on the heat transfer surfaces of the condensers cooled with water from the River Danube and returns to the steam generators. The Paks Nuclear Plant uses the water of the River Danube for cooling and discharges it back to the Danube after warming it up. The main transformers (2 for each unit) transform the electricity generated to 400 kV.



Turbinacsarnok – Turbine building
Reaktorépület – Reactor building
Lokalizációs torony – Localization building

Figure 4.3.1-2: East-west cross-section of the Paks Nuclear Power Plant [4-7]

Figure 4.3.1-3: View of the twin units of the Paks Nuclear Power Plant [4-8]

Fuel management and storage

The used or spent fuel assemblies, i.e. those no longer fit for use in the reactors, must be kept in a sub-critical condition, must be shielded for protection against radiation, and must be cooled to carry away their remaining heat. After their removal, the spent fuel assemblies are temporarily stored in a fuel pond, with an independent cooling circuit, in the immediate vicinity of the reactor.

Following their storage for 3 to 5 years in the fuel pond, the spent fuels are transported to the Spent Fuel Interim Storage (KKÁT/SFIS) in order to free up the fuel pond for uninterrupted reactor operation.

4.3.1.1 Security zone of the Paks Nuclear Power Plant

The minimum width of the security zone of the Paks Nuclear Plant is 500 m calculated from the following elements and structures:

- the walls of the rooms comprising emergency cooling water pumps at water intake plants,
- the walls of the ducts where emergency cooling water pipes run and the pipes themselves where they are buried in the ground,
- the walls of the turbine engine room,
- the walls of the desalinated water pump rooms,
- the walls of the electrical cross bus line galleries,
- the walls of the reactor halls, including the walls of the localisation towers,
- the outermost points of the subterranean fuel tanks of diesel generators,
- the walls of diesel engine rooms,
- the walls of the auxiliary buildings, and
- the walls of the reinforced concrete tube bridge.

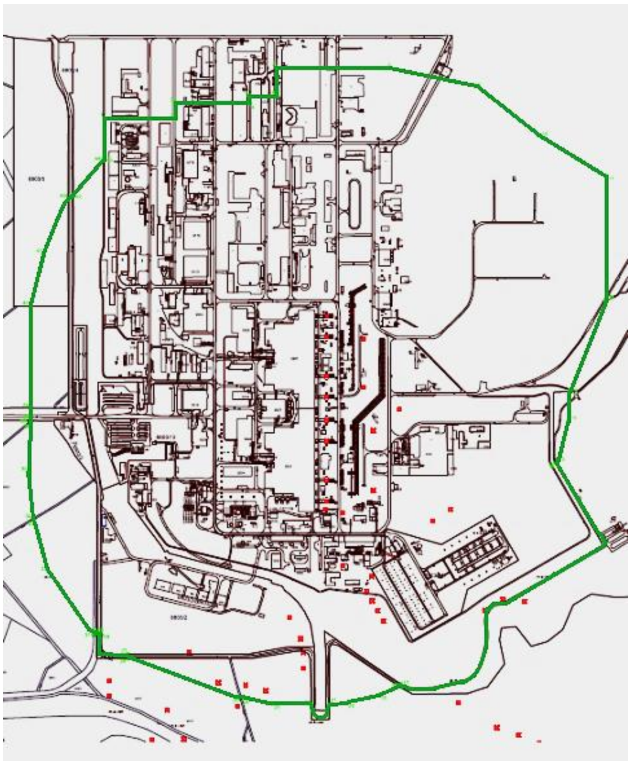


Figure 4.3.1-4: The security zone of the Paks Nuclear Power Plant [4-6]

4.3.2 400 kV SUBSTATION

The electricity generated by the turbines of the Paks Nuclear Plant is transformed by the main transformers to 400 kV. The main transformers are connected via a 400 kV overhead electrical power line to a 400 / 120 kV substation, constituting part of the national grid, in the south east of the Paks Plant. The 400 kV transmission lines running from the substation provide the main routes of the delivery of the electricity generated. The 400 kV station section is connected to a 120 kV substation and, hence, the 120 kV long-distance transmission line via two 400 / 120 / 18 kV, 250 / 250/ 75 MVA booster transformers.

The 400 kV substation uses SF6 gas-insulated switchgear technology in a one-and-a-half breaker arrangement. The 120 kV part is a traditional substation with 2 main and 1 auxiliary bus lines.

The substation is owned by MAVIR. Entry to the premises is only possible from the premises of the Paks Nuclear Plant. [4-8], [4-6]

4.3.3 SPENT FUEL INTERIM STORAGE (SFIS)

The spent fuel generated during the operation of the power plant must be temporarily stored prior to any further processing or final placement without reprocessing. Following their storage for 3 to 5 years in the fuel pond, the spent fuel cartridges are moved to the Spent Fuel Interim Storage (KKÁT/SFIS) located next to the Paks Nuclear Power Plant.

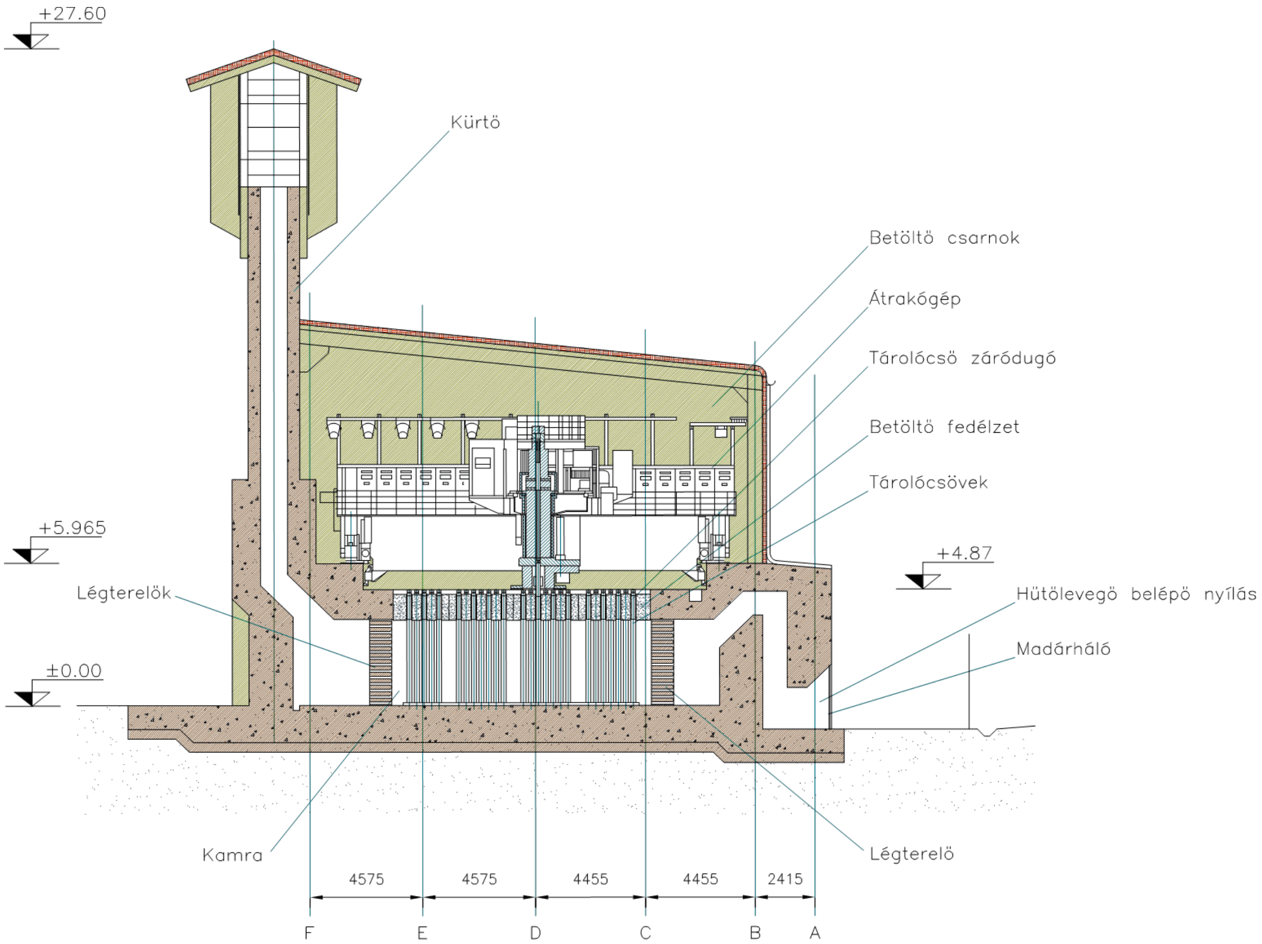
Figure 4.3.3-1: Paks Nuclear Power Plant KKÁT/SFIS [4-6]

In the SFIS the cassettes are placed in storage tubes filled with nitrogen gas. One storage tube contains only one cassette. In the course of storage, maintenance of the subcritical condition is guaranteed by the geometric arrangement of the storage tubes. The radiological shielding of the cartridges is ensured by a concrete structure that surrounds the storage tubes, and the cartridges are cooled by natural draught.

The storage facility can be divided into three parts. One part is the storage chamber described above. The next one is the so called loading hall above the storage chambers, where the cartridges delivered to the facility are loaded in a loading machine into the individual storage tubes. The third part of the facility is the receiving building, where the spent fuels transported in a C30 container are prepared for storage and where the other systems required for the operation of the facility are located. In the C30 container the fuels are transported under water. Before the fuels are placed in the storage tubes, they must be dried after removal from the container. For this reason, the receiving building also houses the technological systems and equipment required for servicing the container and drying the fuels.

The SFIS is a modular interim storage facility, with a storage capacity that can be expanded by the addition of new storage modules. Pursuant to Act CXVI of 1996 (Atomic Energy Act), the interim storage of spent fuels is assigned to Radioaktív Hulladékokat Kezelő Közhasznú Nonprofit Kft. The SFIS is located next to the Paks Nuclear Power Plant. It is a separate nuclear facility, independent of the operator of the power plant, having its own separate Final Safety Report and operating license.

The cross-section of the storage chamber that contains the storage tubes and ensures natural draught is illustrated in Figure 4.3.3-2.



kürtő – flue, légterelők – air baffles, betöltő csarnok – load chamber, átrakodógép – transfer machine, tárolócső záródugó – plug of storage tube, betöltő fedélzet – loading platform, tárloócsövek – storage tubes, hűtőlevegő belépő nyílás –cooling air inlet, madárháló – catch net, kamra – chamber

Figure 4.3.3-2: Cross-section of the SFIS [4-6]

4.3.3.1 The SFIS safety zone

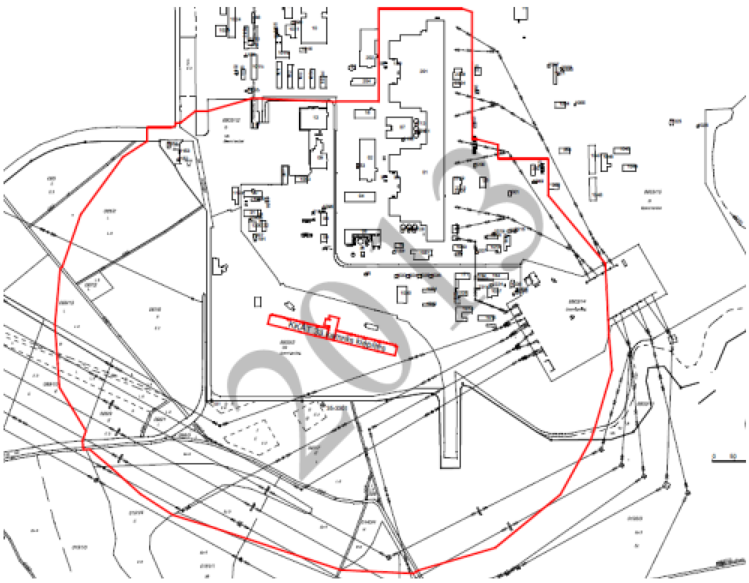


Figure 4.3.3-3: SFIS safety zone [4-6]

4.4 MONITORING SYSTEMS IN THE NEIGHBOURHOOD OF THE PAKS NUCLEAR POWER PLANT

Like all other power generating facilities, the Paks Nuclear Power Plant continuously monitors its characteristic environmental emissions that are necessary concomitants of is technology, as well as their appearance in the environment (immissions), and furnishes a summary report of them, cf. the 2013 Environmental Report of the MVM Paksi Atomerőmű Zrt. [4-9]

4.4.1 CONTROL OF TRADITIONAL ENVIRONMENTAL CONDITION INDICATORS

4.4.1.1 Control of waste water and used water emission

Waste and used water emission is monitored in compliance with the Self-Revision Plan approved by DdKTVF.

Temperature monitoring

The temperature of the Danube water is measured at the northern supporting buttress of the baffle wall of the cold water channel.

The temperature of the warmed-up coolant (warm water) is measured at the end of the warm water conduit, before the left-bank gate.

Water volume measurement

Water volume is measured by ultrasound volume meters installed on the warm water conduit and the back mixing pipes.

Water quality monitoring

V1 sampling and remote metering station: sampling from the cold water conduit

V2 sampling and remote metering station: sampling from the warm water conduit

V4 sampling station (sample pumped from the cassette of the energy dissipation device): sampling the mixture of used water and purified waste waters returned to the Danube; conventional emission limits apply at this point

Expansion area pump shaft: Quality of waste water transferred to the Paks city waste water treatment plant (with a set threshold).

Other sampling places: before and after the communal waste water treatment plant, at the caustic sludge pool and the chemical waste water pool

4.4.1.2 Groundwater monitoring

In order to monitor potential sources of environmental pollution, the Paks Nuclear Power Plant operates a groundwater monitoring system, as required by its environmental licenses. In the system set up for monitoring conventional emissions, the following parameters are measured and analysed at the following sampling points:

At wells in the neighbourhood of the operational hazardous waste collection site: pH, total salt, total oil, KOI_{ps}, Fe, Mn, Cu, Zn, Pb, Cr, Ni values,

At the sludge area wells: pH, conductivity, total hardness, total salt content, ammonium, total oil, KOI_{ps}, NO_3^-, Fe, Mn, Cu, Zn, Pb, Cr, Ni, Cl^- values,

At the wells located next to the oil tanks: pH, oil content, NO_3^-, ammonium, Cl values,

At the monitoring wells designated on the operating area: pH, ammonium, nitrate, KOI_{ps}.

4.4.1.3 Exposure of the Danube to heat

Inspection of compliance with the heat load limits applicable to the Danube is performed according to the Self-Revision Plan approved by DdKTVF. According to the provisions of this Plan, the temperature of the water removed from and returned to the Danube is continuously measured, and if the temperature of the water discharged to the Danube exceeds 25 °C, the temperature of the Danube water 500 m downstream of the warm water discharge point is also measured.

4.4.2 OPERATIONAL ENVIRONMENTAL RADIATION PROTECTION CONTROL SYSTEM (PERMS)

The environs of the Paks Nuclear Power Plant have been monitored since 1978 by measuring the radioactivity of samples taken from the environment, from baseline surveys to continuous operational metering.

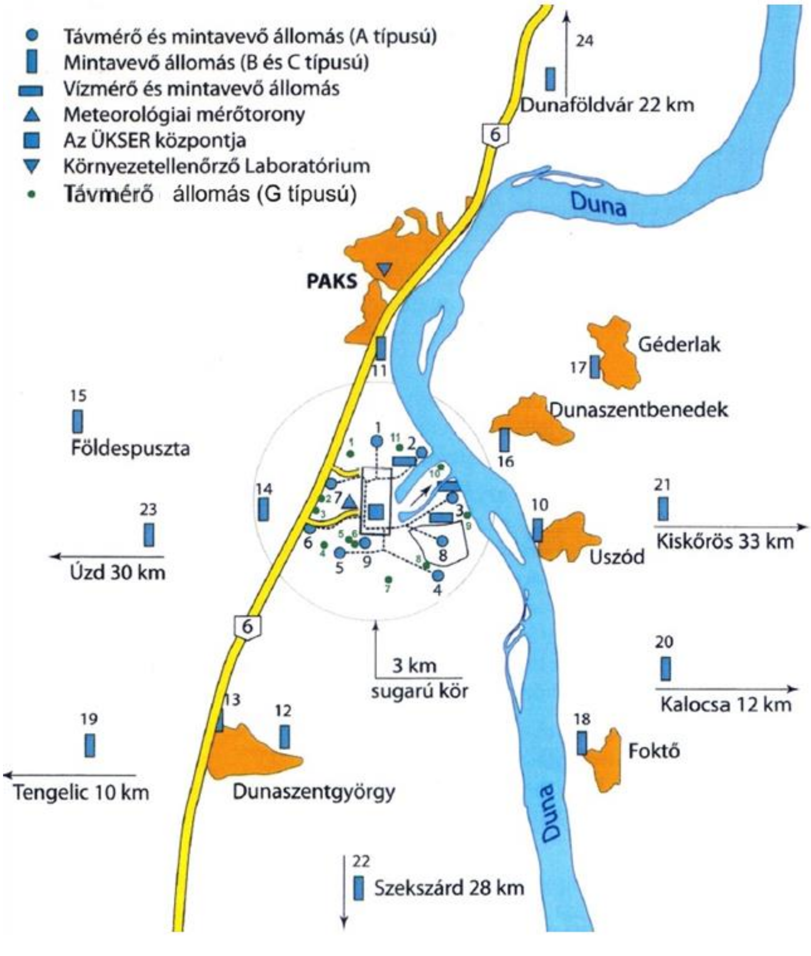
These measurements were performed by the Paks Nuclear Power Plant, various authorities and other institutions.

The fundamental purpose of nuclear environmental monitoring is to survey the nuclear power plant's emission of radioactive substances, the appearance of the latter in the environment, and to identify environmental radiation levels.

The metering obligation is based on Decree 15/2001. (VI. 6.) of the Minister for the Environment on radioactive emissions to the air and to waters and on their control, which stipulates that during the use of nuclear energy the levels of environmental radioactivity related to the emissions of the power plant must be monitored in the air and in water.

The continuous monitoring of the vicinity of the Paks Nuclear Power Plant must be performed by the Operational Environmental Radiation Protection Control System (PERMS). The summary report of the findings related to the measured ambient radiation and radioactive concentration based on sampling from the individual environmental media is published each year under the title "Radiation Protection Activity in the Paks Nuclear Power Plant".

The territorial arrangement of the radiological and environmental monitoring system of the Paks Nuclear Power Plant is shown Figure 4.4.2-1.



Távmérő és mintavevő állomás (A típusú) – Remote measuring and sampling station (type A)
Mintavevő állomás (B és C típusú) – Sampling station (type B and C)
Vízmérő és mintavevő állomás – Water metering and sampling station
Meteorológiai mérőtorony – Meteorological monitoring tower
Az ÜKSER központja – PERMS centre
Környezetellenőrző Laboratórium – Environmental Monitoring Laboratory
Távmérő állomás (G típusú) – Sampling station (type G)

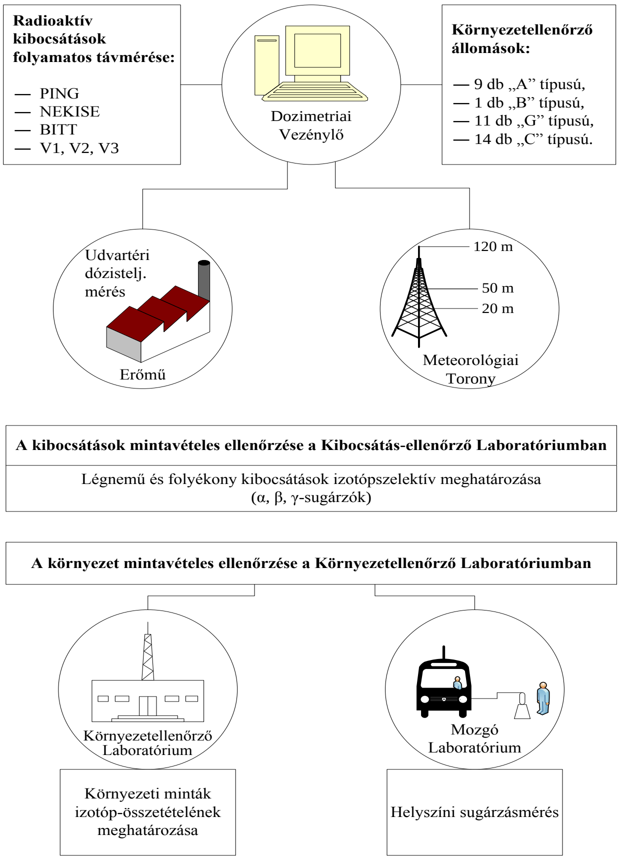
Figure 4.4.2-1: Geographic location of the radiological and environmental monitoring system of the Paks Nuclear Power Plant [4-10]

Emissions and the condition of the environment are assessed by monitoring at two levels:

- by continuous measurement
  - *The online remote monitoring networks measure the most significant radioactive emissions (aeriform and liquid) and environmental radiation volumes on an continuous basis.*
- by sampling
  - *The Emission Monitoring Laboratory uses isotope selective, high-precision laboratory investigation methods to improve the accuracy of the remotely measured values of the samples taken from the emitted media.*
  - *The Environment Monitoring Laboratory measures the isotope selective radioactive concentration, the gamma radiation dose and the dose rate of the various environmental samples taken from of the environment within 30 km of the plant.*

Both laboratories are accredited by the National Accreditation Board.

The structure of the two-level radiological and environmental monitoring system of the Paks Nuclear Power Plant is shown in Figure 4.4.2-2.



Radioaktív folyamatok folyamatos távmérése – Continuous remote monitoring of radioactive emissions
Dozimetriai Vezénylő – Dosimetric control room
Környezetellenőrző állomások – Environmental monitoring stations:
- 9 of type A
- 1 of type B
- 11 of type G
- 14 of type C

Udvartéri dózisteljesítmény mérés – Doseage metering on the courtyard
Meteorológiai Torony – Meteorological tower
Erőmű – Power plant
A kibocsátások mintavételes ellenőrzése a Kibocsátás-ellenőrző laboratóriumban – Monitoring emissions by sampling in the Emission Monitoring Laboratory
Légnemű és folyékony kibocsátások izotópszelektív meghatározása (α-, β- és γ- sugárzók) – Isotope-selective definition of aeriform and liquid emissions (α-, β- and γ- emitters)
A környezet mintavételes ellenőrzése a Környezetellenőrző Laboratóriumban - Environmental monitoring by sampling in the Environmental Monitoring Laboratory
Környezetellenőrző Laboratórium – Environmental Monitoring Laboratory
Mozgó Laboratórium – Mobile Laboratory
Környezeti minták izotóp-összetételének meghatározása – Definition of the isotope-composition of environmental samples
Helyszíni sugárzásmérés – On-site radiation measurement

Figure 4.4.2-2: Structure of the two-level radiological and environmental monitoring system of the Paks Nuclear Power Plant [4-11]

4.4.2.1 Radioactive emissions and their control

In 2004 the emission limitation system prescribed by Decree No. 15/2001. (VI.8.) of the Minister for the Environment entered into force. It compares both aeriform and liquid emissions to the isotope specific emission limits derived from the dose limits (90 μSv/year) set for the Paks Nuclear Power Plant.

In 2013, the Paks Nuclear Power Plant used 0.26% of the emission limit, in other words, 0.26% of the permitted values were emitted. Utilisation of the limits on liquid emissions was 1.77 10^{-3}, i.e. 0.18%, while 7.77$10^{-4}$ or 0.08% of the aeriform emission limit was used.

Utilisation was similar in the previous years: 2012 - 0.26%, 2011 - 0.20%, 2010 – 0.25%, 2009 - 0.22%.

4.4.2.1.1 Aeriform emissions

Gases of radioactive content are emitted from systems of the Paks Nuclear Power Plant to the environment through systems that ensure filtering and control in order to expose the environment and the power plant staff to the lowest reasonable radiation.

In addition to the systems managing exhaustions from the potentially polluted premises of the Paks Nuclear Power Plant, special gas purifying systems and a hydrogen treatment system ensure minimum emission to the air. The gas purifying system's function is to purify low- and high-activity gas reliefs. The function of the hydrogen treatment system is to catalize the burning of the hydrogen gas leaving the primary circuit heat carrier of the unit in order to prevent the building up of an explosive concentration.

Aeriform (aerosol, steam and gas) radioactive substances are emitted from the Paks Nuclear Power Plant through three points in a controlled way:

Emission point No. 1: ventilation chimney of reactor units 1-2
Emission point No. 2: air funnel of the sanitary building
Emission point No. 3: ventilation chimney of reactor units 3-4

The chimney is measured online, inert gases are metered by a gamma spectroscopic method (NEKISE), ^{85}Kr is measured by sampling, aerosol is also measured by sampling, from daily and weekly samples, iodine is measured with the sampling method, from daily and weekly average samples, and ^{89,90}Sr, T, ^{14}C are also measured from samples.

Radionuclides	Total emission [Bq]	Utilisation of the emission limit
Corrosion and fission products	1.19 – 10^{9}	1.93 10^{-4}
Radioactive inert gases	2.86 10^{13}	3.46 10^{-4}
Radio-iodines	7.37 – 10^{7}	3.29 10^{-5}
Tritium	4.05 10^{12}	2.34 10^{-5}
Radio-carbon	6.39 10^{11}	1.81 10^{-4}
Total		7.77 10^{-4}

Table 4.4.2-1: Aeriform emissions by the Paks Nuclear Power Plant – 2013 [4-12]

In 2013, utilisation of the limits on aeriform emissions was 7.77 10^{-4}, i.e. 0.08%.

4.4.2.1.2 Liquid emissions

In view of the place of generation, the liquid radioactive wastes generated during operation are as follows:

- above-balance waters;
- boric acid wastes of unscheduled primary circuit leakages, drainages and ventings;
- waste from room decontaminations and other runoff;
- regeneration waste and loosening water of primary circuit water purifiers,
- spent ion-exchange resins of primary circuit water purifiers,
- chemical waste from equipment decontaminations,
- evaporator acidifying solutions,
- waste water generated in the primary circuit laboratories, laundry waste water and polluted showering water,
- polluted organic diluents (washing benzine, washing alcohol, petroleum) and oils,
- scheduled primary circuit leakages and various primary circuit boric acid solutions.

The generated liquid wastes, concentrates and used ion-exchange resins are stored in tanks in auxiliary building No. 1 of units 1-2, and auxiliary building No. 2 of units 3-4.

Waste water generated in the primary circuit laboratories, laundry waste water and polluted shower water are transferred to various storage tanks in the healthcare laboratory building.

Liquid radioactive materials are emitted from the Paks Nuclear Power Plant through one point in a controlled way: the waters emitted from controlled tanks are drained to the warm water channel via permitted emission routes, through the outlet conduit that collects purified communal waste water above-balance waters before the energy dissipation device, and then they are let into the Danube.

Summary data of the 2013 liquid radioactive emissions:

Radionuclides	Total emission [Bq/year]	Utilisation of the emission limit
Corrosion and fission products	2.91 x 10^{9}	1.00 10^{-3}
Tritium	2.24 x 10^{13}	7.73 10^{-4}
Alpha-emitting radionuclides	1.87 x 10^{6}	1.93 10^{-6}
Total		*1.77 10^{-3}*

Table 4.4.2–2: Liquid emissions by the Paks Nuclear Power Plant – 2013 [4-12]

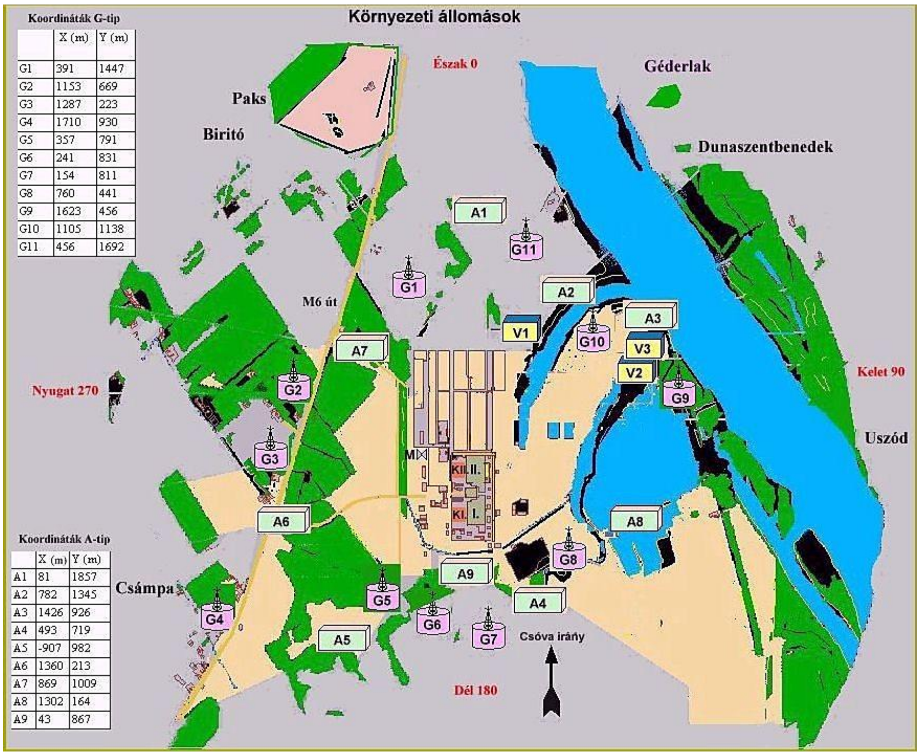
In 2013, utilisation of the liquid emission limit was 1.77 10^{-3}, i.e. 0.18%.

4.4.2.2 Assessment of the state of the environment

The state of the environment is assessed by analyzing the results of the following measurements:

- measuring the radioactive concentration of the air, fall-out, the soil, groundwater and natural vegetation (grass),
- measuring activity in surface waters (Danube, fish ponds, catch drain), water, sludge and fish samples,
- measuring activity concentration in certain food samples (milk),
- measuring the ambient gamma radiation dose and dose rate.

Figure 4.4.2-3 shows the location of remote monitoring stations that monitor the state of the environment in the vicinity of the Paks Nuclear Power Plant.



Környezeti Állomások – Environmental stations
Koordináták G-típ – Co-ordinates type G
Koordináták S-típ – Co-ordinates type S

Figure 4.4.2-3: Type "A" and "G" remote monitoring stations monitoring the condition of the environment in the vicinity of the Paks Nuclear Power Plant [4-12]

4.4.2.2.1 Remote metering systems

Remote metering systems within a 1.5-km radius of the Paks Nuclear Power Plant

Nine type "A" measuring and sampling stations (A1 to A9)

- gamma dose rate measuring (on-line)
- (online) measuring the total beta activity concentration in aerosols
- (online) measuring the radio-iodine elementary and organic phases
- taking aerosol and iodine samples for laboratory measurements (weekly and monthly)
- [6] fall-out, wash-out sampler (monthly)
- $T/^{14}C$ sampler (T: aqueous vapour and hydrogen), ^{14}C: CO_2, and $CO_2 + C_nH_m$); (monthly)

11 stations of the type "G" (G1-G11)

- gamma dose rate measuring (on-line)

[6] *The fall-out of radioactive isotopes in the air may take place by deposition (gravitational precipitation), or as a result of the erosion effect of falling rain or snow. Collectively these processes are termed fall-out.*

Remote metering systems within 30 km of the Paks Nuclear Power Plant

One measuring and sampling station of type “B” (B24) – **Reference** (***control) station at Dunaföldvár***

For the purpose of determining reference or background levels, the same measurements are performed as with type “A” stations.

15 stations of the type “C”

- dose measurements performed by thermo-luminescent detectors (TLD) (monthly)
- fall-out sampling and analysis (periodically)

4.4.2.2.2 Sampling, laboratory tests

- water samples at water sampling points V1, V2 and V3 (daily sampling for total gamma, total beta, and monthly or quarterly sampling for isotope selective measurements)
- water samples and sludge samples
  - Danube, fish ponds, catch drain, lime sludge pool (quarterly)
  - Danube Backwater at Fadd (monthly)
- soil and grass samples from the vicinity of remote monitoring stations (periodically)
- milk samples from the dairies at Dunaszentgyörgy and Tengelic (monthly)
- fish samples from angling ponds (quarterly)

4.4.2.2.3 Measurement of groundwater tritium activity concentration

To measure the tritium content of the groundwater under the main building, the Paks Nuclear Power Plant runs a monitoring system in order to meet the requirements of Section 13-2 a) of resolution HA-4797 (IBJ tasks) of OAH.

Fundamentally, the tests are based on the network of groundwater monitoring wells surrounding the nuclear power plant, consisting of nearly 140 wells, of which 52 are sampled monthly or annually by the Radiation and Environmental Protection Department. The tritium activity concentration measurement of the samples was supplemented by total beta and gamma spectrometry measurements whenever tritium concentration exceeded 500 Bq/dm^3. Within the framework of environmental monitoring, continuous water samplers were installed in 25 wells for the main purpose of detecting other radioactive substances that might be present (gamma spectrometry once in 2 months, ^{14}C once in 4 months, $^{89,90}Sr$ once in 4 months, Pu-TRU trans-uranium once in 8 months from large-volume (20 liter per month) average samples), in addition to monitoring tritium.

The annual additional exposure to radiation from groundwater tritium is about 0.01 nSv/year, practically negligible in comparison to the exposure to natural background radiation, which is about 20% higher in Hungary than the global average (2,4 mSv/year), as it amounts to 3, or at certain places 4 mSv/year.

4.4.2.3 Additional exposure of the population to radiation

Based on the 2013 emission and meteorological data of normal operation, the annual additional exposure of the population to radiation, resulting from the normal operation of the plant, is shown in the following table.

Dose limit	μSv/year	90
Population dose	μSv/year	$4.83\ 10^{-2}$
Limit utilisation	%	$5.37\ 10^{-2}$

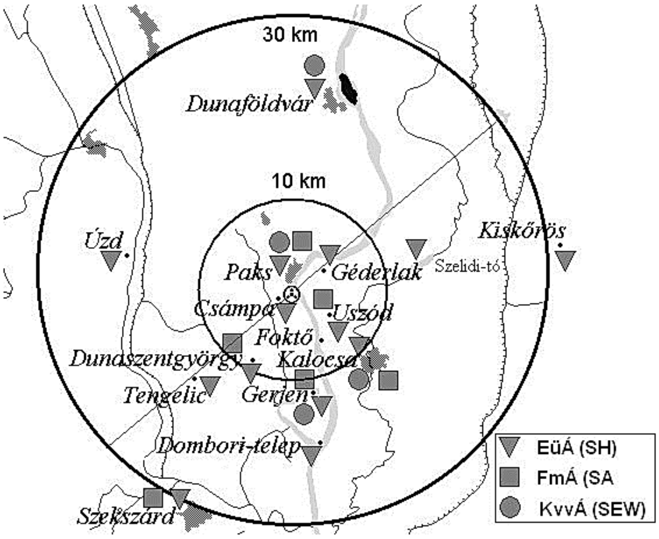
Table 4.4.2–3: Dose limit utilisation at the site of the Paks Nuclear Power Plant – 2013 [4-12]

According to calculations the 2013 additional exposure to electromagnetic fields resulting from the normal operation of the Paks Nuclear Power Plant was 48.3 nSv, which is 0.0537% of the 90 Sv permitted annual dose limit.

This additional radiation exposure is identical to the effective dose received during about half an hour in the open air, thus it does not impose practically any health hazard, and the population was exposed to a negligible amount of additional radiation.

4.4.3 JOINT ENVIRONMENTAL RADIATION MONITORING SYSTEM (JERMS)

The Joint Environmental Radiation Monitoring System (JERMS), run by the authorities to check the radiation protection of the power plant operates in parallel with the measurements performed by the Paks Nuclear Power Plant.



Note:
EüÁ – healthcare
FmÁ – agriculture
KvVÁ - environment and water management

Figure 4.4.3-1: Official measuring points within 30 km of the Paks Nuclear Power Plant [4-13]

The following ministries are members of JERMS:

Ministry of Human Resources (EMMI), Healthcare Division (EüÁ)
Ministry of Agriculture (FM)
Agriculture Division (FmÁ)
Environment and Water Management Division (KvVÁ)

In the framework of inspections by the authority, in addition to the survey of atmospheric and aquatic environmental emissions, laboratory analyses are also made of the Danube water and sludge, soil, plant and milk samples.

In addition to measuring the dose rate of ambient radiation, the authorities have been measuring the following activities since 2001:

- atmospheric aerosol,
- atmospheric fall-out, dry-out,
- surface waters (rivers, natural and artificial lakes, channels)
- drinking water (wells, depth)
- deposit (rivers, natural and artificial lakes)
- soil and grass samples (irrigated and non-irrigated arable land, garden, meadow and road-side)
- leaf vegetables (kitchen garden indicator plants, raw kitchen garden food, fruits)
- meats (pork, beef, lamb, poultry, game, fish)
- raw milk

In the course of the impact assessment of the environs of Paks II, the data measured by JERMS were analysed in detail in the chapter entitled "Environmental Radioactivity".

Under the title *Report of the Joint Environmental Radiation Monitoring System,* JERMS publishes annual reports of its activities performed in the scope of its regulatory inspection of the neighborhood of the Paks Nuclear Power Plant. The reports containing the findings recorded between 1999-2012 are public and can be downloaded from the JERMS website:

http://www.hakser.hu/eredmenyek/eredmenyek.html

4.4.4 NATIONAL ENVIRONMENTAL RADIOLOGICAL MONITORING SYSTEM (NERMS) [4-14]

Under Government Decree 275/2002. (XII.21.) Korm. the core responsibility of the National Environmental Radiological Monitoring System (NERMS) includes the collection of countrywide measurement results of natural and man-made environmental radiation to which the population is exposed, and of the concentration of radioactive materials in the environment.

The following are measured:

- ambient radiation dose rate,
- activity concentration of radioactive isotopes,
  - in the environmental elements (air, soil, surface waters, natural and agricultural plants, wild fauna and livestock),
  - in the animal and plant-based foods consumed by the population and their raw materials,
  - in drinking water,
  - in construction materials and raw materials,
- activity concentration of radon and its daughters in the open air and inside buildings,
- internal radioactive pollution of the human body.

Based on the NERMS measurements, additional tasks include:

- ❖ furnishing the population with information,
- ❖ publishing the outcomes of the surveys in annual reports,
- ❖ digesting the survey data collected on a national level to inform the Commission of the European Communities.

Various public administration organisations and certain special institutions, i.e. NERM members participate in the activity of NERMS. NERMS' activity is managed by a Steering Committee (NERMS SC). The centralized online collection and evaluation of the results collected by the separate radiological environmental monitoring networks of the individual NERMS members and the administrative tasks of NERMS are performed by the Information Centre of NERMS (NERMS IC).

The following ministries, national organisations and key facilities are members of NERMS:

Ministry of Human Resources
Ministry of National Development
Ministry of Agriculture
Ministry for the National Economy
Ministry of Defense
Hungarian Academy of Sciences
Hungarian Atomic Energy Authority
Political State Secretary Contributing to the Management of Civilian State Security Services
MVM Paksi Atomerőmű Zártkörűen Működő Részvénytársaság
Radioaktív Hulladékokat Kezelő Közhasznú Nonprofit Kft. (Public Limited Liability Company for Radioactive Waste Management)

NERMS uses the findings of the following radiological laboratories, operated by NERMS members, and the environmental monitoring results of monitoring network for the analysis of the radiological characteristics of Hungary.

Ministry of Human Resources
Radiological Monitoring and Data Acquisition Network (RAMDAN)

Ministry of Agriculture
Radiological Monitoring Network (RMN)
Hungarian Meteorological Service

Hungarian Academy of Sciences
KFKI Atomic Energy Research Institute

Ministry of Human Resources

Budapest University of Technology and Economics, Nuclear Technical Institute

Ministry of the Interior

National Disaster Control, General Directorate, Nuclear Accident Information Centre
National Radiation. Monitoring and Signaling System (NERMS), remote monitoring network

Paksi Atomerőmű Zártkörűen Működő Részvénytársaság

Operational Environmental Radiation Protection Control System

Radioaktív Hulladékokat Kezelő Közhasznú Nonprofit Kft. (Public Limited Liability Company for Radioactive Waste Management)

Operational Environmental Radiation Protection Control System

Conclusion of the 2012 NERMS Report

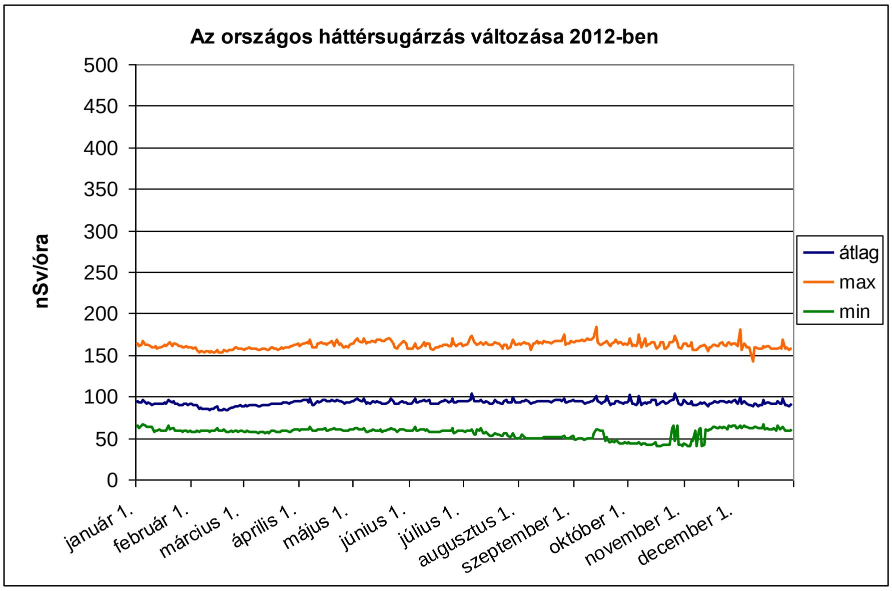
The 2012 Report of the National Environmental Radiological Monitoring System (NERMS) summarizes the results of measurements conducted in Hungary as follows:

*"It must be emphasized that while according to the relevant regulation of the European Union {*Post-Chernobyl 733/2008/EC, Council Regulation No 733/2008 of 15 July 2008 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power plant (codified version); Council Regulation (EC) No 1048/2009 extends its validity until 31 March 2020) (OJ L-201 of 30/07/2008, page 1)*} the maximum permitted levels of accumulated maximum radioactive level in terms of caesium-134 and -137 is 600 Bq/kg (370 Bq/kg for milk, milk products and baby food), the highest values measured in 2012 in processed foodstuffs in Hungary remained below 40 Bq/kg.*

"Finally we mention that the exposure of the population to radiation from man-made sources – other than those used for medical purposes – can be estimated between 3 to 6 μSv in recent years in Hungary, while exposure to radiation from natural sources is higher by nearly three orders of magnitude."

"In summary it can be stated that according to both national and facility-specific environmental monitoring results, the activities subject to licensing have negligible impacts on the environment and on the population, and the radioactive isotope concentration values remain below the detection limit for many kinds of samples."

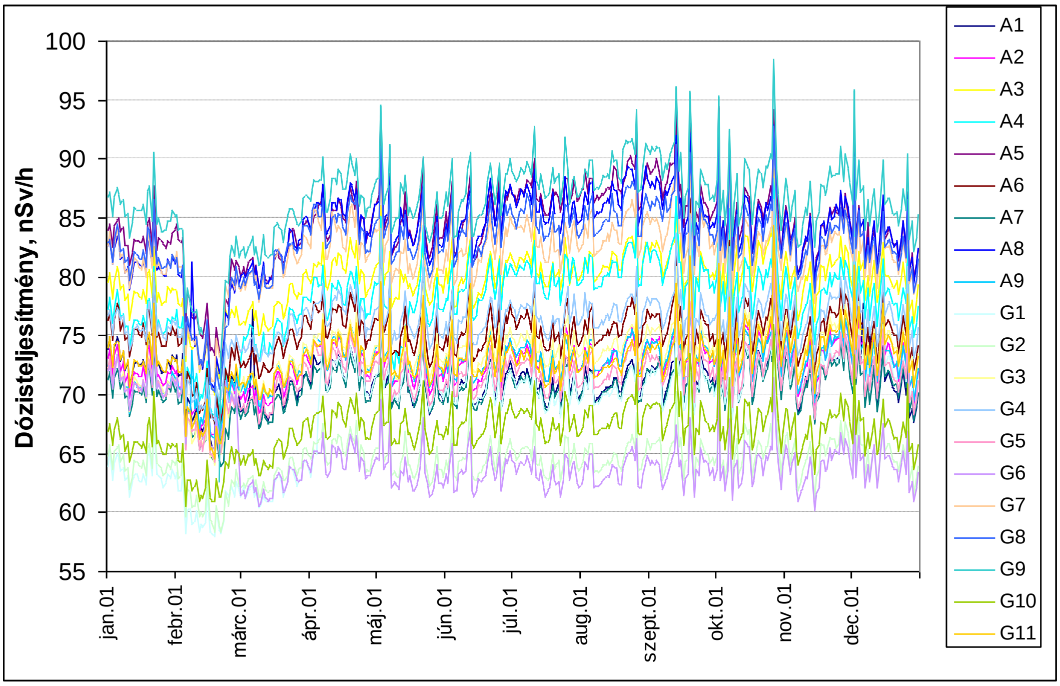
In line with the above, Figure 4.4.4-1 shows changes in the national average and daily maximum and minimum gamma dose rates for the purpose of characterizing the conditions prevailing in Hungary.



Az országos háttérsugárzás változása 2012-ben – Changes in the background radiation, 2012
nSV/óra – nSv/h
átlag – average
max. – max.
min. – min. –
január 1 – January 1 – február 1 – February 1 március 1 – March 1 április 1 – April 1 május 1 – May 1 június 1 – June 1 július 1 – July 1 augusztus 1 – August 1 – szeptember 1 – September 1 október 1 – October 1 november 1 –November 1 december 1 – December 1

Figure 4.4.4-1: Changes in the national average, maximum and minimum gamma dose rates in 2012 [4-15]

The daily dose rates measured by the dose rate probes included in the environmental monitoring system of the Paks Nuclear Power Plant in 2012 at type "A" and "G" environmental monitoring stations show environmental dose rates fluctuating between 58 and 98 nSv/h in the ambience of the Paks Nuclear Power Plant. These values represent the lower range of all values measured in Hungary. The temporal changes in the measured values are shown below.



Dózisteljesítmény, nSv/h – Dosage rate nSv/h

Figure 4.4.4-2: 2012 daily dose rates of the Paks Nuclear Power Plant, measured at its environment monitoring stations [4-12]

4.5 SUMMARY OF THE TOPOGRAPHIC FEATURES AND CHARACTERISTICS OF THE PAKS SITE

The Paks site has numerous favourable features for the implementation of new nuclear power plant units:

- ✓ a nuclear power plant has been operating at the Paks site for over 30 years,
- ✓ the population living in its vicinity has accepted the existence and operation of the Paks Nuclear Power Plant,
- ✓ the site and environs of the nuclear power plant is a meticulously investigated and studied area,
- ✓ the impacts resulting from the operation of the nuclear power plant are continuously monitored by a monitoring systems operating on the site and in its environs,
- ✓ the site is directly on the bank of the Danube,
- ✓ the Danube is available as a cooling water resource,
- ✓ the required infrastructure is implemented and is available at the site,
- ✓ the site is easy to access by road and rail,
- ✓ part of the construction materials and large equipment can be transported by water,
- ✓ due to the special layout of the surface of the area, flood and excess surface water control are ensured,
- ✓ the meteorological properties are favourable,
- ✓ population density is below the national average in the 30 km vicinity of the power plant, with the exception of the city of Paks,
- ✓ the national electricity grid is readily accessible,

- ✓ qualified and skilled manpower experienced in work at the nuclear power plant is available in the region,
- ✓ Due to its natural and infrastructural resources, Paks offers a good opportunity for the accommodation of the people engaged in the building and later in the operation of the new plant.

Compliance with the geological and nuclear safety requirements will be evaluated in detail and certified by the Hungarian Atomic Energy Authority in the framework of a site licensing procedure to be conducted on the basis of the Nuclear Safety Regulations (NSR) attached as annexes to Government Decree No. 118/2011. (VII.11.) on the nuclear safety requirements of nuclear facilities and the related activities of authorities.

4.6 REFERENCES

[4-1] MVM Magyar Villamos Művek Zrt. Implementation of new nuclear power plant units, Preliminary consultation documentation, PÖYRY ERŐTERV, 04/15/2010

[4-2] District Land Registry, Paks, November 22, 2012 Certified copy of map

[4-3] http://www.atomeromu.hu/download/1450/A%20tervezett%20blokkok%20helye.jpg

[4-4] Analysis of the Items Beyond the Contractor's Scope for the new nuclear power plant units to be implemented at the Paks site, 2013, MVM ERBE Zrt.

[4-5] Lévai Project, Implementation of a new nuclear power plant, Decision Support Feasibility Study, PÖYRY ERŐTERV Zrt.

[4-6] MVM Paksi Atomerőmű Zrt. units 1-4; Final Safety Report 2013

[4-7] Dr Gyula Csom, Nuclear Power Plants, Hungarian Nuclear Forum Association, Budapest, June 2004

[4-8] MVM Magyar Villamos Művek Zrt. Implementation of new nuclear power plant units, Preliminary consultation documentation, PÖYRY ERŐTERV, 10/02/2010

[4-9] MVM Paksi Atomerőmű Zrt.'s 2013 Environmental Report

[4-10] Dr Tibor Bujtás, Emission and Environmental Monitoring in the Paks Nuclear Power Plant, Debrecen, 09/04/2009

[4-11] MVM Paks II. Zrt. Tibor Ranga, 04/25/2014

[4-12] Radiation protection activity in the Paks Nuclear Power Plant in 2013 (Annual Report), MVM Paksi Atomerőmű Zrt. Directorate for Safety, Radiation and Environmental Protection Department, Paks, March 2014

[4-13] 2011 Report of the Joint Environmental Radiation Monitoring System (JERMS)

[4-14] http://www.okser.hu

[4-15] 2012 Report of the National Environmental Exposure Control System (NERMS) [12/27/2013]

5 POSSIBLE CONDENSER COOLING METHODS OF NEW NUCLEAR UNITS

5.1 COOLING REQUIREMENTS AND OPTIONS FOR ELECTRICITY PRODUCING POWER PLANTS WITH CONDENSERS

In the case of condenser cooled power plants of all types the laws of physics dictate that the majority of heat emitted by the fuel – or the fuel rods in the case of nuclear power plants – that cannot be utilized for electric power production be discharged into the natural environment, which acts as the final heat absorber. The reason for this is that the condenser cannot be cooled below the actual ambient temperature. This also determines the efficiency of this cyclical process.

In the case of modern nuclear power plants with current state of art technology, about 65-67% of the heat released in the reactor is eventually released into the environment, at a temperature close to the actual ambient temperature.

In addition to electric power generation, there is also heat produced in the primary and secondary circuits of nuclear power plants that cannot be used for electric power production, and which is carried off by the cooling systems. The waste heat produced in the primary circuit of power plants is carried off by the so-called emergency cooling water system; the condensation heat to be extracted from the condenser in the secondary circuit is carried off by the condenser cooling water system; and the heat generated in the technological systems of the secondary circuit is carried off by the technological cooling water system.

More than 95% of cooling demand in a nuclear power plant is met by cooling the condenser.

Primarily, the following choices are considered to absorb the generated heat, depending on the amenities of the site:

- high yield river;
- large lake;
- sea.

In cases where there is a large amount of water available in the vicinity of a power plant, cooling is achieved by streaming the cooling water directly through the condenser; this is the so-called fresh water cooling method. The warmed-up cooling water is discharged into the sea or river.

When the amount of available fresh water is insufficient for cooling, wet or dry cooling towers are used. The water inside the cooling towers recirculates between the cooling tower and the condenser. In this case, the majority of the heat to be discharged is carried off by the evaporation heat of the cooling water, and the rest of the heat is absorbed by the air through heat transfer.

Nearly ¾ of nuclear power plants in operation today utilize fresh water cooling, and the rest use cooling towers.

Fresh water cooling			**Cooling towers**
Sea	River	Lake	Wet/Dry
45%	14%	15%	26%
74%			26%

Table 5.1-1: Breakdown of current nuclear power plant cooling systems [5-1]

In the case of the planned new nuclear units, the main technology and the majority of auxiliary systems and facilities have a relatively low dependency on the installation environment; however, the cooling system must be chosen in a project specific manner, taking the features of the actual environment into consideration. The cooling method affects the technical and economical features and the environmental impact of the planned new nuclear units.

5.2 STATUTORY FRAMEWORK AND LIMIT VALUES FOR THE THERMAL LOAD OF AQUATIC ENVIRONMENTS

The warm water discharged into the aquatic environment (thermal discharge) may affect the recipient aquatic life, including fish and other aquatic organisms. The adverse effects on the aquatic flora and fauna can be mitigated by reducing the temperature of the water before being discharged, as well as by increasing mixing and heat loss. These effects can be regulated by the criteria governing the heat discharge limit values and the mixing zone.

5.2.1 GENERAL REGULATION AND LIMITS APPLICABLE TO HEAT LOAD ON THE AQUATIC ENVIRONMENT

5.2.1.1 European Union

Thermal discharge is limited by Annex I to Directive 2006/44 (EC) of the European Parliament and the Council:

- ✓ in the case of cyprinid waters, the temperature measured downstream of a point of thermal discharge (at the edge of the mixing zone) must not exceed the unaffected temperature by more than 3%
- ✓ thermal discharges must not cause the temperature downstream of the point of thermal discharge (at the edge of the mixing zone) to exceed 28°C.

Due to the uneven mixing of the discharged water in the recipient water, zones of higher temperature may be formed inside the mixing zone. The main factors affecting the mixing zone include temperature, speed and the amount of discharged water.

5.2.1.2 Hungary

The general rules are set forth in Government Decree 220/2004. (VII. 21.) on the protection of surface water quality and Decree 28/2004. (XII. 25.) KvVM on the emission limits of water pollutants and the rules governing the application of these limits. The limit values for the thermal load of the aquatic environment must be specified based on independent analysis, taking into account the sensitivity and load bearing capacity of the recipient water, with a view to preserve the desirable chemical and ecological balances. No limitation is given on heat emission and exposure to heat in Decree 10/2010. (VIII. 18.) VM on surface water contamination limits and the rules governing their application.

Table I of Annex 4 in Decree 6/2002. (XI.5.) of the Minister of Transport and Water Management (KvVM) sets the following limits on the contamination of surface waters designated as drinking water sources or reserves as well as surface waters protected for fish:

Quality parameters		Trout waters	Barbel waters	Bream waters
Temperature*	°C	18	25	30
Temperature change**	°C	1.5	3	5

Note:
temporary deviations from the water contamination limit value are allowed Article 12 (1)
**: temperature measured downstream of a point of thermal discharge (at the edge of the mixing zone) must not exceed the unaffected temperature by more than the value indicated above.

Table 5.2.1-1:Water contamination limit values for fish waters

To this date, only a few surface waters have been categorized; these are listed in Annex 7 to Decree No. 6/2002. (XI. 5.) of the Minister of Transport and Water Management. The Danube is not included here, thus according to the relevant statute *(as of June 7, 2014),* it does not qualify as a fish water. The classification of the Danube, or some of its sections, as a fish water of some type should be based on ecological impact assessment studies.

Licensing practice

During the licensing procedure of traditional power plants, the authorities specify the allowed difference between the temperature of the removed and returned water (ΔT_{max}), the maximum allowed temperature of the water to be discharged (T_{max}), the increase in temperature after mixing (ΔT) and the place of measurement.

5.2.2 REGULATION OF THE HEAT LOAD IMPOSED BY NUCLEAR POWER PLANTS

5.2.2.1 Member States of the European Union

Here are a few examples for such regulations in a few Member States.

Finland

There is no separate regulation for thermal discharge by nuclear power plants in Finland; limits are set by the competent authorities in accordance with the local characteristics of each project.

The two nuclear power plants currently in operation, Olkiluoto and Loviisa, use sea water cooling. Discharge limit value for Olkiluoto is 30°C (weekly rolling average), measured at a distance of 500 meters from the discharge channel.

For Loviisa, the limit value is 34°C (hourly average), measured at the discharge point.

Germany

In Germany, the temperature difference between the removed and returned water must not exceed 10°C. The maximum temperature of discharged water depends on the cooling method; 30°C in the case of fresh water cooling, 33°C in the case of open system cooling towers and 35°C in the case of closed system cooling towers.

The amount of water removed must not exceed 1/3 of the lowest water yield.

Sweden

There is no separate regulation for water removal; limits for the amount of water that may be removed and for the thermal discharge are set by the competent authorities in accordance with the local characteristics of each project.

Typically, the amount of water removed by nuclear power plants does not exceed 200 m3/s (per site), and the allowed temperature increase is 10°C. [5-2]

5.2.2.2 Hungary

Statutory regulation applicable to heat loading by fresh water cooling systems

High priority facilities, and more specifically, nuclear power plants, are subject to a special regulation set forth in Decree 15/2001. (VI. 6.) of the Minister for the Environment (KöM) on radioactive emissions to the air and to waters and on their control. The provisions for protecting surface waters and water bearing formations against thermal pollution are set out in Article 10 (1) of the Decree.

Article 10 (1): At high priority sites the following rules must be observed for protecting surface waters and water bearing formations against thermal contamination:

a) the temperature difference between the water to be discharged and the recipient water must not exceed 11°C, or 14°C if the temperature of the recipient water is less than +4°C;

b) the temperature of the recipient water measured anywhere in a section 500 meters downstream of the point of discharge must not exceed 30°C.

Based on Article 66 (1) of Act LIII of 1995 on the general rules of environmental protection, other heat load limits required for protecting water quality are determined by the supervisory authority in the course of licensing the use of the environment.

Statutory regulation applicable to heat production by cooling tower cooling systems

There is no statutory regulation in effect that would limit atmospheric thermal load, and there is no known atmospheric purity protection metric or limit value for the assessment of the effects of vapour formation and condensation.

5.3 COOLING METHODS TO BE TAKEN INTO CONSIDERATION REGARDING THE PAKS SITE

The cooling tower options applicable to the envisaged new nuclear power plant units of Paks were analysed in separate studies. The purpose of these investigations was to select a cooling method that can be built and operated economically with the best possible technology and efficiency under the circumstances and environmental conditions, and which complies with the environmental regulations during its planned lifetime.

The results of the analyses revealed that the two cooling methods feasible at Paks are fresh water cooling and cooling tower cooling. These two options, i.e. the **fresh water cooling system** utilizing the water of the Danube, the principle of which is identical to the cooling method of existing units 1 to 4, and the **wet cooling tower cooling system**, which can operate independently of the Danube in air cooling mode, were analysed in depth.

The key solutions analysed and their possible alternatives are summarized in Chapter 5.3.1 and Chapter 5.3.2 below, for the fresh water cooling system and the wet cooling tower cooling system, respectively.

5.3.1 FRESH-WATER COOLING

In the case of fresh water cooling – the method currently used at the four existing units of Paks – the waste heat is removed by circulating Danube water through the condenser. For this cooling solution, water is removed by pumps at the water intake plant from the Danube, and fed through appropriate filters and pipelines to the unit's turbine engine room. The cooling water flows through the condenser, and the warmed cooling water is released back into the Danube through the warm water channel and the return structure.

The fresh water cooling system has been analysed from the standpoints of technology, economics, and environmental protection. The analyses essentially explored the possibilities of removing the cooling water from the Danube and feeding it to the cooling water unit, as well as the technical solutions of returning the warmed cooling water to the Danube.

5.3.1.1 Alternative cooling water supply solutions

When analyzing the possible cooling water supply alternatives [5-5], the aspects of technology, cost-effectiveness and environmental protection were considered.

For the technology, the aim is to supply an adequate amount of cooling water, taking into consideration the characteristics of the Danube, the different water levels, water yields and water temperatures. Water may be sourced either from the Danube bank or the river bay of the existing cold water channel of the Paks Nuclear Power Plant. As the site of the Paks Nuclear Power Plant was chosen so that further units may be built there, cost-effectiveness criteria for cooling water supply dictate making use of the amenities of the site and the existing facilities as much as possible.

From the aspect of environmental protection, it is also advisable to use the existing facilities, with modifications applied where necessary. In order to limit the encroachment of new routes and facilities on Natura 2000 classified areas, efforts shall be made to make sure that Natura 2000 areas are affected as little as possible.

The most important alternatives studied for cooling water intake and supply are the following:

- Cooling water supply using a Danube bank water intake structure
- Cooling water supply using the in-bay water intake structure (selected solution)

5.3.1.1.1 Two-stage cooling water supply using a Danube bank water intake structure

In this alternative, the water intake plant would be erected on the right bank of the Danube, about 400 meters away from the mouth of the existing cold water channel of the Paks Nuclear Power Plant, facing upstream. Water is removed from the Danube by the pumps of the water intake plant to be installed on the river bank, and then the cooling water is fed via a free flow channel, filters and a closed, reinforced concrete channel to the pump station located next to the turbine engine room. The condenser cooling water pumps located here circulate the water through the condenser, and then the warmed cooling water is fed via a closed, reinforced concrete channel to the spillway. After the spillway, the warmed cooling water of the new units is released back into the Danube.

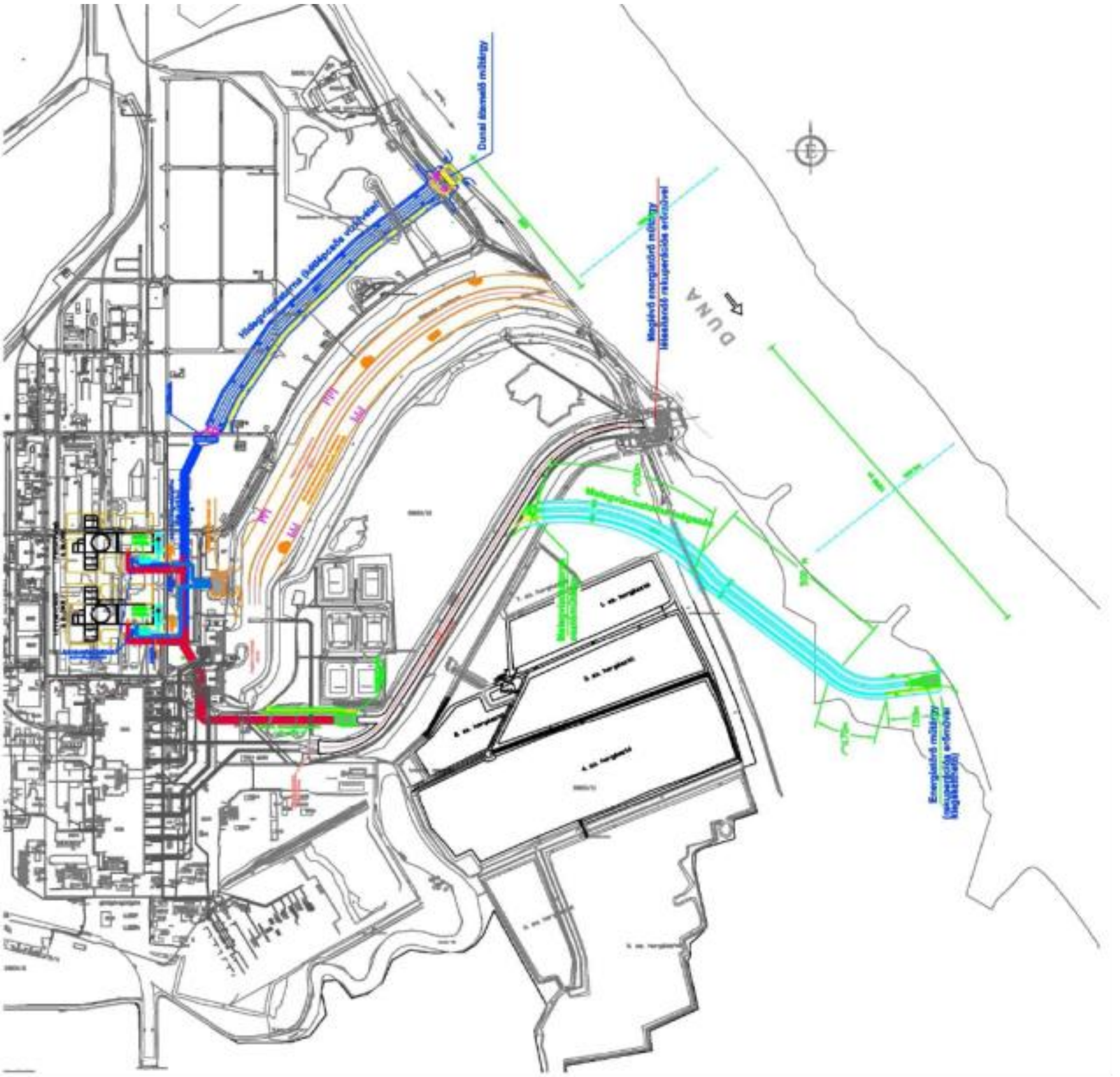


Figure 5.3.1-1: Two stage fresh water cooling system – layout [5-3], [5-4]

5.3.1.1.2 Cooling water supply using a bay water intake structure

In this alternative, the new intake plant built in the river bay is located about 150 meters north of the existing water intake plant, next to the existing cold water channel of the Paks Nuclear Power Plant. The cold water channel is used jointly by the units of Paks Nuclear Power Plant and Paks II. Nuclear Power Plant. The cold water channel needs to be extended to provide an adequate volume of cooling water and to adapt to the continuous deepening of the Danube. The water from the Danube is fed via the existing, adequately enlarged, free flow cold water channel with partially aproned earth bed to both the new and the existing water intake plants. The pump station of the new water intake plant that supplies the new units with cooling water feeds the cooling water via a pipeline to the condensers of the new units.

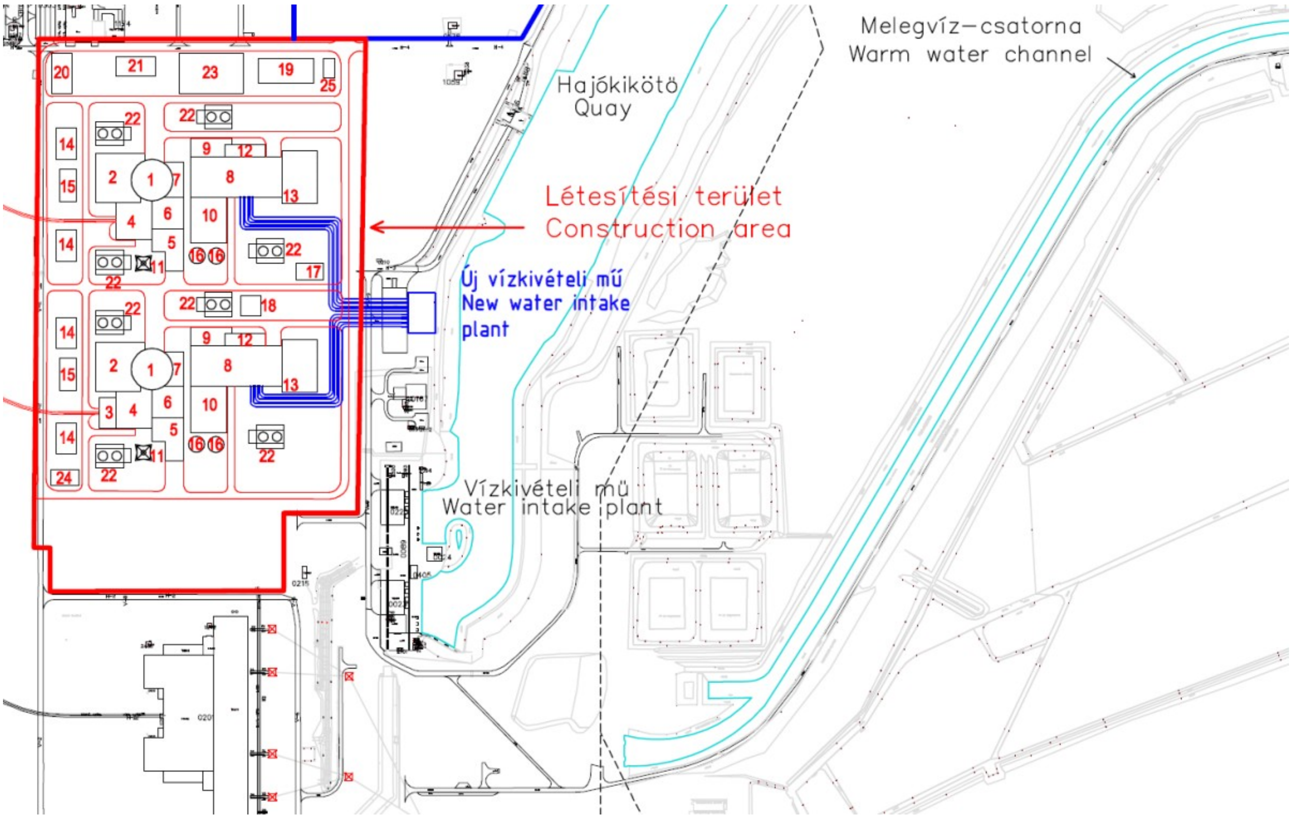


Figure 5.3.1-2: River bay cooling water supply, water intake from the existing cold water channel - site map

Of the analysed cooling water supply alternatives, the bay water supply basically differs from the two stage fresh water cooling system in that in this case, the existing cold water channel is a facility shared with the existing Paks Nuclear Power Plant. With the adequate expansion of the cold water channel, the necessary amount of cooling water can be provided for the both the existing units of Paks Nuclear Power Plant and the planned new units of Paks II.

5.3.1.1.3 Evaluation

Cooling water supply from the bay is more favourable from the aspect of construction and operation than the two stage fresh water cooling system.

From the aspect of environmental protection, the option with the lowest self-consumption and the one resulting in the smallest amount of lost electric power is the most favourable, as any electric power lost to self-consumption must be produced in another power plant. The most favourable considered alternative is the bay cooling water supply.

In terms of environmental impacts, in the case of the two-stage cooling water supply, a narrow section of Natura 2000 area is affected due to the water intake on the Danube bank, which presents yet another disadvantage compared to the river bay cooling water supply.

Based on survey results and in light of the technological, financial, environmental and nature conservation considerations, the bay cooling water intake and supply alternative was chosen.

5.3.1.2 Alternative solutions for the discharge of heated cooling water into the Danube

During the analysis and comparison of the different options of passing the warmed cooling water (henceforth: warm water) from the units to the spillway, and onward from there to the Danube, then discharging it into the river, the primary aim was to stay clear of the safety systems of the current operating units of the Paks Nuclear Power Plant.

Regarding the discharge of warm water from the spillway to the Danube, we also investigated the use of the existing warm water channel. The results show that it is preferable to make use of the existing warm water channel.

The alternatives of discharging warm water into the Danube are as follows:

- o discharge into the Danube on the left bank,
- o discharge into the Danube beyond the shipping lane, at the bottom of the bed,
- o discharge into the Danube on the right bank (selected solution).

Based on currently known conditions, discharging the warm water on the left bank of the Danube was discarded due to unfavourable mixing and significant investment costs compared to the other two alternatives.

Discharging the warm water beyond the shipping lane of the Danube is possible, and mixing is favourable in this case, but this solution requires a few significant technical interventions, and installing the structure that handles the deepening of the river bed is very expensive. Based on currently known conditions, discharging the warm water beyond the shipping lane of the Danube is only a secondary solution to the warm water discharge on the right bank of the Danube.

The following are the most important alternatives that can be considered for discharging warm water to the Danube on the right bank and that were analysed in detail:

- ✓ discharge through the existing energy dissipation device and the southern side channel,
- ✓ discharge through the existing energy dissipation device and through the northern channel branching, through a new baffle structure (selected solution)

5.3.1.2.1 Discharge of warm water through the existing energy dissipation device and through the southern side channel branching from the new warm water channel

Detailed analyses were carried out regarding the discharge of the warm water from the new nuclear units via the existing baffle structure of the existing warm water channel and the new southern side channel branching off from the warm water channel. Discharging at the existing warm water channel mouth and at a point ca. 1 000 meters south downstream therefrom are shown on the right hand side in Figure 5.3.1-1. This second outlet point would enable the warm water to better mix into and cool in the Danube.

However, the mixing analysis revealed that the second side channel outlet point located ca. 1000 meters to the south creates more unfavourable mixing conditions than a “quasi single-point” discharge. The main reason is that the current line of the Danube shifts from the right bank toward the left, which would result in insufficient mixing if a second discharge point was set up 1000 meters downstream from the current discharge point.

Further downstream from the existing warm water channel outlet, the Danube is getting shallower along the right bank, while discharging at a point further away from the warm water channel mouth would affect an ever greater Natura 2000 area.

Thus, as a result of surveys conducted in consideration of environmental and nature conservation consideration it was concluded that discharge through the side channel on the Natura 2000 area makes it hard to meet the environmental requirements presented in Chapter 5.2.2.2.

5.3.1.2.2 Discharging the warm water through the existing energy dissipation device and through the northern channel branching from the warm water channel

If warm water from the existing and new nuclear units is discharged via the energy dissipation structure located at the warm water channel mouth and via the new structure to be installed on the northern side channel branching off from the warm water channel (Figure 5.3.1-3), the size of affected Natura 2000 areas can be minimized, while an adequately designed new structure can also help improve mixing. This new structure could also house the recovery water power plant, which – according to the analyses – further improves the mixing of warm water discharged into the Danube.

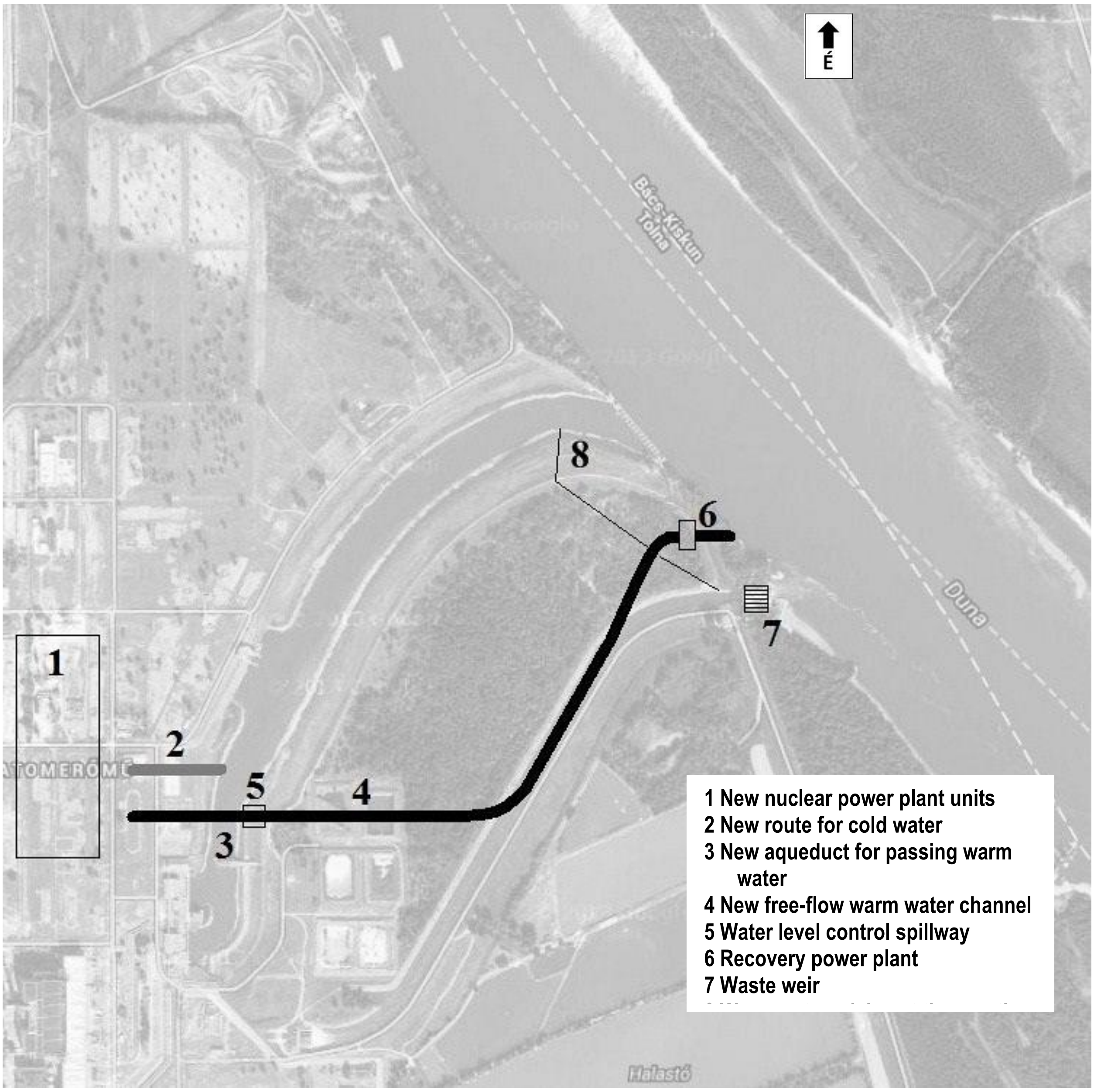


Figure 5.3.1-3: Warm cooling water returned using the existing warm water channel, with a new structure at the outlet that improves mixing – site plan

5.3.1.2.3 Evaluation

In terms of construction and operation, discharge of the warm water of the new nuclear units into the Danube is more favourable via the northern side channel of the existing warm water channel than via the southern one.

In terms of environmental protection, the more favourable alternative is the one that ensures a more thorough mixing of the discharged warm water with the Danube water. In this respect the northern branching off is a considerable better solution, because in this section mixing conditions are better.

If impacts on nature are considered, the northern side channel is the more favourable solution again, because only a narrow belt of Natura 2000 classified area is affected, resulting in a considerable advantage compared to the southern side channel.

Based on the conducted survey, and in light of the technical, financial, environmental and nature conservation considerations, discharge through the northern side channel branching from the existing warm water channel was chosen.

By implementing the northern side channel and a new warm water discharge structure (e.g. recovery power plant) in the area encircled by the existing cold water channel and the existing warm water channel, it is possible to improve the mixing of the warm water discharged into the Danube, along with minimizing the affected size of Natura 2000 areas.

5.3.1.3 Discharge of heated cooling water in summer

In summer, when the water temperature of the Danube exceeds 25°C, and water yield is low, it might be necessary to apply an additional solution in order to observe the T_{max}=30 ° temperature limit value specified for the Danube section 500 meters downstream of the warm water discharge point, especially in view of the increase in the water temperatures of the Danube over time, as a result of climate change.

In order to meet environmental regulations, the following possibilities were analysed:

- Limiting the electrical output of the unit
- Mixing in cold cooling water
- Using supplemental cooling.

The analyses assumed a 3°C temperature drop (basically resulting from mixing) between the warm water discharge point and the section 500 meter downstream therefrom, which allows a maximum of 33 °C warm water temperature at the discharge point.

5.3.1.3.1 Limiting the electrical output of the unit

If this solution is used, then maintaining the maximum allowed temperature of the warmed cooling water is achieved by limiting the electrical output of the nuclear unit. By reducing electrical output, the amount of heat to be removed from the condenser, and therefore – in the case of an unchanged cooling water mass flow – the rate of warming of the cooling water is reduced.

5.3.1.3.2 Mixing in cold cooling water

In the case of this cooling alternative, maintaining the maximum allowed temperature of the warmed cooling water is achieved by mixing the excess Danube water that bypasses the turbine condensers from the cold water channel into the warm water channel. The excess cooling water required for mixing in cold water is supplied by the additional pump located in the water inlet plant, which can be replaced by the pumps in the existing water inlet plant after the units currently operation are shut down. The cooling water warmed up in the condenser and the necessary amount of cold water mixed in is returned into the Danube via the existing warm water channel and an adequately sized structure that improves mixing at the discharge point.

5.3.1.3.3 Using supplemental cooling

When supplemental cooling is applied, the maximum allowed temperature of the warmed cooling water is maintained by the full-flow cooling of the warmed cooling water that leaves the turbine condensers in a cellular cooling tower with induced draught. The volume passed through the supplemental cooler can be optimized. The cooling water that has passed through the condenser and cooled down in the supplemental cooling water is returned to the Danube through the existing warm water channel and an appropriate structure that improves mixing.

5.3.1.3.4 Evaluation

Each of the studied supplemental solutions are suitable for maintaining the temperature of the warmed cooling water below 33 °C, as required for discharge into the Danube.

The minimum allowed partial load of the units puts a limit on reducing the output of Paks II units, while cold water mixing may be limited by the available yield of the Danube and the total amount of cooling water extraction for Paks and Paks II, and the expandability of jointly used structures and aftercooling may be limited by noise. However, under our basic assumptions, technical limitation factors do not render any of the alternatives unfeasible.

The analyses show that the technical, financial and environmental considerations bring forward different benefits in each of the outlined three solutions, but according to current knowledge, temporary limiting of the electrical output of the units is an optimal solution, both on the basis of the results of life cost calculations, and in terms of environmental protection, as it does not entail either additional environmental emission or encroachment on additional areas.

5.3.2 COOLING TOWER TECHNOLOGY

If a wet cooling tower cooling system installed near the existing cold water channel of the power plant is used for the new units, their heat is predominantly discharged into the air. The water taken from the Danube and treated by chemicals is only needed to replace the water lost by evaporation, entrainment and elutriation. In the case of a wet cooling tower system, the cooling water passed through the surface condenser of the steam turbine is returned to the cooling tower, then with the help of the water distributing sprinkler system, it is evenly dispersed on the fill media. The water film formed on the fill media cools down again, as a result of evaporation into the countercurrent ambient air. In order to dramatically reduce entrainment in the course of passing through the wet fill formation, all modern wet cooling systems have fill media and apply an entrainment separator above the nozzles. From the fill media the cooled water is returned to the cooling water pool, from where the circulating pumps carry it back to the condensers. Evaporation increases the salt content of the cooling water. For this reason, in order to avoid excessive concentration, a part of the cooling water is elutriated and replaced by treated fresh water. Water lost by entrainment must also be replaced. In order to avoid the deposition of salt on wetted surfaces, the cooling water used in the cooling system is treated by chemicals, and to prevent the growth of algae and the settlement of mussels, biocides are added to the water.

5.3.2.1 Analysis of tower cooling alternatives

Separate surveys were carried out for the analyses of the cooling tower options applicable with the new nuclear power plant units planned to be installed on the Paks site [5-4], [5-6], [5-7]. The various alternatives were analysed in detail according to the considerations of technical, financial, environmental and social acceptability. In the course of the assessments the following technical alternatives were analysed in detail within the category of tower cooling systems:

- Natural draught wet cooling tower (approx. 186 m high),
- Natural draught wet cooling tower limited to 100 m height,
- Natural draught wet tower cooling, with additional fan cooling,
- Hybrid (dry/wet) tower cooling.

The most important technical characteristics of the analysed alternatives are summed up in Table 5.3.2-1 for 2 x 1200 MW_e capacity.

for units of 2 x 1200 MW electrical capacity	Natural draught	Natural draught with limited height	Natural draught with an additional fan	Hybrid (dry / wet) tower cooling
Number of cooling towers	2x1	2x5	2x1	2x1
Cooling tower height [m]	186	100	70	60
Base diameter of the cooling tower [m]	136.5	88	150	160
Cooling tower throat diameter [m]	77.5	60	95	74
Net area occupied by the cooling towers (for two units) [m^2]	30,000	61,000	36,000	40,000
Accelerated cooling water volume flow rate m^3/hour	2 x 136,820	2 x 5 x 27,364	2 x 136,820	2 x 136,820
Additional cooling water [m^3/h]	about 2 x 2,900	about 2 x 2,900	about 2 x 2,900	about 2 x 2,600

Table 5.3.2-1: Specifications of wet tower cooling systems

5.3.2.1.1 Waste heat emission

Based on the literature, cooling tower waste heat and moisture emission are likely to have mainly local impacts on the atmosphere, under certain weather conditions the probability of certain weather phenomena (relative humidity increase, reduced visibility, fog, drizzle, icing, hoar-frost) may increase, cloud, rain and snow formation may be affected, the place of shower formation and the time of rainfall may change. Over the longer term, they might slightly affect the micro-climate of the emitter. Cooling towers have no currently known global impact.

The protective forest planted in the vicinity of the industrial area and a green surface of a higher biological activity can offset part of the heat island impact. In addition to climate related considerations, these solutions are recommended because they are suitable for the reduction of other environmental exposures (air contamination, noise) and the for the partial concealment of the facility. In winter situations preventive anti-skid road treatment and the operative use of warning weather forecasts may reduce the damages caused by increased icing.

Tower cooling systems may emit waste waters as a result of the continuous elutriation of cooling tower pools, and waste water release by the replacement cooling water preparatory technologies. The emitted waste waters contain the salts of the chemicals required for the treatment of the cooling water circulating in the tower cooling system and the chemicals and regenerates used for the development of replacement cooling water.

5.3.2.1.2 Main sources of noise and their characteristics

Noise of water falling from the evaporator fills

A characteristic noise source of wet cooling towers is the splash of water falling from the evaporator fills to the pool of the cooling tower. The resulting noise level may reach 90-92 dB(A) at a distance of 1 m from the cooling tower, and thus noise reduction is required to meet noise protection regulations. In order to reduce noise levels to 85 dB(A), the erection of a screen is sufficient.

Noise emission by fans

In the case of solutions with induced draught, in addition to the noise generated by falling water, fans and their driving engines may also increase cooling tower noise emissions, depending on the cooling tower design. In order to reduce the acoustic pressure of these type of cooling towers below 85 dB(A), noise mufflers must be built into the air suction part of fans, and to also abate the noise emission of falling water. As a drawback, the aerodynamic resistance of these mufflers increases the power demand of the fans.

Noise emission by pumps

The noise emission of the pumps used in cooling systems stays at around the industry average, i.e. typically it does not exceed 85 dB(A), and consequently no noise abatement is required.

5.3.2.1.3 Landscape protection analysis of the studied cooling solutions

The landscape protection considerations and the compatibility of the considered cooling solutions with the landscape were analysed in the first half of 2012, for the then worst case, which was 2 x 1600 MW. The findings of the analysis are also valid for the currently studied 2 x 1200 MW units, with the difference being that 2x7 natural draught wet cooling towers would be needed for 2 x 1600 MW, while only 2 x 5 such towers are required for 2 x 1200 MW.

Natural draught wet tower cooling

In respect of impacts on and compatibility with the landscape, two 186 m high natural draught wet cooling towers would be highly unfavourable in terms of their impacts on the landscape, but the same can be said of the natural draught wet tower cooling solution with up to 100 m high towers.

Fitting natural draught wet cooling towers into the landscape is practically impossible, as they have the most powerful visual impact, and examples for structure of such a number and size are not found anywhere in Hungary or abroad.

Natural draught wet tower cooling, with a cooling tower of 100 m high

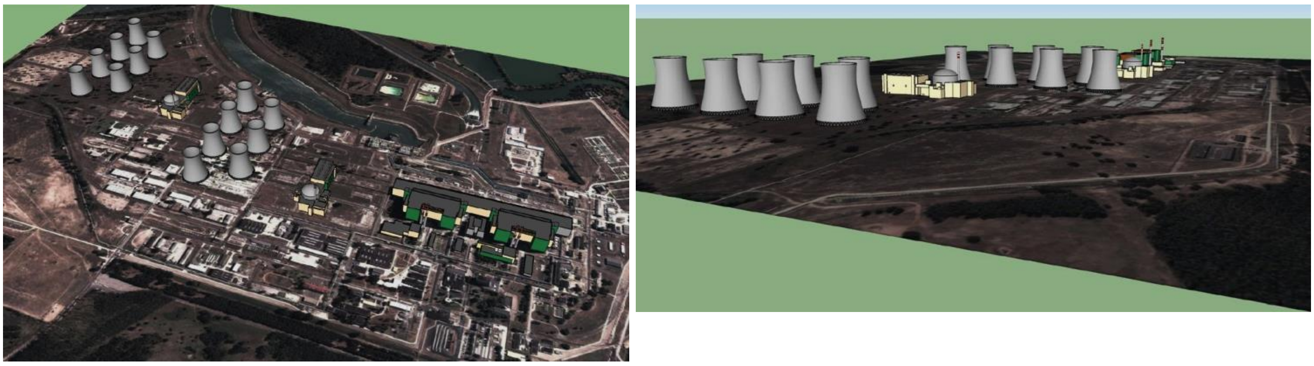


Figure 5.3.2-1: Natural draught wet cooling tower, up to 100 m high – visual design (bird's-eye view and side view)

The two natural draught wet cooling towers with additional fans and the two hybrid wet cooling towers with additional fans can both be merged to the landscape, they do not show any significant difference. The slightly lower hybrid cooling tower is more favourable because of the lower visibility of the vapour cloud, but it has a larger footprint.

Natural draught wet tower cooling, with additional fan cooling

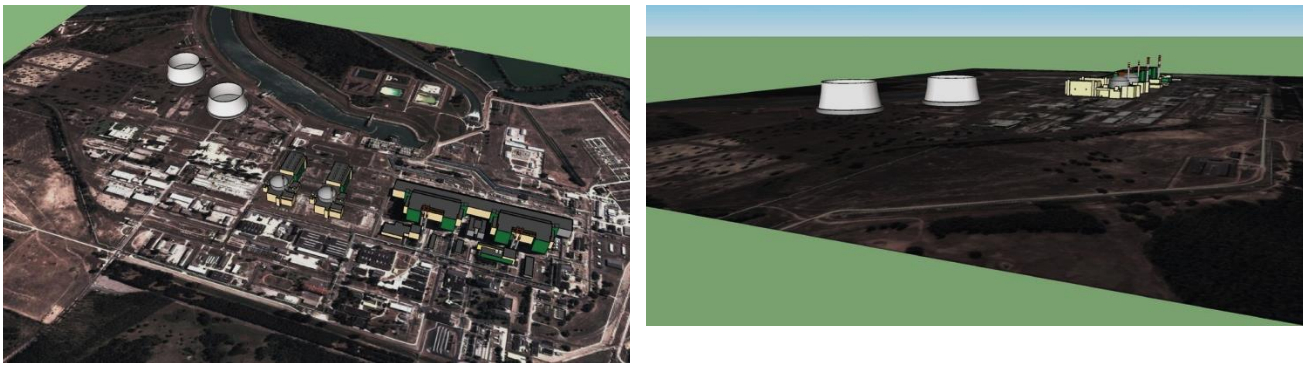


Figure 5.3.2-2: Natural draught wet cooling tower, with additional fan cooling – visual design (bird's-eye view and side view)

Hybrid (dry/wet) tower cooling

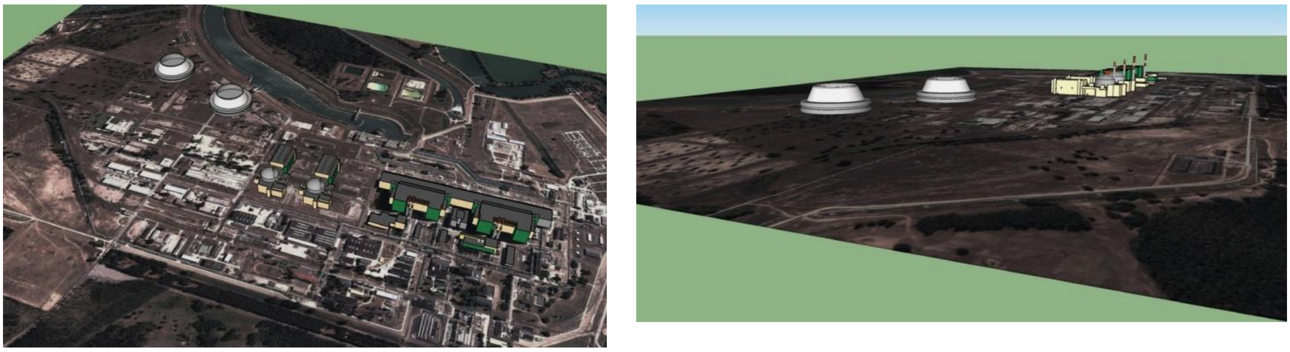


Figure 5.3.2-3: Hybrid cooling tower with additional fan – visual design (bird's-eye view and side view)

5.3.3 COST-BENEFIT ANALYSIS OF THE ALTERNATIVE COOLING SYSTEMS

The choice between the fresh water cooling and tower cooling options described in the foregoing chapters needs to be supported by a cost-benefit analysis aimed at providing evidence that the best environmental solution is also cost effective. The purpose of the cost-benefit analysis is to determine the social and economic benefits and costs involved. Benefits and costs can be analysed and interpreted by using methods of economic analysis, and based on the results the optimal solution – which also includes the objective – can be chosen.

Within the context of the fresh water cooling option, the optimal solution for the discharge of warm cooling water should be chosen based on the results of a cost-benefit analysis as the various alternative solutions offer the same level of social benefits. Based on the outcome of the cost-benefit analysis the solution suitable for achieving a specific objective at the lowest cost possible can be chosen.

5.3.3.1 Cost-benefit analysis of fresh water and tower cooling technologies

Fresh water cooling operates on the principle of removing heat by circulating water, withdrawn from the Danube, through a condenser, while in the case of tower cooling the water warmed up in the condenser is recirculated through the cooling tower and spread evenly on wet fill media by spray nozzles. The water film formed as a result of the above process is re-cooled by the counterflow of ambient air circulated through the fill media.

The project cost and operating costs of the two alternatives can be readily estimated, but the social/economic and environmental effects are difficult to assess and the benefits are hard to quantify. For that reason, the engineering solutions that have been chosen for both options offer more or less the same level of risks and ensure compliance with the relevant environmental regulations. The two alternatives have different environmental impacts but may be regarded as having the same level of social impact. Consequently, with the level of risk being similar and compliance with the relevant regulations ensured, the lowest-cost solution can be chosen.

The following table shows a comparative analysis of the fresh water cooling system:

	Benefits / useful factors	**Drawbacks / costly factors**
Inherent factors	Strengths: - *The lifecycle costs of fresh water cooling alternatives are lower than those of tower cooling systems (depending on the characteristics of the various alternatives and the discount rate).* - *No or very little chemical use is required.* - *The water resource fees, the amount of which is comparable to the cost of chemicals required by the cooling towers, go to the government budget.* - *Due to daily fluctuations in ambient temperature the periodic variation in electric power generation during the day is minimal.* - *Higher cycle efficiency and electricity yield.* - *Readily available operational experience due to the similarity of this technology to that of the existing units.*	Weaknesses: - *An additional solution or intervention is required due to exceeding (for a few hundred hours per year) the maximum allowable temperature limit applicable to the warmed cooling water.* - *Water resource fees must be paid, of a magnitude comparable to the project costs of the various fresh water cooling options.* - *50 percent of the water resource fee has to be paid on an annual basis as early as during the construction phase.*
External factors	Opportunities: - *Due to the slow fluctuation and seasonal nature of the water temperature of the Danube, planned maintenance can be scheduled in the expected periods of output power limitation.* - *The slow fluctuation of the water temperature of the Danube permits a longer term planning of output power limitation than in the case of the cooling tower options.* - *The public acceptance of this option is expected to be higher than that of the cooling tower alternatives as it is more compatible with the landscape character and no vapour cloud appears.* - *Fresh water cooling technology prevents icing that occurs in winter time due to vapour generation and might damage the built environment and poses risks to the environment in general.* - *As compared to cooling towers, its sizing to the same level of earthquake resistance involves much lower costs.* - *In the case of fresh water cooling, the contribution of domestic suppliers can be higher.*	Threats: - *Legislative changes might result in changes to the maximum allowable temperature limit applicable to warmed cooling water, necessitating additional investment at a later stage.* - *Changes in the water resource fee might result in a substantial increase in the costs of operation.* - *Any unforeseen changes in the deepening of the Danube riverbed might have an impact on the operation.*

Table 5.3.3-1: A comparative analysis of the fresh water cooling technology

5.3.3.2 Cost-benefit analysis of the discharge of heated cooling water in summer

Within the context of fresh water cooling, additional solutions need to be in place in order to ensure that a temperature of 30°C can be maintained in the 500 meter downstream section after the discharged warm water has mixed with the river water. The three alternatives serve the same purpose, namely to ensure compliance with the statutory limits pertaining to the temperature of the discharged water mixing with the Danube river water, as this represents the entire environmental impact on the Danube. Based on the 3D modelling of the mixing, a comparative analysis of solutions for a discharge temperature of 33°C has been performed. As such, the difference lies in the engineering solutions applied in order to achieve the desired outcome. The assessed solutions included the limitation of the output power of the units, the addition of cold cooling water, and the use of supplemental cooling – these are the scenarios that have been compared to each other. We compared the limitation of the output power of the units first, then the addition of cold cooling water, and finally the use of supplemental cooling, to the other two alternative solutions.

5.3.3.2.1 Fresh water cooling accompanied by limiting the electrical output of the units

In the case of the alternative cooling scenario ‘Fresh water cooling with output power limitation of the units’, compliance with the maximum temperature limit permitted at the point of discharge is maintained through the limitation of the output power of the power plant units.

	Benefits / useful factors	**Drawbacks / costly factors**
Inherent factors	Strengths: - *Of the alternative cooling solutions assessed, this has the lowest project cost.* - *No additional space requirement.* - *No chemical is required.* - *No additional noise load.* - *No additional water withdrawal from the Danube.*	Weaknesses: - *The periods of high electricity demand (air conditioning) and output restriction (high Danube water temperatures) generally coincide.* - *Of all the solutions to be used in addition to fresh water cooling, it is in this scenario that the power plant output depends the most on weather conditions (namely, the water temperature of the Danube).* - *Of all the solutions to be used in addition to fresh water cooling, the level of lost electric power is the highest in this scenario.* - *The discharge temperature cannot be substantially reduced if this solution is used exclusively.*
External factors	Opportunities: - *No additional type of environmental impact (the level of impact on landscape compatibility, as well as noise and heat load is similar to that of the existing scenario, with the additional effect of the new units).* - *Lowest impact on the built environment.* - *Due to the slow fluctuation and seasonal nature of the water temperature of the Danube, planned maintenance can largely be scheduled to coincide with the expected periods of output power limitation.*	Threats: - *The average amount of electric power lost per unit due to output limitation during critical periods is 150 to 500 MW_e.*

Table 5.3.3-2: Fresh water cooling with output power limitation

5.3.3.2.2 Fresh water cooling with added cold cooling water

In the case of the ‘Fresh water cooling with addition of cold cooling water’ scenario, compliance with the maximum allowable temperature limit of the warmed cooling water is maintained through the mixing of additional amounts of Danube water bypassing the turbine condensers into the warm water channel.

	Benefits / useful factors	Drawbacks / costly factors
Inherent factors	Strengths: - *Has substantially lower space requirements than the other alternatives of additional cooling.* - *Of all the solutions to be used in addition to fresh water cooling, in this scenario is the power plant output the least dependent on weather conditions (namely, the water temperature of the Danube).* - *No chemical dosing is required.* - *Low additional noise load in the operating area of the power plant*	Weaknesses: - *Requires the withdrawal of more water from the Danube than the other fresh water cooling variants.* - *The additional water intake is subject to a permit from the water authorities.* - *- Higher water resource fee.* - *The discharge temperature cannot be substantially reduced if this solution is used exclusively.*
External factors	Opportunities: - *There is no new kind of environmental impact (the landscape is similar to the previous one, noise and heat load are increased by the additional effect of the new units).*	Threats: - *- If only this additional solution is used, the combined water intake of the existing and newly implemented units could approximate 300 m^3/s of the Danube's water flow.*

Table 5.3.3-3: Analysis of the 'Fresh water cooling with addition of cold cooling water' scenario

5.3.3.2.3 Fresh water cooling with supplemental cooling

When supplemental cooling is applied, the maximum allowed temperature of the warmed cooling water is maintained by the cooling of the warmed cooling water that leaves the turbine condensers in a cellular cooling tower with induced draught.

Analysis of fresh water cooling by supplemental cooling

	Benefits / useful factors	Drawbacks / costly factors
Inherent factors	Strengths: - *No additional water withdrawal from the Danube.* - *Its operation is independent of the water level of the Danube.*	Weaknesses: - *Of the fresh water cooling variants assessed, this involves the highest project cost.* - *Unlike the other fresh water cooling variants assessed, this solution requires periodic chemical dosing (biocides).* - *Substantial periodic noise load in the operating area of the power plant.*
External factors	Opportunities: - *This solution is flexibly adaptable (expandable) if stricter discharge limits are introduced.* - *Due to its modular design it is adaptable to the effects of climate change, to any extent desired.* - *Unlike in the case of cooling tower variants, no icing occurs.*	Threats: - *Of the fresh water cooling variants assessed, this one can have the most substantial impact on the built environment.* - *Visible vapour emissions are likely to occur but only to a small extent as supplemental cooling is required during the warmest periods.*

Table 5.3.3-4: Analysis of the 'Fresh water cooling with supplemental cooling' scenario

Based on the results of the above analyses, the alternative solution offering the lowest lifecycle cost, highest social benefits and lowest environmental impact is currently the output power limitation of the units, and thus it is this solution that will be applied during the implementation; however, it does not exclude the use of additional solutions at a later stage.

In the course of the operation of the power plant units, the cost-benefit analysis may be updated depending on changes in the price of electricity, in the maximum water temperature of the Danube and in the project costs, and the most favourable supplemental solution may then be chosen based on the updated analysis.

5.3.4 EVALUATION

Based on the analyses performed, it can be concluded that both the wet tower cooling system and the fresh water cooling system are feasible; compliance with the current environmental regulations can be ensured through the application of adequate engineering solutions; the risks posed by the various alternative solutions are manageable; and the various alternative solutions can be ranked in terms of their cost effectiveness.

From an engineering perspective, with the application of the fresh water cooling system the planned new power plant units would offer a higher level of efficiency and electricity yield than with the tower cooling variant. Also, due to its similarities to the existing units, the fresh water cooling system has the additional advantage of readily available operational experience.

The icing caused by the water vapour emitted by cooling towers in winter might damage the built environment and poses risks to the environment in general.

As far as construction is concerned, the fresh water cooling system basically consists of types of structures that have already been built in Hungary, i.e. building and construction experience has been gained, while a wet tower cooling system applying natural draught technology has not yet been constructed on such a scale in Hungary.

From an environmental perspective, the fresh water cooling system requires no – or very little – chemical use, while the tower cooling system involves substantial chemical use for the processing of replacement cooling water and the chemical conditioning of the cooling water circulated in the cooling system.

From the point of view of the impact on the natural environment, the cooling towers comprising the tower cooling system are less compatible with the landscape character due to the higher number of towers, even if tower height is limited. The noise load, as well as the project cost and operating cost of cooling towers with fan-assisted draught inducers are significantly higher.

From an economic perspective, it can be concluded that the total lifecycle cost of the tower cooling system is higher than that of fresh water cooling.

As a result of the analyses performed, the technology chosen – similarly to that of the four existing units – is the fresh water cooling system. [5-7]

5.4 REFERENCES

[5-1] IAEA Nuclear Energy Series: Efficient Water Management in Water Cooled Reactors (No. NP-T-2.6), IAEA, Vienna, 2012.

[5-2] Development of Environmental Impact Assessment Related Requirements for NPP Projects Report of Environmental Impact Assessment Co-ordination Group of EUR, Date of issue of this report: 28/06/2011

[5-3] MVM Magyar Villamos Művek Zrt. Implementation of new nuclear power plant units, Preliminary consultation documentation, PÖYRY ERŐTERV, 10/05/2010

[5-4] MVM Magyar Villamos Művek Zrt. Analysis of the alternative cooling options for the new units to be implemented on the territory of the Paks Nuclear Power Plant, Decision support study, Vol. III, PÖYRY ERŐTERV ZRt, Budapest, 05/04/2011

[5-5] Comparative analysis of the new nuclear power plant units to be implemented at the Paks site, July 2012, MVM ERBE Zrt.

[5-6] MVM Magyar Villamos Művek Zrt. Analysis of the alternative cooling options for the new units to be implemented on the territory of the Paks Nuclear Power Plant, Decision support study, Vol. I, GEA EGI Energiagazdálkodási Zrt, Budapest, 05/04/2011

[5-7] Detailed analysis of the alternative tower cooling technologies connected to the new nuclear power plant units to be implemented at the Paks site, July 2012, MVM ERBE Zrt.

6 CHARACTERISTICS AND SPECIFICATIONS OF THE PAKS II NUCLEAR POWER PLANT PLANNED TO BE BUILT AT THE PAKS SITE

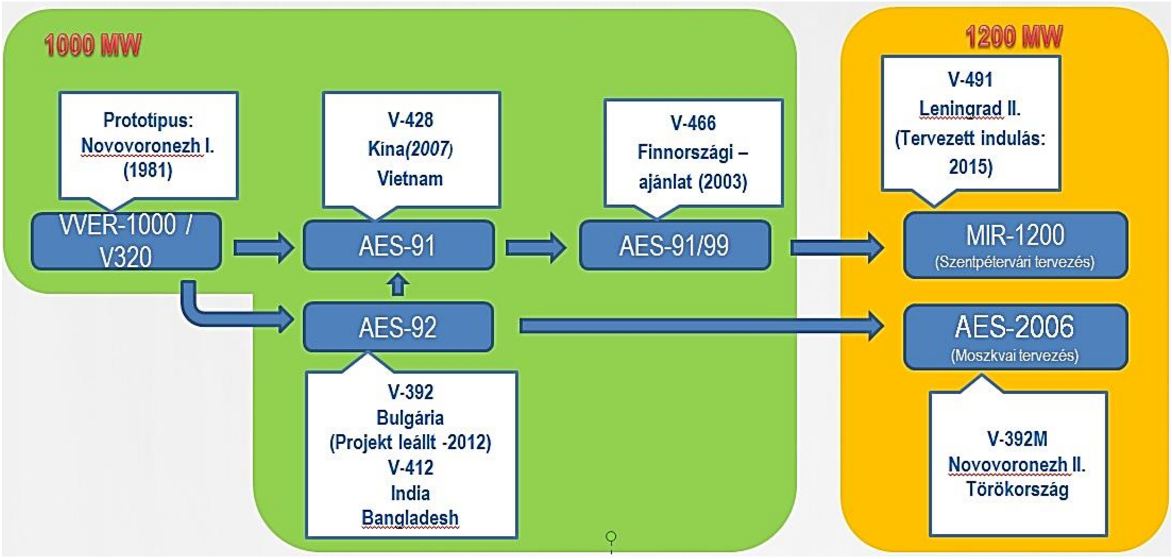
6.1 DEVELOPMENT OF THE RUSSIAN VVER UNITS

The Russian manufacturer's currently available III+ generation unit model is VVER-1200.

The unit's thermal capacity is 3200 MW, with a gross electric capacity of 1200 MW, and a district heating capacity of 300 MW.

VVER-1200 is an improved version of the VVER-1000 unit with a longer designed operating life (60 years), with a higher built-in capacity and higher thermal efficiency.

The unit is available in several versions, the difference between them lying in the different philosophy of safety systems designed by different chief designers (MIR-1200 – St Petersburg design, AES-2006 – Moscow design).



Prototípus – Prototype
V-428 Kína (2007) – V-428 China (2007)
V-466 Finnországi ajánlat (2003) – V-466 Proposal from Finland (2003)
V-491 Leningrad II (Tervezett indulás: 2015) – V-491 Leningrad II (Planned start: 2015)
V-392 Bulgária (Projekt leállt -2012) – V-392 Bulgaria (Project was stopped – 2012)
MIR-1200 (Szentpétervári tervezés) – MIR-1200 (Design of Saint Petersburg)
AES-2006 (Moszkvai tervezés) – AES 2006 (Design of Moscow)
V-392 M Novovoronezh II Törökország – V-392 M Novovoronezh II Turkey

Figure 6.1-1 Development of the Russian VVER units [6-1]

The VVER-1200 unit is better in terms both of its economy (unit capacity, efficiency) and availability (92% utilisation factor, 60 years operating life).

Besides safety changes, the main circulating pumps have been improved (through eliminating oil lubrication), a new fuel has been introduced that burns out[7] reactor poisons, and the reliability of steam generators has been upped. The newly constructed units use integrated, digital control technology. The steam turbine has normal revolution (3000 rpm) but the use of low speed (1500 rpm) machines is also being planned.

Through consistent application of the internationally accepted safety norms and EUR recommendations the VVER-1200 unit has practically been elevated to the level of AP1000 and EPR reactors. This is proved by the fact that VVER-1200 has been certified and approved by EUR.

7 *Reactor poisons absorb neutrons (and thus reduce the multiplicator effect) without contributing to the chain reaction.*

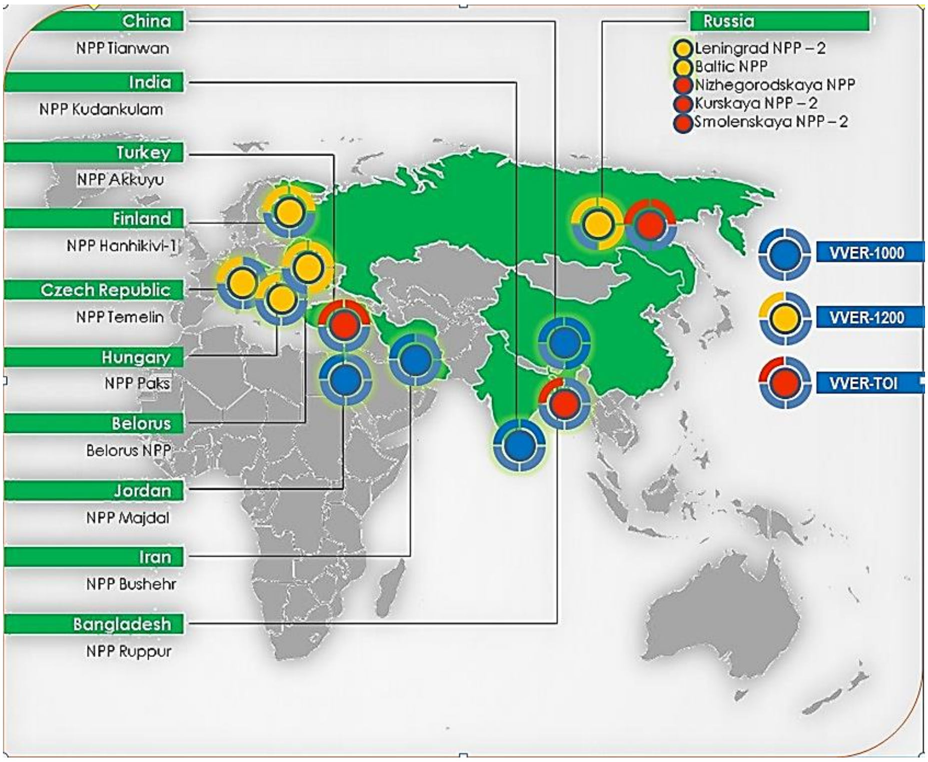


Figure 6.1-2 Russian units under construction [6-1]

Site	Reactor type	MW_e	Status	Start of operation
Novovoronezh II-1	VVER-1200/V-392M	1200	Under construction 6/08	2014
Rostov 3	VVER-1000/V-320	1100	Under construction 1983, restarted 9/09	2014
Leningrad II-1	VVER-1200/V-491	1200	Under construction 10/08	2016
Novovoronezh II-2	VVER-1200/V-392M	1200	Under construction 7/09	2015
Leningrad II-2	VVER-1200/V-491	1200	Under construction 4/10	2018
Baltic 1 (Kaliningrad)	VVER-1200/V-491	1194	Under construction 4/12, suspended 6/13-6/14	2017 (delay)

Table 6.1-1 Russian units under construction [6-2]

In the Russian Federation two VVER-1200 units are being built at the Leningrad Nuclear Power Plant (Sosnovij Bor) and another two at the Novovoronezh Nuclear Power Plant and are expected to start operation in 2018 or 2019.

The Russian Federation plans to expand its nuclear generation capacity significantly with VVER-1200 type units. 17 units are scheduled to come online by 2020, with a total new capacity of 20,000 MWe.

Site	Reactor type	MW_e	Status	Start of operation
Leningrad II-3	VVER-1200/V-491	1200	Scheduled: 2015	2021
Leningrad II-4	VVER-1200/V-491	1200	Scheduled: 2016	2022
Kursk II-1	VVER-1200/V-510	1300	Scheduled: 2015	12/2020
Kursk II-2	VVER-1200/V-510	1300	Scheduled: 2016	12/2021
Smolensk II-1	VVER-1200/V-510	1200	Scheduled: 2016	2022
Smolensk II-2	VVER-1200/V-510	1200	Scheduled: 2017	2023

Table 6.1-2: Currently designed projects [6-2]

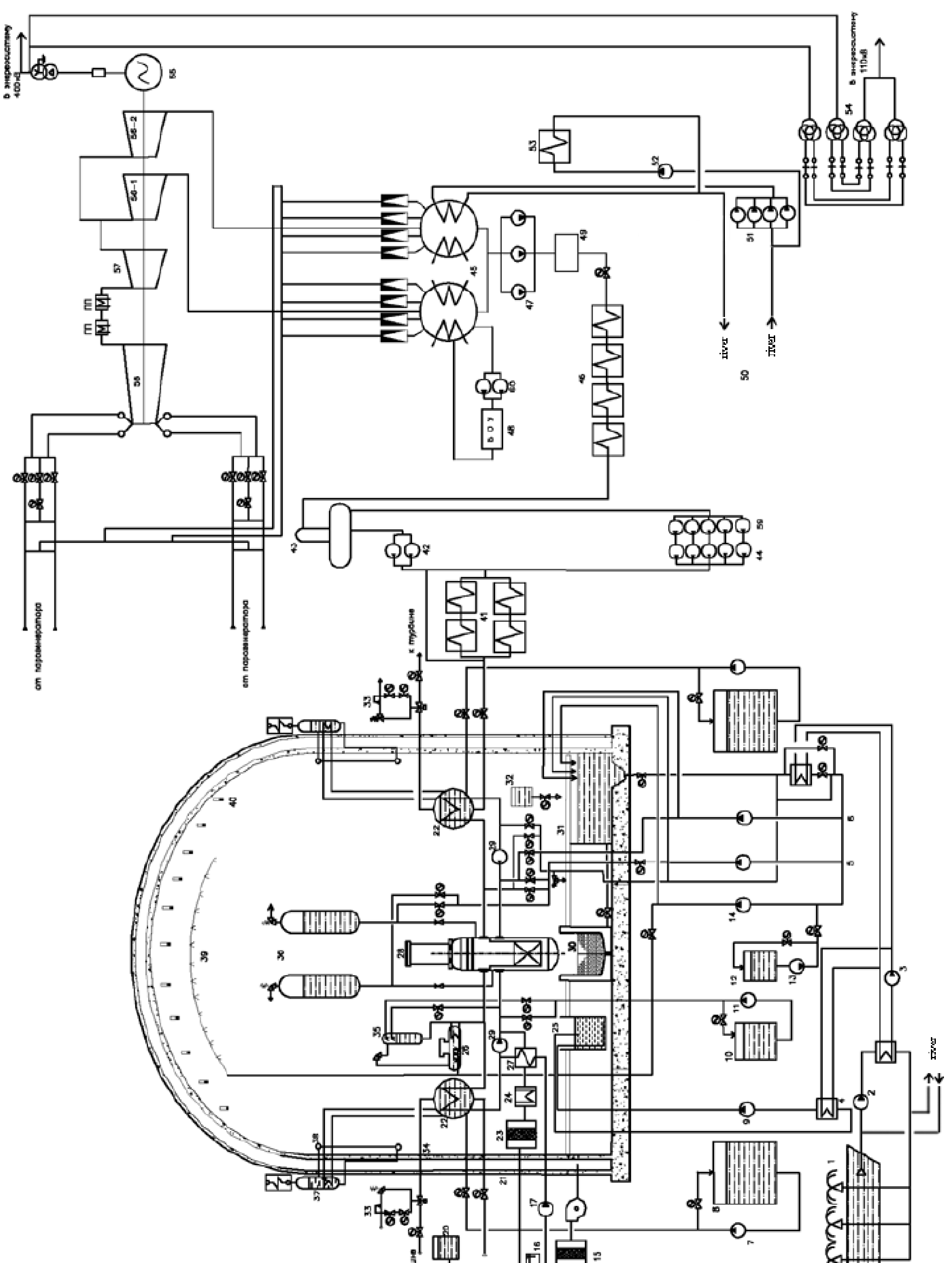


Figure 6.1-3: Simplified block diagram of a VVER-1200 unit [6-3]

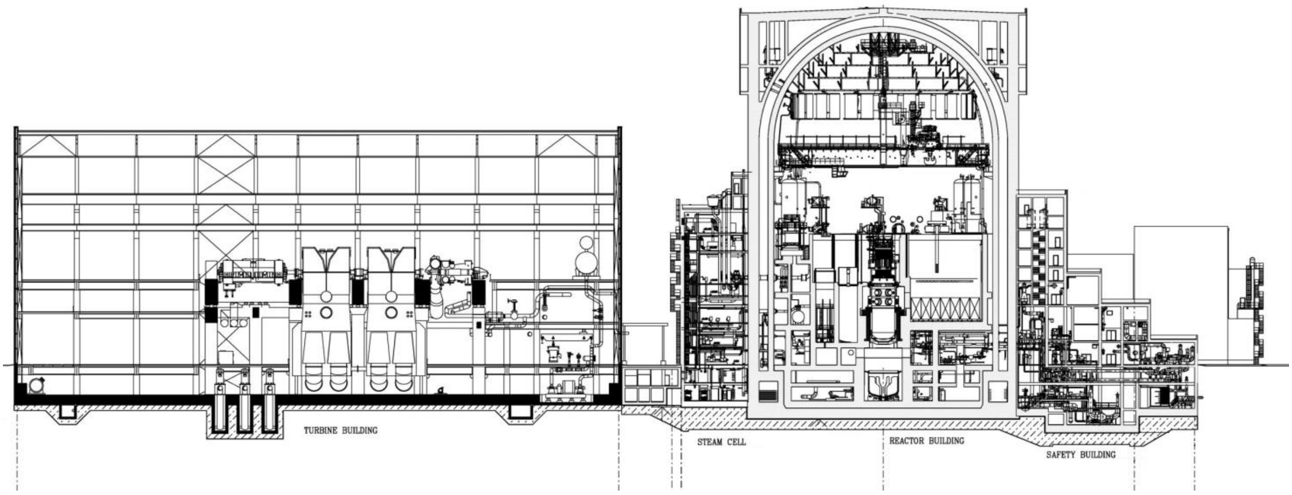


Figure 6.1-4: Longitudinal section of a VVER-1200 unit [6-3]

6.2 CHARACTERISTICS OF THE RUSSIAN UNITS PLANNED TO BE INSTALLED ON THE PAKS SITE

6.2.1 KEY TECHNICAL PARAMETERS

Table 6.2.1-1 lists the main technical parameters of VVER-1200 units:

Reactor heat output	3,200 MW_e
Net deliverable output (depends on the secondary circuit technologies used)	1113 MW_e
Operating life	60 years
Planned output utilisation factor	>90%
Time lost per year due to scheduled major maintenance	20 days
Self-consumption	7.1%
Type of usable fuel	UO_2
Fuel cycle, time spent by a cassette in the reactor	54 months (3 x 18 months)
Campaign length	18 months
Fuel requirement	40.58 t UO_2 / 18 months
Fuels required (fuel + cassette)	56.4 t / 18 months
Number of fresh cassettes at the time of replacement (equilibrium)	76
Average enrichment of fresh cassettes	4.95% (^{235}U)
Average burning rate	47.5 Mwday / kgU
Controllability	50 % to 100 %, yearly max. 250 units
Number of loops and main circulating pumps (FKSZ/MCP)	4, 4 FKSZ/MAP
Pressure in the primary circuit	162 bar
Reactor inlet / outlet temperature	298.2 / 328.9 °C
Steam generator	4 units, horizontal
Steam generator outlet pressure	62.7 bar
Total coolant flow rate in the primary circuit	86,000 m^3/h

Table 6.2.1-1: Main technical parameters of the VVER-1200 type unit [6-4], [6-5], [6-6]

Based on available information, the campaign length of the units to be installed is 12 months at the beginning of productive operation, after that it is expected to be 18 months. Later if conditions of design and technology are properly adjusted, it may even be extended to 24 months. This study assumes a campaign length of 18 months.

6.2.2 SAFETY OBJECTIVES AND DESIGN SOLUTIONS

Safety objective	Design solutions or risk countermeasures applied to achieve the objective
Management of incidents related to the design extension condition	– Double-walled containment – Cooling system – Containment cooling system – Hydrogen recombination systems – Core catcher
Prevention of high-pressure processes leading to early breakdown of the containment structure	– Pressure reducing valves – Cooling system
The treatment of produced hydrogen	– Recombination systems
Stabilisation and cooling of core melt	– Core catcher
Containment pressure reduction	– Large surface coolers (0 to 24 hours) – Mobile equipment (24 to 72 hours)

Table 6.2.2-1: Design solutions or risk countermeasures applied to achieve the objective [6-4], [6-5]

The nuclear systems of the unit are placed in a double-walled containment. The inner wall seals the containment hermetically, while the outer wall protects the hermetic space from outside impacts (e.g. against aircraft hits). The lower part of the containment works as a core catcher for core melt.

The security systems that have a 100% protection capacity each are arranged in four independent channels. Each safety channel is equipped with its own diesel generator of 7.5 MW output.

In case of a breakdown, the systems that provide the cooling of the reactor and the primary circle are augmented by 4 high-pressure hydro-accumulators, which keep the active zone under water without operator intervention in the initial period of breakdowns that involve significant loss of heat transfer agents in the primary circuit, until the active zone malfunction cooling systems (ZÜHR/ZMCS) kick in.

6.3 FUEL

The new nuclear power plant units to be built at the Paks site use enriched uranium-dioxide.

The fuel will be transported to the site in containers that conform to the relevant legislation, normally by train.

The first charge will be delivered to the site approximately 1 to 1.5 years before the start of commercial operation. Fresh fuel needed for the replacement of spent fuel will be delivered in conformity with the fuel cycle and the time of replacement, on schedule, every 18 months during the planned operating life of 60 years. As a strategic supply, fresh fuel equal to two replacements is stored onsite.

After the spent fuels have been removed from the reactor, they are placed in a fuel pond, where the residual heat is removed until the heat output falls to the level enabling the temporary dry storage of the fuel. Fuels may spend a maximum of 10 years in the fuel pond.

After being stored in the fuel pond, the spent fuels will be stored temporarily. At present, this can be done by either of the following two options:

- the spent fuels are transported to the territory of the Russian Federation for temporary technological storage or technological storage and reprocessing. The spent fuels, or in the case of reprocessing the nuclear waste will be stored on the territory of the Russian Federation for a length of time prescribed in the agreement (contract) mentioned in Article 7 paragraph 1 for the supply of nuclear fuel (20 years), and subsequently they will be returned to Hungary.
- temporary storage of the spent fuels in Hungary.

In view of the planned operational time of the new units and the periods specified in the intergovernmental agreement, we assume **temporary storage in Hungary**, at the site of the units or in their immediate vicinity. Temporary storage is used until the fuels can be directly and finally disposed of or the high activity waste resulting from the reprocessing of the fuels is can be safely put to final storage in Hungary.

Following temporary storage we assume direct and final disposal of the spent fuels in Hungary, in view of the following:

- according to the Act on Nuclear Energy, one of the conditions for the final disposal abroad of waste generated in Hungary – namely that a radioactive waste storage facility has been licensed for the radioactive waste to be delivered and has been in operation before the delivery – is not met
- owing to the length of the planned operating life, the long-term feasibility of other options is questionable and involves significant risks

In the case of the strategy for the acquisition of fuel and the disposal of spent fuel outlined above, Table 6.3-1 shows the amount of fresh and spent fuel on the site for 1200 MW_e units. The table shows the full mass of the fuels and does not contain the quantity that may have to be stored in temporary storage facilities.

Unit output	1 x 1200 MW_e	2 x 1200 MW_e
Fuel (cassette) in the reactors, first charge (163 cassettes)	**about 120.94 t**	**about 241.88 t**
Fresh fuels needed for replacement (in a state of equilibrium)	**about 56.4 t / 18 months**	**about 112.8 t / 18 months**
Strategic stock of fresh fuel (quantity needed for two replacements)	**about 112.8 t**	**about 225.6 t**
Volume of fuel stored in the fuel ponds (assuming 7 fuel cycles spanning about 10 years)	**about 540 t**	**about 1080 t**
Maximum amount of fresh and spent fuel at the same time within the nuclear island	**about 773.74 t**	**about 1547.48 t**

Table 6.3-1: Fresh and spent fuel mass [6-5]

6.4 PRIMARY CIRCUIT

Based on the energy generation process, the planned new nuclear power plant units can be divided into two main parts: the primary and the secondary circuit.

The primary circuit passes the heat generated in the active zone of the reactor (reactor core) to the steam generator, the steam generated in the steam generator drives the turbine of the secondary circuit and generates power in the generator connected to the turbine.

The primary circuit contains the following equipment:

Reactor vessel
Steam generator
Circulating pumps
Expansion tank

Reactor	
Nominal heat output of the reactor	3200 MW_{th}
Pressure in the primary circuit coolant	16.2 MPa
Coolant inlet temperature	298.2 °C
Coolant outlet temperature	328.9 °C
Steam generator	
Pressure in the primary circuit	17.64 MPa
Pressure in the secondary circuit	7.0 MPa
Circulating pumps	
Type of drive	electric motor
Number of circulating pumps	4
Total coolant flow rate in the primary circuit	86,000 m^3/h

Table 6.4-1: Specifications of the main equipment in the primary circuit [6-5]

6.5 SECONDARY CIRCUIT

The secondary circuit contains the following apparatuses:

- Main steam system
  - Main steam pipe
  - Steam turbine
  - Entrainment separator and steam superheater chamber
- Condensate / feedwater system
  - Condenser
  - Condenser pumps
  - Low-pressure and high-pressure preheaters
  - Feedstock storage tank
  - Injection pumps

The role of the secondary circuit is to transform the heat generated in the reactor into kinetic and then electric energy. The feedwater flowing in the secondary circuit is boiled up by the 300 to 320ºC water of the primary circuit flowing through the heat exchange pipes of the steam generator.

The steam leaving the steam generator enters the turbine, where its kinetic energy starts driving the rotor of the turbine. The high and low pressure blocks as well as the rotor of the generator share the same turbine shaft. In the high pressure turbine block, the temperature of steam decreases whereas its moisture content increases significantly. For this reason, before the steam gets into the low pressure block, it passes through an entrainment separator and superheater chamber, where water drops harmful for the turbine blades are removed from it.

Steam that has already done its job (dead steam) enters the condenser, where cooling water flows in thousands of thin pipes. On the surfaces of these cooling pipes the steam condenses at a temperature of about 25ºC, after which it is being redirected into the steam generator by the injection pumps through a multi-stage preheater used to increase efficiency.

The efficiency of the steam cycle is about 37%.

Turbine	
Number of turbine blocks (HP/MP/LP)	1/0/4
Inlet pressure	68 bar
Inlet temperature	283.8°C
Steam mass flow	6464.5t/h
Net electric output (depends on the chosen technologies of the secondary circuit)	1113 MW
Rotational speed	3000 rpm
Frequency	50 Hz
Condenser	
Condenser pressure	49 mbar
Temperature of cooling water	18°C
Volume flow rate of cooling water	237,600 m^3/h
Feedwater system	
Number of low pressure preheater stages	4
Number of high pressure preheater stages	2
Feedwater temperature	227°C
Feedwater injection pumps	
Type of drive	electric motor
Number of feedwater pumps	4

Note:
HP/MP/LP – high pressure, medium pressure, low pressure

Table 6.5-1: Specifications of the main equipment in the secondary circuit [6-5]

6.6 COOLING SYSTEMS

Both the primary and the secondary circuits produce heat that cannot be used for electric power generation. This heat is removed with the help of the cooling systems.

The cooling systems of the planned new nuclear power plant units consist of three main parts:

- the cooling system of the condenser,
- the technological cooling system, and
- the emergency cooling system.

The role of the condenser's cooling system is to remove the condensation heat of the steam cycle from the *condensers* installed in the *secondary circuit* of the nuclear power plant by circulating mechanically filtered Danube water through the surface condensers.

The technological cooling system, on the other hand, removes excess heat generated in the *auxiliary systems of the secondary circuit*. In new nuclear power plant units, the technological cooling system removes the waste heat of the turbine-generator group, of the injection pump and of the high capacity electric motors via a closed, intermediary cooling circuit. The technological cooling system branches off from the condenser's cooling system inside the turbine building, and the warmed up technological cooling water is drained off together with the condenser's cooling water back into the Danube.

The role of the emergency cooling system is to supply cooling water to the equipment of the *primary circuit* of the new nuclear power plant that require constant cooling during normal operation of the primary circuit. In addition, the emergency cooling system is also responsible for cooling the units during emergencies, by removing both primary circuit heat and residual heat from the reactor, as well as from the fuel handling sites and the fuel pond. The emergency cooling system has two alternative operation modes. One uses forced air cooled cells that pass on excess heat to the air, whereas the other uses fresh water to remove the heat, and in this case the final heat absorber is the Danube river. Basically, the emergency cooling system operates in the fresh water cooling mode, but if, for any reason (such as extreme meteorological circumstances, extreme water levels, or damage to the water extraction facilities preventing their functioning), it is impossible to resort to this solution in order to meet the needs of emergency cooling, the unit automatically switches to the cooling cell mode. The planned new nuclear power plant units will be designed with the site's characteristics in mind, therefore their emergency cooling systems will operate in the fresh-water cooling mode most of the time.

6.6.1 WATER INTAKE FROM THE DANUBE

Depending on the emergency cooling system's operating mode, volumes of water taken from the Danube will differ slightly.

If the emergency cooling system uses a *cooling tower*, the total volume of raw water taken from the Danube (for the condenser, for technological purposes and for replacement) is shown in the following table.

Description	Unit	1 x 1200 MW_e	2 x 1200 MW_e
Cooling water for the condenser*	m^3/s	61.5	123
Cooling water for technological uses (secondary circuit)*	m^3/s	2.6	5.2
Emergency cooling water (primary circuit)*	m^3/s	0	0
Raw water for preparing makeup water (desalinated water as well as replacement cooling water)	m^3/s	0.06	0.12
Total water intake from the Danube**	m^3/s	64.16	128.32

Source of data:
*Data provided by MVM Paks II Ltd.
** Calculations by MVM ERBE Ltd.

Table 6.6.1-1: Water volumes taken from the Danube for the emergency cooling system in cooling tower mode

If the emergency cooling system uses *fresh-water technology*, the total volume of raw water taken from the Danube (for condenser cooling, for technological cooling, for emergency cooling and for makeup-water pre-treament) is shown in the following table.

Description	Unit	1 x 1200 MW_e	2 x 1200 MW_e
Cooling water for the condenser*	m^3/s	61.5	123
Cooling water for technological uses (secondary circuit)*	m^3/s	2.6	5.2
Safety (primary circuit) coolant*	m^3/s	1.9	3.8
Raw water for preparing makeup water (desalinated water)**	m^3/s	0.01	0.02
Total water intake from the Danube**	m^3/s	66.01	132.02
Annual (8760 h), maximum cooling water demand**	billion (10^9) cubic meters per year	2.08	4.16

Source of data:
*Data provided by MVM Paks II Ltd.
** Calculations by MVM ERBE Ltd.

Table 6.6.1-2: Volumes of water taken from the Danube for the emergency cooling system in fresh-water cooling mode

Depending on the type of cooling used for the emergency cooling system, the volumes of water extracted from the Danube are 64.15 m^3/s and 66.01 m^3/s, respectively, for one unit, totalling 128.3 m^3/s and 132.02 m^3/s, respectively, for two units. For the purpose of evaluating the impacts of water extraction from and discharge into the Danube, always the higher values have been taken into account.

6.6.2 CONDENSER COOLING SYSTEM

The cooling water system of the condenser, just like in the case of the four existing units of the nuclear power plant, removes the excess heat with the help of water taken from the Danube, by circulating it through the condenser. The water of the Danube is extracted with the help of a water extraction pump, and is fed through the appropriate filters and pipes to the condensers located in the turbine building.

The cooling system of the condenser also carries the water needed for technological uses to the machine room.

Based on the examined varieties of condenser cooling systems for the new nuclear power plant units, taking into account technical, financially reasonable, environmental and environmental protection considerations, the solution of choice was to take the cooling water from the river bay, and to discharge warm water by crossing the existing cold-water channel and expanding the existing warm water channel.

The volume flow rate of the cooling water needed for the condenser at an approach temperature of $\Delta t = 8°C$ within the condenser, and for about 2,075 MW_{th} of heat to be removed, is expected to be 61.5 m^3/s for one unit and 123 m^3/s for two units during normal operation.

Unit output	Unit	1 x 1200 MW_e	2 x 1200 MW_e
Volume flow rate of cooling water*	m^3/s	61.5	123
Volume flow rate of cooling water**	m^3/h	221,400	442,800
Warming of coolant inside the condenser*	°C	8	8
Annual (8760 h), maximum cooling water demand**	billion (10^9) cubic meters per year	1.94	3.88

Source of data:
*Data provided by MVM Paks II Ltd.
**Calculations by MVM ERBE Ltd.

Table 6.6.2-1*: Volumes of cooling water for the condenser*

6.6.3 TECHNOLOGICAL (SECONDARY CIRCUIT) COOLING WATER SYSTEM [6-9]

Cooling needs apart from that of the condenser of the secondary circuit of the nuclear power plant are met by the technological cooling system. Water required for this purpose is carried by the condenser's cooling system up to the turbine building, where it branches off and is carried along with the help of a properly sized pump increasing its pressure, down to all the users of the technological cooling system. Water warmed up in the technological cooling system returns into the warm water branch of the condenser's cooling system. The technological cooling water and the condenser's cooling waters are discharged together into the Danube. The cooling agent of the technological cooling system is the water of the Danube river, which is first filtered for use in the condenser, and then further cleaned through fine mechanical filters in order to ensure the safe operation of heat exchangers. Inside the closed intermediary cooling system of the turbine building desalinated water cools the heat exchangers of the technological cooling system.

The technological cooling water system is redundant (2x100%), which means that all major parts of the system consist of 2 parallel units, cross connected to each other.

The cooling water requirement of the technological cooling system for one unit during normal operation is expected to be 9,360 m^3/h, and for two units 18,720 m^3/h during normal operation. Transitional operation phases (such as start/stop) do not require significantly different amounts than normal. Calculations for technological water needs have been made assuming 86.6 MW_{th} of heat/unit to be removed, with a temperature increase of 8°C, which is identical to that of the condenser cooling system.

Unit output	Unit	1 x 1200 MW_e	2 x 1200 MW_e
Volume flow rate of technological cooling water during regular operation	m^3/s	2.6	5.2
Volume flow rate of technological cooling water during regular operation	m^3/h	9,360	18,720
Warming of cooling water inside the technological cooling system	°C	8	8
Maximum annual technological cooling water demand	million m^3/year	82	164

Table 6.6.3-1: Technological cooling water volumes

6.6.4 EMERGENCY COOLING WATER SYSTEM [6-9]

The auxiliary systems of the primary circuit are cooled by emergency cooling systems built for each unit separately. One unit requires four identical independent supply systems. During normal operation, one redundant system is used, whereas during transitional periods of operation two redundant systems are involved.

This system is independent from both the condenser cooling of the secondary circuit, and from its technological cooling system. Joint engineering structures are only envisaged for their supply and drainage.

The water demand of the emergency cooling system for one unit during normal operation is expected at 6,840 m^3/h, and for two units during normal operation at 13,680 m^3/h. The same for transitional operating conditions (such as start/stop) for one unit is 13,680 m^3/h. Since for operational reasons the two units are not expected to be in a transitional state at the same time, the combined water demand of the two units is not likely to exceed a volume flow rate of 20,520 m^3/h. Calculations for safety water needs have been made with a temperature increase of 8°C, identical with that of the condenser cooling system.

Unit output	Unit	1 x 1200 MW_e	2 x 1200 MW_e
Volume flow rate of emergency cooling water during normal operation	m^3/s	1.9	3.8
Volume flow rate of emergency cooling water during normal operation	m^3/h	6,840	13,680
Volume flow rate of cooling water during transitional operating conditions	m^3/h	13,680	20,520
Warming of coolant inside the emergency cooling system	°C	8	8

Table 6.6.4-1: Emergency cooling water volumes

Cooling with forced air cooled cells

One possible method of operating the emergency cooling system is to use forced air cooled cells that pass on excess heat to the air, the final heat absorber being the surrounding atmosphere. In this case, the emergency cooling system does not extract excess heat by circulating the Danube's water and thus does not discharge any warm water back into the river. This is a quasi-closed system, in which the coolant circulates between the emergency cooling cells and the heat exchangers of the emergency cooling system. After the system is filled up at start, it is only necessary to replace the amount evaporated, separated or lost due to sludge removal. This lost amount of water is replaced by the dedicated makeup water preparation system of the plant. The annual demand for replacement cooling water is minimal, since the emergency cooling towers are expected to work about a month a year at most, therefore their demand for Danube water is negligible compared to other water extraction volumes for cooling.

Unit output	Unit	1 x 1200 MW_e	2 x 1200 MW_e
Volume of replacement cooling water	m^3/s	0.04	0.08
Maximum annual demand for replacement cooling water (for emergency cooling, taken from the Danube)	million m^3/year	about 0.1	about 0.2

Table 6.6.4-2: Volumes of replacement cooling water for emergency cooling, with emergency cooling towers

Cooling towers using forced air cooled cells for removing the heat of the emergency cooling system have 4x100% redundancy for each unit. (The amount of reserves is to be finalized on the basis of safety analyses conducted at the site). During normal operation, one emergency cooling cell is used and all the others are reserves. On the other hand, at times of start-ups, stops and cooling sessions following stops, two emergency cooling cells are in operation.

These 4 emergency cooling cells for each unit are located next to the containment building. The floor area of the emergency cooling cells is 17x35 m, their full height is about 15 m, the cells themselves being 13 m tall, whereas the chimneys above them are about 2 m high. The emergency cooling pumps are located next to the cooling cells, and their role is to circulate the cooling water between the safety systems and the cooling cell. Emergency cooling towers are twin-cell structures, i.e. all cooling cells have two water distribution systems and two fans.

Water warmed up inside the safety systems of the primary circuit is fed to the safety cells and, with the help of nozzles, is distributed evenly on the wet cooling inlays. The film of water forming on the surface of the cooling inlay is cooled down as a result of a counterflow of atmospheric air. In order to minimize entrainment during this flow across the cooling inlay, a separator is used above the cooling inlays and the nozzles. The chilled cooling water returns from the cooling inlay to the cooling water pool, and from there the circulating pumps carry it back to the safety systems of the primary circuit. Evaporated and separated water is replaced by the makeup water system, which also adds the chemicals needed for the safe operation of the system.

Fresh-water cooling

The second option for operating the emergency cooling system is to use the water of the Danube to remove excess heat from the system, which then is discharged to the river through the warm water channel. In this case the emergency cooling system can be considered an open system, in which the volume flow rate refers to the water of the Danube extracted from the river and circulated through the heat exchangers of the emergency cooling system. The annual maximum demand for cooling water in this case is calculated for 8760 hours of operation, since there might be years when the system's cooling is exclusively provided for by the fresh-water cooling system.

Unit output	Unit	1 x 1200 MW_e	2 x 1200 MW_e
Volume flow rate of the emergency cooling water during normal operation (circulated cooling water or Danube water)	m^3/s	1.9	3.8
Annual, maximum demand for emergency cooling water (taken from the Danube)	million m^3/year	59.9	119.8

Table 6.6.4-3: Emergency cooling water volumes for fresh-water cooling

The method of choice for cooling can be finalized after the technological and safety analyses conducted at the site, and if required, the cooling of safety systems can also be solved by building a spray pool or by cooling water supplied from a water intake structure independent from that of the condenser's cooling system.

The emergency cooling system must comply with the requirement set forth by both IAEA and the Nuclear Safety Regulations stating that the removal of residual heat from the reactor must be solved even if the normal procedures of heat absorption are dysfunctional, and even if such condition is caused by external impacts (earthquakes, extreme meteorological conditions, extreme cold, wind, snowstorm, aircraft impacts, fires etc.).

6.6.5 WATER ENGINEERING STRUCTURES OF COOLING WATER SYSTEMS

The cooling water systems of the planned new nuclear power plant are served by the following major water engineering structures:

Existing extended cold-water channel
Water intake structure (in the bay of the cold-water channel)
Cooling water pipes
Turbine condensers (in the turbine building)
Closed warm-water channels
Aqueduct with a reinforced concrete channel
Water level control spillway
New free flow, trapezoid cross-section channel
Existing extended warm-water channel
Existing energy dissipation device and a second, new discharge point with a energy recovery hydroelectric plant

6.6.5.1 Existing extended cold-water channel

The existent cold-water channel is used jointly by the units of Paks Nuclear Power Plant and Paks II. Nuclear Power Plant. The cold-water channel needs to be extended by about 1300 m to provide an adequate volume of cooling water.

During the implementation of the Paks Nuclear Power Plant, the existing cold-water channel was made suitable for supplying the cooling requirements of the Paks Nuclear Power Plant as well as 2 x 1000 MW additional units planned at that time, this is why the cold-water channel has a capacity of 220 m^3/s. The suitability of the cold-water channel for the planned 2 x 1200 MW units was reviewed in consideration of the expected deepening of the Danube riverbed and the limits applicable to the minimum water levels of the existing water intake plant of the Paks Nuclear Power Plant. The boundary conditions taken into account for the extension of the cold-water channel are summed up in the following table:

Description	Unit	
Total coolant volume (for the existing units 1 to 4 and the planned two new units)	m^3/s	about 232
Period when the highest volume of water is used	year	2030-2032
Minimum water level in the Danube in 2030 (LKV_{2030})	mBf	83.8
Minimum water level permitted for the water intake plant of the Paks Nuclear Power Plant	mBf	83.6
Reduction in the level of water in the case of LKV_{2030}	m	0.2

Table 6.6.5-1: Boundary conditions of cold-water channel extension [6-7]

Year	Paks Nuclear Power Plant				Paks II		Total
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 1	Unit 2	
	Volume flow rate of cooling water [m^3/s]						
- 2024	25	25	25	25	0	0	100
2025 - 2029	25	25	25	25	66	0	166
2030 - 2032	25	25	25	25	66	66	232
2032 - 2034	0	25	25	25	66	66	207
2034 - 2036	0	0	25	25	66	66	182
2036 - 2037	0	0	0	25	66	66	157
2037 - 2084	0	0	0	0	66	66	132
2085 - 2089	0	0	0	0	0	66	66

Table 6.6.5-2: Paks Nuclear Power Plant and Paks II Coolant volume flow rates during the operation of the Paks nuclear power plant

In order to allow the intake of an appropriate amount of water (as shown in Table 6.6.5-2) through the cold-water channel in 2030, when the existing 4 units will operate simultaneously with the planned 2 new units, the cold-water channel must be extended as specified in Table 6.6.5-3

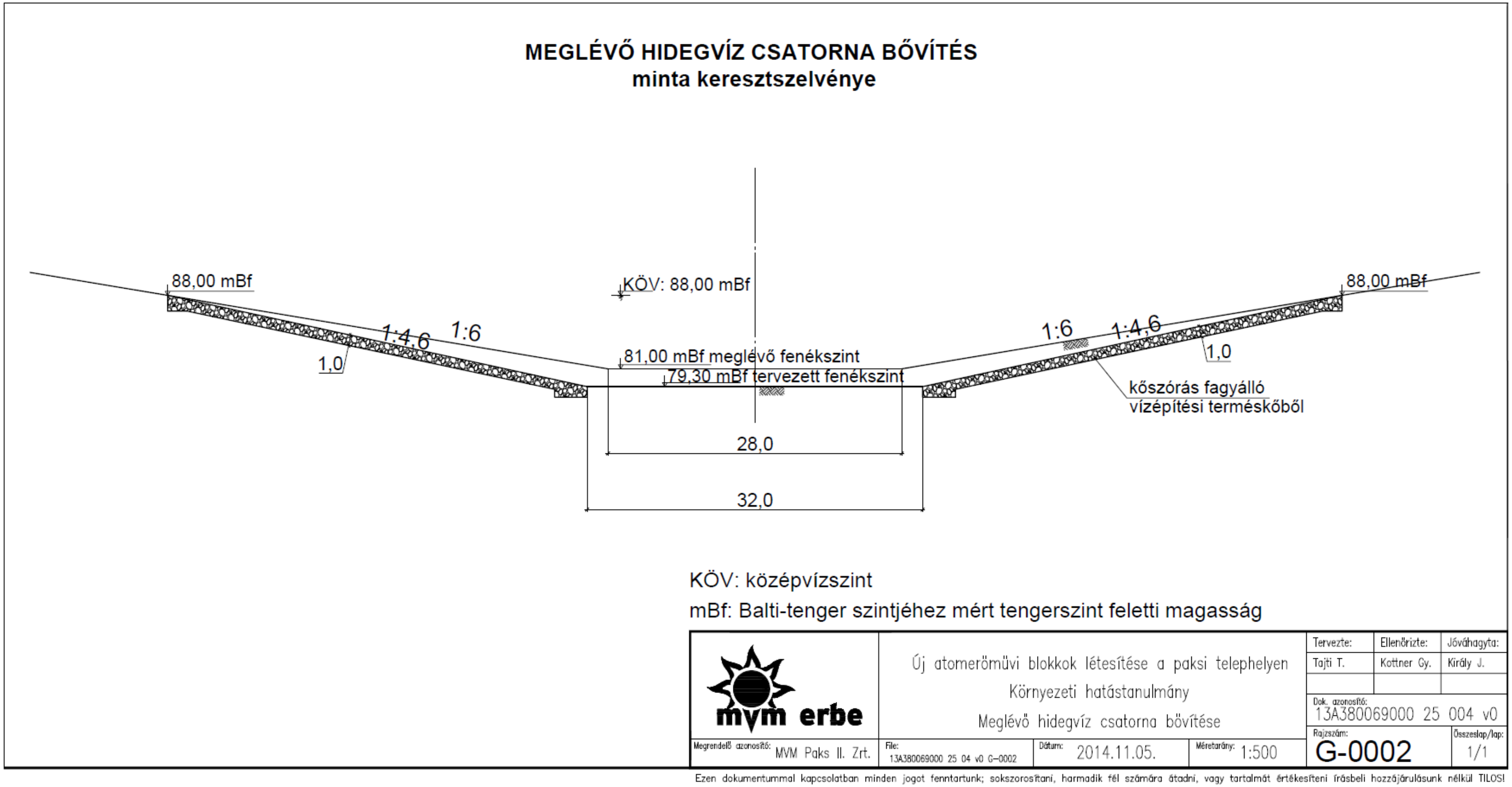
Description	Unit	
Total coolant volume (for the existing units 1 to 4 and the planned two new units)	m^3/s	about 232
Average channel bed level of the extended cold-water channel	mBf	79.3
Average channel bed deepening	m	1.7
Extended bed width	m	32
Modified slope of the channel embankment wall below 88 mBF	-	1:4.2
Dynamic water level expected in 2030 with the lowest volume of water	mBf	83.8

Table 6.6.5-3: Extension of the cold-water channel [6-7]

The characteristic cross-section of the planned cold-water channel extension is illustrated in Figure 6.6.5-1.

As the new unit to be commissioned in 2025 also requires deepening the bed of the cold-water channel, modification of the slope of the embankment wall, and an apron on the embankment wall in the section below the mean water level, the bed depth of the extended channel required in 2030 was assumed modified by 2025, when the first new unit will be put to operation.

As the currently operating nuclear plant units are expected to be shut down between 2032 and 2037, approximately 25 m^3/s less coolant will required to be supplied by the cold-water channel to the water intake plants. Lower coolant volume rates of flow will result in gradually decreasing level drops, which is the most significant when the Danube has the lowest water level. The gradually reducing level drop in the cold-water channel caused by reduced coolant volume rates of flow will offset the impacts of Danube riverbed deepening.



Note: The dimensions indicated in the drawing are in meters.

Meglévő hidegvíz csatorna bővítés minta keresztszelvénye – Extension of the existing cold-water channel sample cross-section
Meglévő fenékszint – existing bottom level
Tervezett fenékszint – Design bottom level
Középvízszint –mean water level
Kőszórás fagyálló vízépítési terméskőből – apron made of non-freezing hydraulic engineering rubble stone
Balti tenger szintjéhez mért tengerszint feletti magasság – height above the level of the Baltic Sea

Figure 6.6.5-1: Characteristic cross-section of the existing cold-water channel extension [6-7], [6-8]

6.6.5.2 Water intake structure

Based on the performed feasibility analyses, the best place for the new river-bay intake plant to serve the new nuclear power plant units is located about 150 meters north of the existing water intake plant, on the bank of the existing cold-water channel of the Paks Nuclear Power Plant.

The water intake plant consists of either 3 x 33% or 4 x 25% condenser coolant pumps and filtering systems (6 to 8 parallel systems for the two units). The water intake plant will include a mechanically cleaned rack, a travelling water band screen and appropriate shuttering panels.

The external wall thickness of the reinforced concrete structure is about 1 m, made as a cutoff wall. The internal structure will also be made of dimensioned reinforced concrete walls and floor structures. On the water inlet side, chambers will be made for moving the rack and the shutters, followed by the pump room, where several reinforced concrete service platforms can be built depending on the pump fitting and maintenance requirements. The portal crane used for lifting the pumps runs on the closing roof structure. This load must also be taken into consideration when the structure is sized.

Each pump can be disconnected with the help of mechanically moved shutters placed before the pumps and the valves located after the pumps.

When the safety coolant system is operated with freshwater cooling, water is taken from the Danube by 4 safety coolant pumps per unit, housed in the water intake plant. Depending on design allowing for the site features, the water intake plant of the safety coolant system is expected to operate in a significant part of the running time.

6.6.5.3 Cooling water pipes

The coolant of the condenser cooling water system (including the coolant of the technological cooling water system) will be carried in underground pipes along a 300 to 400 m long route, above the water intake plant and the turbine building. The coolant pipes will be covered by about 1.2 m thick earth on average. The volume of coolant passing through the cooling water system will be carried by 3 pipes of 3.2 to 4 m in diameter.

The coolant in the emergency cooling water system runs parallel with the condenser cooling water system to the turbine building, and then follows a separate route to the building that houses the emergency cooling system. The volume of coolant passing through the emergency cooling water system is carried in 4 pipes of 0.5 to 0.8 m in diameter.

6.6.5.4 Turbine condensers and cooling system heat exchangers

The coolant flowing through the condenser cooling water system absorbs the heat that must be absorbed during the condensation of the steam entering the condenser. The heat absorbed in the turbine condenser warms the cooling water that passes through the condenser coolant pipes. The condenser is sized for a 8 °C temperature differential in the coolant.

In the case of the technological and the emergency cooling water systems, the coolant passing through the heat exchangers absorbs the cooling heat from the intermediate closed cooling water system connecting to the technological and the emergency cooling water systems. The absorbed heat warms the cooling (Danube) water passing through the heat exchanger pipes. Similarly to the condenser cooling water system, in the technological and the emergency cooling water systems the temperature of the cooling water is expected to increase by 8°C.

6.6.5.5 Closed warm-water channels

The warmed-up coolant runs from the turbine building to the cold-water channel, then along the bridge built above the cold-water channel, passes through the reinforced concrete channel built after the bridge to the water-level control spillway along a route of about 500 meters. The warmed-up coolant includes the warmed-up technological cooling water that flows into it in the turbine building as well as the emergency cooling water that pours into it outside the engine room (when emergency cooling is in a freshwater cooling operating mode). The approximately 250 to 450 m long section of the coolant channels around the engine room are covered by 1.2 m earth on average, while on the approx. 50 m section before the aqueduct the earth covering is 0.2 m thick. The volume of coolant passing through the cooling water system will be carried by 2 reinforced concrete channels of 5 to 3 m in diameter.

6.6.5.6 Aqueduct

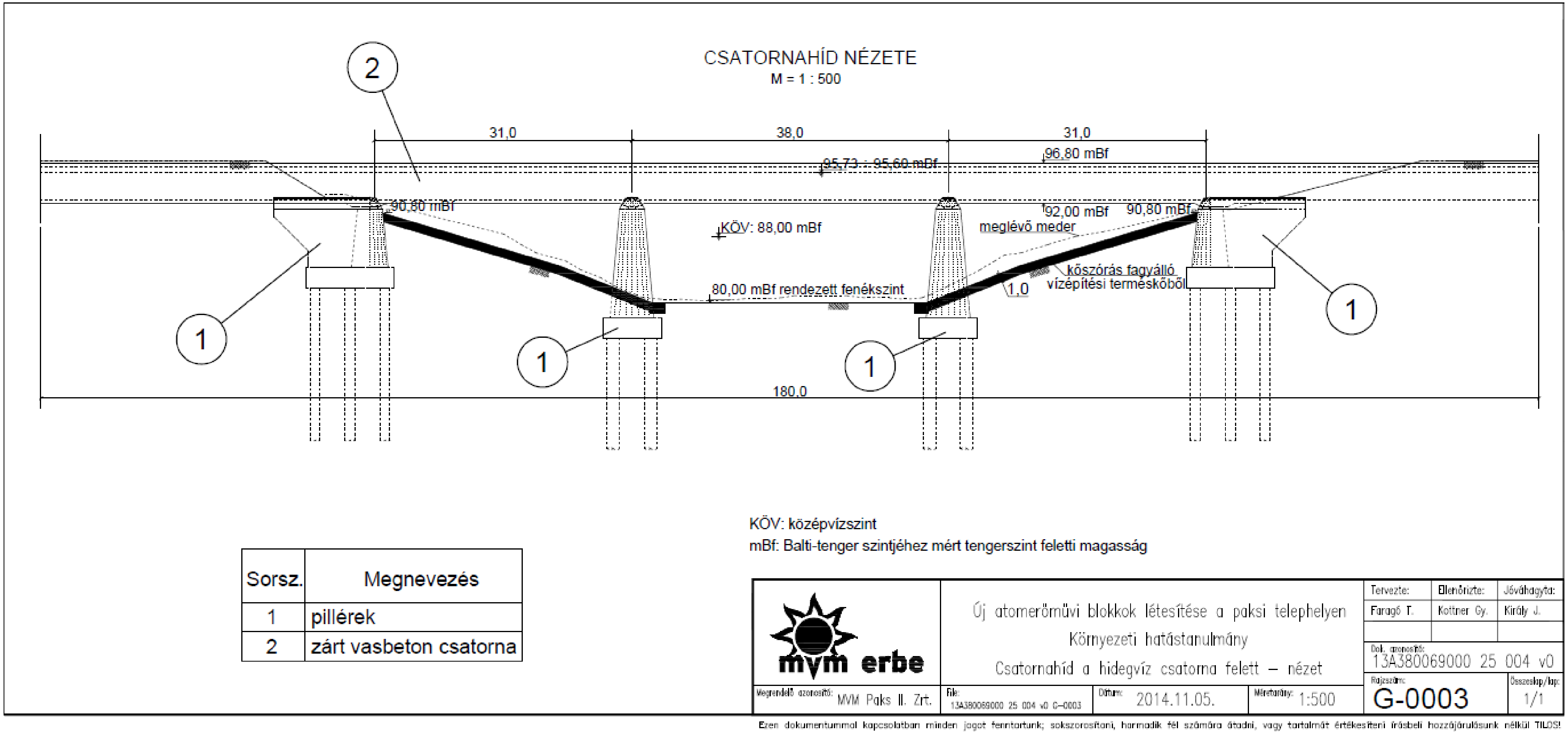
The warned-up coolant will be carried to the water-level control spillway by an appropriate new aqueduct built above the existing cold-water channel. The aqueduct will be built of prefabricated reinforced concrete blocks, with piers located in the bed of the existing cold-water channel. The dimensions of the planned aqueduct are shown in Figure 6.6.5-2, and its cross-section in Figure 6.6.5-3

The width of the bridge is between 25 and 30 m, the largest span between two supports does not exceed 50 m.

Supporting piers of the aqueduct

The piers of the aqueduct are located in the bed of the existing cold-water channel. The overall dimensions of the deepest piers are about 25 x 7 m, with about 10 m extending above the ground level.

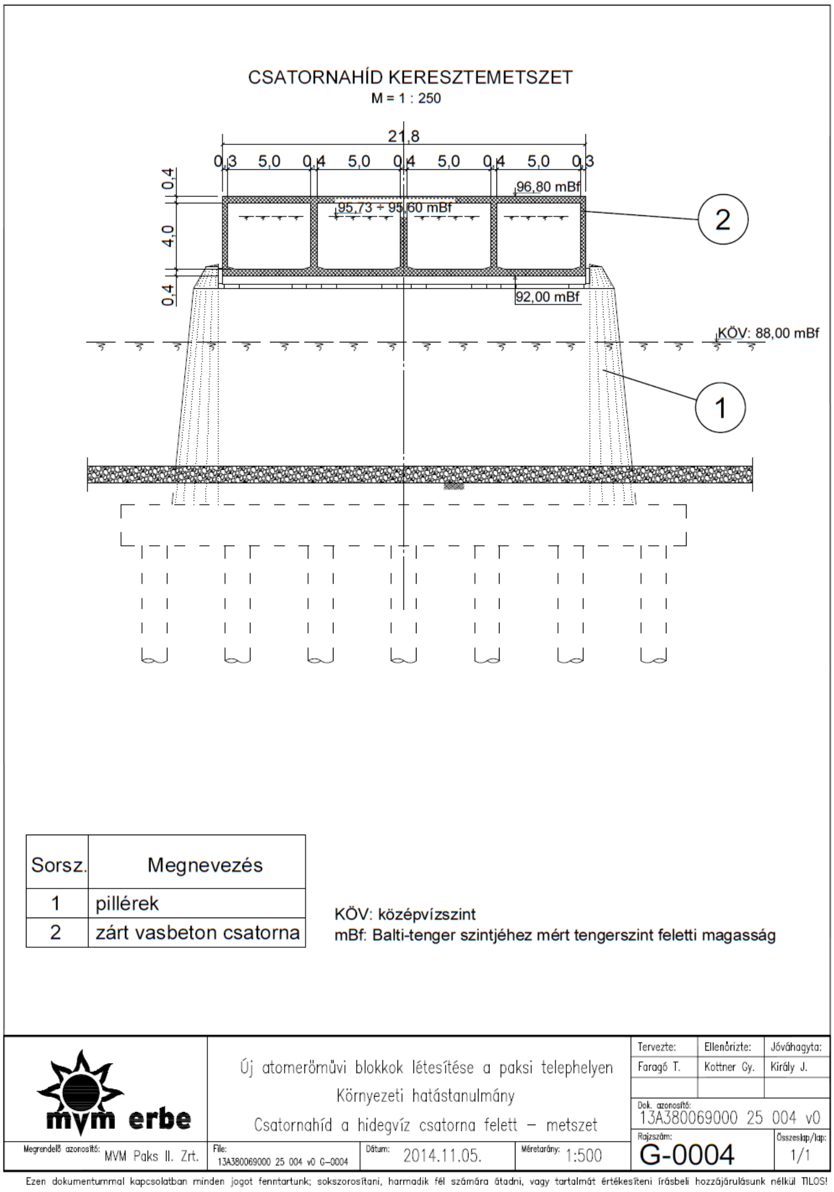
Dimensions: 25 x *7 x 25 m*
Structure: *reinforced concrete*
Foundation: *plate base supported by reinforced concrete piles*
Estimated foundation depth: *15 to 20 m*
Other requirements: *sizing for earthquakes*



Note: The dimensions indicated in the drawing are in meters.

meglévő meder – existing river bed, kőszórás fagyálló vízépítési terméskőből – apron made of non-freezing hydraulic engineering rubble stone
rendezett fenékszint – modified river bed KÖV – mean water level Balti-tenger szintjéhez mért tengerszint feletti magasság – height above the level of the Baltic Sea
megnevezés – description, sorsz. – No., pillérek – piers, zárt vasbeton csatorna – closed reinforced concrete channel
Tervezte – Designer, ellenőrizte– Supervisor, Jóváhagyó – Approved by, Megrendelő azonosító szám – Customer ID, Dátum – Dated, Méretarány – Scale, Dok. azonosító – Doc ID, Rajzszám – Drawing No. Oldalszám – Pages

Figure 6.6.5-2: Aqueduct view [6-7], [6-8]



Note: The dimensions indicated in the drawing are in meters.

KÖV – mean water level
mBf: Balti-tenger szintjéhez mért tengerszint feletti magasság – height above the level of the Baltic Sea
megnevezés – description, sorsz. – No., pillérek – piers, zárt vasbeton csatorna – closed reinforced concrete channel
Tervezte – Designer, ellenőrizte– Supervisor, Jóváhagyó – Approved by, Megrendelő azonosító szám – Customer ID, Dátum – Dated, Méretarány – Scale, Dok. azonosító – Doc ID, Rajzszám – Drawing No. Oldalszám – Pages

Figure 6.6.5-3: Characteristic cross-section of the channel bridge above the cold-water channel [6-7]

6.6.5.7 Water-level control spillway

The function of the level-control spillway is to ensure the condenser coolant pressure required for the reliable operation of the condenser cooling water system and to provide an option for back mixing warm water into the cold water channel.

Water level control spillway

This reinforced concrete structure is placed after the aqueduct, partly sunk into the ground. Its overall dimensions are about 26 x 46 m, with a height of 8.50 m, of which only about 50 cm is above the ground level.

Dimensions: *26 x 46 x 8.5 m*
Structure: *reinforced concrete*
Foundation: *plate base supported by reinforced concrete piles*
Estimated foundation depth: *about 8 m*

Its foundation will be plate foundation at a depth of 8 m. Its side walls will be cut-off walls, made of watertight concrete sized to withstand earth and water pressure.

6.6.5.8 New free flow, trapezoid cross-section channel

From the level-control spillway to the existing warm-water channel a new, trapezoid cross-section, free-flow warm-water channel section needs to be made of reinforced concrete, including a new fork piece to feed the warm water coming from the new units to the existing warm-water channel. In the new free-flow channel, warm water is moved by gravitation towards the existing warm-water channel along a route of about 500 m. The planned bottom width of the new free-flow channel is 16 m, with a channel width of 80 m (and a freeboard width of 50 m), the 1:2 slope, and an average water height of about 2.5 to 3 m.

6.6.5.9 Existing extended warm-water channel

After the new fork piece, the warmed-up coolant is transferred to the return structure through an appropriately extended section of the warm-water channel. The warmed-up coolant is returned to the Danube through the appropriately extended warm-water channel by gravity.

During the implementation of the Paks Nuclear Power Plant, the existing warm-water channel was made suitable for supplying the warm water requirements of the Paks Nuclear Power Plant as well as 2 x 1000 MW additional units planned at that time. Based on that concept, the warm-water channel was sized for 220 m^3/s. Suitability of the warm-water channel for the planned 2 x 1200 MW units was reviewed in consideration of the expected water levels of the Danube and of the fact that the existing water-level control spillway of the Paks Nuclear Power Plant limits the maximum water levels that can be maintained in the warm-water channel. The boundary conditions taken into account for the extension of the warm-water channel are summarized in the following Table 6.6.5-4.

Description	Unit	
Total coolant volume (for the existing units 1 to 4 and the planned two new units)	m^3/s	about 232
Period when the highest volume of water is used	year	2030-2032
Average water-level drop in the warm-water channel	m	0.6
Water speed at maximum permissible water level	m/s	1.5

Table 6.6.5-4:Boundary conditions of warm-water channel extension [6-7]

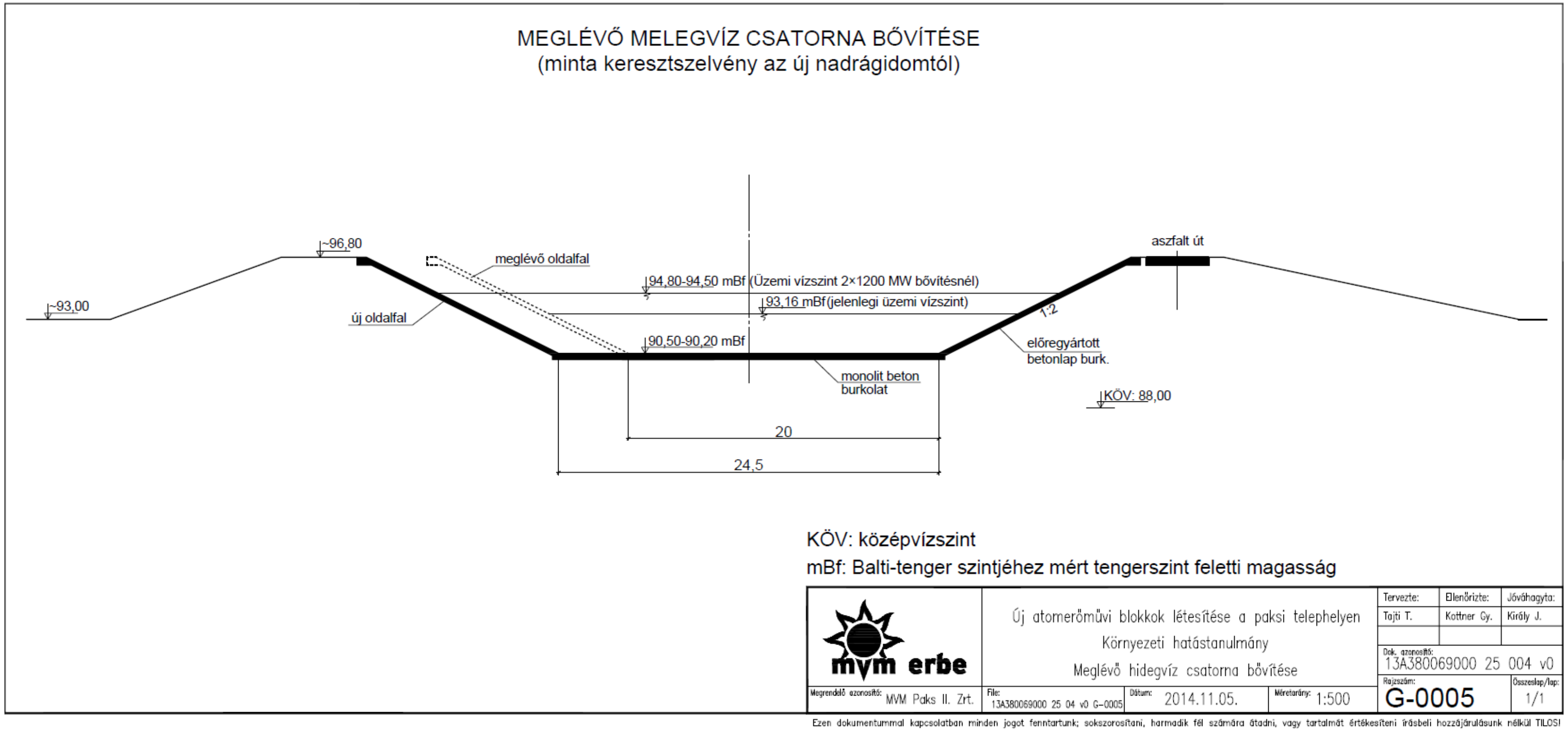
In order to allow the warm-water channel to drain warm water from the 6 units in 2030, when the existing 4 units will operate simultaneously with the planned 2 new units, the warm-water channel must be extended (Table 6.6.5-5)

Description	Unit	
Total coolant volume (for the existing units 1 to 4 and the planned two new units)	m^3/s	about 232
Design operating water level	m	4.5
Relocation of the left-bank slope (downstream)	m	4.5
Extended bed width	m	24.5

Table 6.6.5-5: Extension of the warm-water channel[6-7]

As in 2025 the volume of water required for the new units would significantly increase water level in the warm-water channel and would render the extension of the warm-water channel more difficult, it is advisable to complete the channel extension that will become necessary in 2030 already by 2025.

The characteristic cross-section of the planned warm-water channel extension is illustrated in Figure 6.6.5-4.



Note:
The dimensions indicated in the drawing are in meters.

A MEGLÉVŐ MELEGVÍZCSATORNA BŐVÍTÉSE – Extension of the existing warm-water channel
minta keresztszelvény az új nadrágidomtól – sample cross-section from the new fork profile
meglévő oldalfal – existing side-wall
üzemi vízszint 2x1200 MW bővítésénél – operating water level in the case of expansion by 2x1200 MW
aszfalt út – asphalt road
jelenlegi üzemi vízszint – current operating water level
monolit betonburkolat – monolithic concrete covering
előregyártott betonlap burkolat – prefabricated concrete plate covering
középvízszint – mean water level
mBf Balti tenger szintjéhez mért tengerszint feletti magasság – height above the level of the Baltic Sea
megnevezés – description, sorsz. – No., pillérek – piers, zárt vasbeton csatorna – closed reinforced concrete channel, Tervezte – Designer, ellenőrizte– Supervisor, Jóváhagyó – Approved by, Megrendelő azonosító szám – Customer ID, Dátum – Dated, Méretarány – Scale, Dok. azonosító – Doc ID, Rajzszám – Drawing No. Oldalszám – Pages

Figure 6.6.5-4: Characteristic cross-section of the existing warm-water channel extension [6-7], [6-8]

6.6.5.10 Existing energy dissipation device with a second discharge point

Warm water can be returned to the Danube with the help of the new energy dissipation device, developed according to the volume of warm water required for the operation the existing 4 units and the planned 2 new units (Figure 6.6.5-5).

The implementation of a second discharge point offers more benefits than the extension of the existing energy dissipation structure. If a structure is made at the second discharge point on the area enclosed by the cold-water channel and the warm-water channel, and an energy recovery hydroelectric plant is installed in it, it is possible to improve the mixing of the warm water discharged into the Danube, and a considerable amount of electric power can be regained while minimizing the affected Natura 2000 areas.

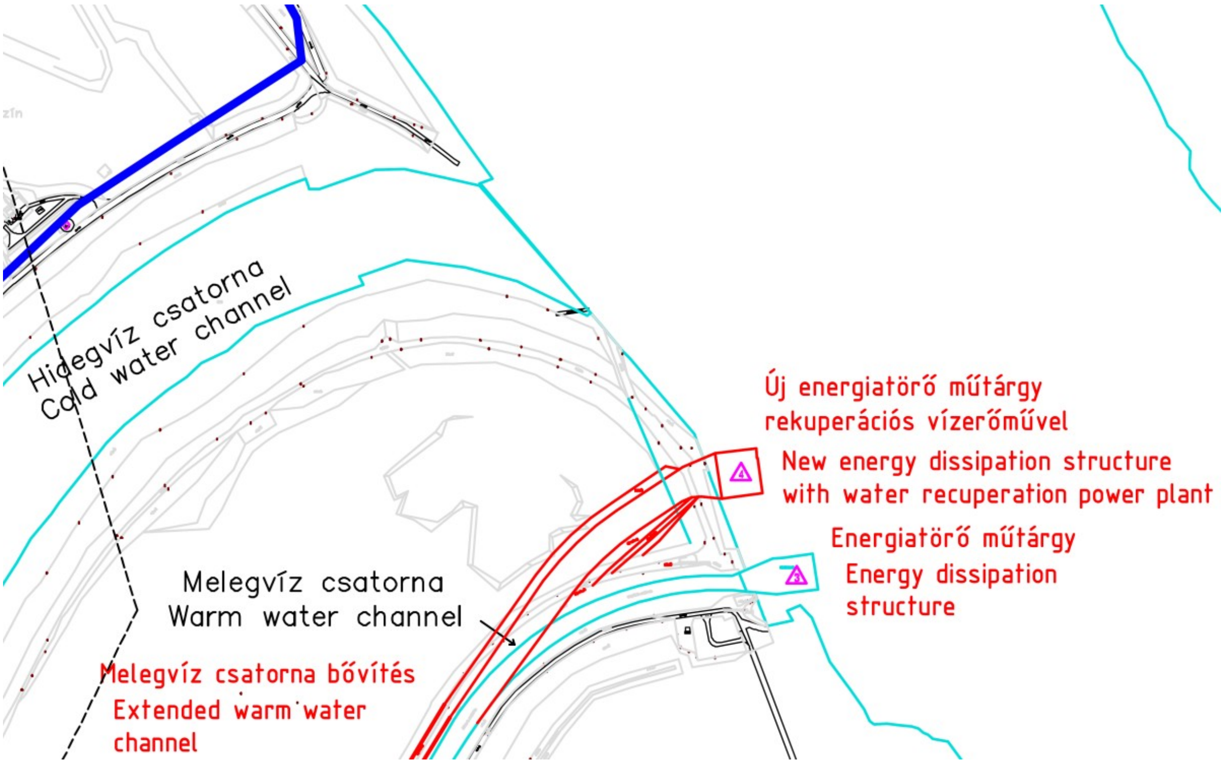


Figure 6.6.5-5: Site plan of the existing energy dissipation device and a second, new discharge point with a recovering hydroelectric plant

6.6.5.11 Energy recovery hydroelectric plant

By damming the warm-water conduit coming from the nuclear power plant, a gradient can be ensured at the Danube mouth of the warm-water channel, which is suitable for the operation of water turbines of approximately 7 to 8 MW total nominal output. Based on the Danube flow regime and the nuclear power plant's operation, nearly 35 GWh energy may be so generated annually.

The upstream water level of the energy recovery hydroelectric plant is dammed by a barrage dam at the end of the warm water channel, with water turbines and direct service facilities. They include the barring structures setting the course of the water along with the components required for the operation of these structures, and the lifting equipment and auxiliary facilities needed for servicing and maintenance. The electric and control engineering equipment, the switchboards and the transformers are located in a separate electrical building next to the hydroelectric plant. The cables providing connection to the power plant and the transmission lines delivering the generated electricity are connected to this facility. The equipment providing auxiliary power, a compressor and an oil station are also located here.

The energy recovery hydroelectric plant has an overflow facility that can provide an outlet for the maximum volume of cooling water coming from the nuclear power plant without any untoward effect and can channel it back safely to the Danube when the water turbines fail to operate or are maintained.

The hydroelectric plant is an autonomous facility is surrounded by its own perimeter fence and does not require the continuous presence of an operator. A physical dam and an alarm system secure the property.

6.7 AUXILIARY SYSTEMS AND AUXILIARY FACILITIES

6.7.1 DESALINATED WATER

A new water pre-treatment facility is planned in connection with the extension of the units planned to be built with a capacity of 3x100% (which means a capacity three times as much as the nominal demand, required for redundancy). 3 parallel units are constructed for the most important elements of the system, with suitable cross connections.

The technology of the pre-treatment process of makeup water consists of the following component processes: clarifying, multimedia filtration, desalinizing with membranes and post-desalinizing with deionisation, if necessary. The desalinizing process with membranes consists of three subdivisions: ultra filtration, reverse osmosis and electro-deionisation. The essence of the pre-treatment of makeup water is desalinizing with membranes and an important characteristic of this process is, that compared to the traditional process of calcareous softening and deionisation desalinizing, it uses at least one order of magnitude fewer chemicals and in this way the quantity of the chemicals emitted together with the produced waste water can be significantly decreased. The pre-treatment equipment provides the necessary supplementary cooling water for the cooling towers of the safety of cooling water system. The water quality specified for the supplementary cooling water can be obtained from the intermediate process of the pre-treatment of makeup water, after the desalinizing process with membranes. Consequently, the preliminary stage of the pre-treatment of makeup water has a bigger capacity (depending on the storage of supplementary cooling water and the requirements for the quality of water in the cooling towers) and the quantity of water that goes through the fine desalinizing is not more than the salt-free water demands of the primary and secondary circles.

Depending on the two possible ways of operations of the emergency cooling water system, the makeup water pre-treatment equipment also has two possible modes of operations. Since the cooling tower operating mode of the emergency cooling water system is available only for a short time (a few days in a year, probably not more than a month) we have supplied the data for the water balance of the pre-treatment equipment of makeup water for the characteristic mode of operation, when the emergency cooling water system is cooled by fresh water and there is no requirement for supplementary cooling water.

Based on the above, the raw water demand of the pre-treatment equipment of makeup water for one unit is expected to be 36 m^3/h and for normal operation; of two units it is expected to be 72 m^3/h. The planned annual raw water demand of the two units is not expected to exceed 640,000 m^3.

Description	Unit of measure	1x1200 MW	2x1200 MW
Raw water (from the Danube)	m^3/s	0.01	0.02
Raw water (from the Danube)	m^3/h	36	72
Waste water	m^3/h	12	24
Generated desalinated water	m^3/h	24	48

Table 6.7.1-1: Water balance of the makeup water pre-treatment plant during normal operation

The function of the desalinated water storage and distribution system is to store and deliver desalinated water to the desalinated water consumers in the primary circle, the turbine building and the auxiliary facilities. The makeup water pre-treatment plant and the desalinated water storage facilities must jointly satisfy the simultaneous maximum desalinated water requirements. The expected desalinated water requirement of the new nuclear power plant units is 24 m^3/h in the case of one unit, and 48 m^3/h for two units during normal operation. The higher desalinated water requirements that arise during interim operational states are met by desalinated water from the desalinated water storage. As interim operational states last only a few days a year, the desalinated water requirement for normal operation is predominant. The combined annual desalinated water requirement of the two planned units is not expected to exceed 420 thousand m^3.

The waste water of the joint makeup-water pre-treatment facility of the new nuclear power plant units is 12 m^3/h during normal operation in the case of one unit, and 24 m^3/h during normal operation for two units. The annual volume of the waste water generated by the makeup-water pre-treatment plant is not expected to exceed 220 thousand m^3.

The waste water generated in the makeup-water pre-treatment plant during the individual technological partial processes is collected and stored in the interim waste water collection store. The waste waters generated in the various processes are mixed and checked before discharge for compliance with the relevant emission limits. If needed, they are chemically neutralized. Waste water is discharged to the technical waste water system of the power plant. [6-9]

6.7.2 TECHNOLOGICAL WASTE WATER [6-9]

6.7.2.1 Primary circuit waste water management system

The primary circuit waste water management system collects, treats and stores the radioactive waste water produced in normal operation. This system also receives the potentially radioactive waste waters of the turbine building systems (e.g. elutriation of the steam generator on the supply water side).

One of the key tasks of liquid radioactive waste handling is the selective collection of different types of waste waters on the basis of the basic physical and chemical properties of waste waters. By separating active and inactive waste waters the selective collection of waste water can significantly reduce the amount of different categories of waste waiting for final disposal. Most of the radioactive waters are returned to the proper technological process of the primary circuit after the required treatment operations. The radioactive waste waters which cannot be fed back into the technological process go through a cleaning technology line and in the end the separated active contaminants are condensed and stored as required. After treatment and disposal, the treated water, tested for radioactive radionuclide concentration, is discharged into the warm water channel from the primary circuit waste water system through a controlled ejector pipe after a control tank.

The expected average maximum annual and daily discharge of treated waste water from the radioactive waste water system is shown in Table 6.7.2-1 The waste water of the radioactive waste water system complies with the requirements specified for the power plant for waste water emission.

Description	Unit of measure	1x1200 MW	2x1200 MW
Normal operation	m^3/h	5	10
Annual waste water quantity	thousand m^3per year	44	88

Table 6.7.2-1: Quantity of beyond balance primary circuit technological waste waters

6.7.2.2 Turbine building waste water management system

The waste water treatment system of the turbine building collects and processes the waste water of the turbine building and the auxiliary equipment. This system only treats non radioactive waste waters.

The turbine building waste water management system can be divided into three subsystems:

- closed condensate collection system;
- leachate collection system;
- industrial waste water system.

One of the key tasks of liquid waste management is the selective collection of different types of waste waters on the basis of their basic physical and chemical properties.

6.7.2.2.1 Closed condensate collection system

The closed condensate collection system receives the discharges of the turbine building and its collected clean condensates, which can be returned to the supply water system. If the quality of the waters is suitable, the closed condensate collection system feeds them into the condensate storage and extra water feeding system of the turbine building.

If the quality of water collected in the closed condensate collection system is not suitable for feeding it back to the supply water system, this water is passed on to the technological waste water system.

6.7.2.2.2 Leachate collection system

The leachate collection system receives water from the free-flow funnelled main discharge pipes of the turbine building and from the floor water channels collecting discharge from the systems and equipment. The quality of waters collected in this system is not suitable for feeding them back into the supply water system.

The leachate collection system feeds the collected waters into the warm water channel if the quality of water is suitable and into the industrial waste water system if the quality is not suitable for feeding into surface waters.

6.7.2.2.3 Industrial waste water system

The industrial waste water system receives the waste waters that are potentially contaminated with oil or contain chemicals. A separate subsystem within the industrial waste water system collects the waters potentially contaminated with oil and another subsystem collects the waters that may contain chemicals. The oleaginous waste water system collects the waste water from all the places where the waste water may be contaminated with oil.

The oleaginous waste water collection system is separated from the condensate, the leachate and the yard gully rain water collection systems. The waste waters contaminated with oil are received in a separate tank and are fed into a settling tank through an oil separator. The industrial waste water system feeds the waters from the settling tanks into the warm water channel if the quality of water is suitable.

The waters contaminated with chemicals, such as the cleaning and rinsing waters of the water treatment equipment, and the waters coming from the water treatment systems after resin regeneration are fed into a neutralizing tank, where they are treated so that their water quality indicators meet the requirements for discharge. The industrial waste water system feeds the waters from the neutralizing tanks into the warm water channel if the quality of the treated water is suitable.

6.7.2.2.4 Volume of turbine building waste water

In normal operation the waste water of the turbine building's closed condensate collection system returns to the supply water system and does not become waste water.

The waste water of the leachate collection system and the industrial waste water system is discharged as waste water after proper treatment, neutralisation or oil removal. Table 6.7.2-2 shows the quantities of waste water in normal operation broken down by year.

Description	Unit of measure	1x1200 MW	2x1200 MW
Normal operation	m^3/h	20	40
Annual waste water quantity	thousand m^3per year	175	350

Table 6.7.2-2: Quantity of liquid waste from the turbine building

The combined annual waste water volume generated in the turbine building and the auxiliary facilities of the two planned units is not expected to exceed 350 thousand m^3. After proper inspection and making sure that discharge limits are met, the waste waters collected by the waste water collection systems are discharged into the warm water channel by the turbine building's waste water system.

6.7.3 WASTE WATER FROM EMERGENCY COOLING CELLS

If the emergency cooling water system is operated in the cooling cell mode, the cooling system must be elutriated during heat transfer, because of the evaporation taking place in the cooling cells and the contamination getting in with the air, in order to limit the concentration of contaminants in the cooling water. The waste water of the elutriation process required when the emergency cooling cell is used is passed into the Danube through the warm water outlet channels together with the warm condenser cooling water. Its quantity is smaller by orders of magnitude than the quantity of the condenser cooling water.

If the emergency cooling system is operated in cooling tower mode, the waste water comes from the elutriation of the cooling cell. Practically, the elutriated water is produced when the water which is partly desalinated in the makeup water preparation equipment is thickened by evaporation in the cooling cell. Table 6.7.3-1 shows the quantities of waste water coming from the cooling cells broken down by hour and year with the assumptions made for operation.

Description	Unit of measure	1x1200 MW	2x1200 MW
Waste water from the elutriation of the waste water in the emergency cooling cells	m^3/h	36	72
Annual maximum average waste water quantity (assuming max. 1 month operating time)	thousand m^3per year	26	52

Table 6.7.3-1: Maximum quantity of waste water from the emergency cooling cells after elutriation

For the two new units, the combined annual quantity of the waste water stemming from the cooling tower operation of the emergency cooling system is not expected to exceed 52 thousand m^3. After proper inspection for meeting the discharge limits, the waste waters generated are discharged into the warm water channel by the turbine building's waste water system.

6.7.4 DRINKING WATER – COMMUNAL WASTE WATER

Studies suggest that the best source of water for the new power plant would be the Csámpa waterworks and its auxiliary systems, and the best communal sewage treatment system would be the water treatment facility and its auxiliary equipment operating on the premises of the Paks Nuclear Power Plant, both for technical and business reasons.

The maximum quantity of drinking water will be needed when the first unit begins operation and the construction of the second unit is under way at the same time, with a maximum quantity of 646 m^3/day, with 95% of this, or 614 m^3/day per day becoming sewage water. [6-10]

Figure 6.7.4-1: Location of the Csámpa Waterworks

Figure 6.7.4-2: Location of the Paks Nuclear Power Plant's sewage treatment facility

6.7.5 RAINWATER

Rainwater drained from the yards and roofs of the new nuclear power plant units and the non-contaminated surface waters collected from other areas are directly fed into the warm water channel.

Clean and potentially oil-contaminated rain waters are collected separately in the operating area. Since the rain water is drained into a receiver, it is treated in accordance with the requirements of the water authority.

In order to catch rainwaters potentially contaminated with oil, oil traps of the required size will be installed in the overground car parks. Transformer foundations will be built with adequately sized shafts to store the accumulated rain water and oil traps will be installed to manage oil leaks. The rainwater collected from the area around the oil tank will also be passed through the oil trap. Rainwater free from oil is drained together with the clean rain water. [6-9]

6.7.6 FIRE WATER

The new nuclear power plant units will have a common fire water network, which will receive water from the raw water system of the new units. A maximum of 380 m^3/h raw water will be fed into the fire water basin through a pipe. The fire water supply system will be built in accordance with the fire protection plan to be prepared later.

Alternatively, the fire water system may also be supplied from the industrial waterworks of the existing nuclear power plant using its riverbank-filtered water. After the existing units are shut down, the riverbank-filtered wells and the direct supply of the new nuclear power plant units will be maintained, if necessary, and the connection points to the existing power plant will be terminated.

The fire water system will be supplied with water from the fire water basins by the fire water pump station.

The fire water system will be supplied with water at the required pressure by "jockey" regular and pressure-keeping pumps installed in the fire water pump station. The pumps will have a 100% reserve. The normal pump will be electrically driven, the reserve pump will be diesel-driven. The pressure-keeping pumps will be electrically driven. The power supply for the electrically driven pumps is secured by multiple levels of safety.

The fire water pipe system of the new nuclear power plant units will cover the entire construction site of the new units. Its task is to ensure the necessary fire water for the indoor wall mounted and outdoor overground underground hydrants as well as the systems using sprinkled water and foam. [6-9]

6.7.7 UNLOADING AND STORAGE OF CHEMICALS

The planned new nuclear power plant has its own unloading and storage system for chemicals. A chemical unloading and storage system receives, extracts, stores and treats all the chemicals used by the power plant in a separate room in the water preparation building. A supply of chemicals sufficient for at least 30 days of normal operation needs to be stored.

The chemical unloading station receives the concentrated chemicals transported on road or railway and stores them in suitable storage tanks. The unloading station will be able to prevent the leakage of chemicals during unloading. In order to ensure that the chemicals do not contaminate the environment, suitable secondary containment basins will be installed. A suitable technical solution will also ensure that the vapour of the chemicals do not get into the environment.

There will be chemical collection basins and floor pits around the chemical storage tanks in the chemical storage building to ensure that potentially leaking chemicals could be passed to the chemical waste water treatment system. There will be proper chemical forwarding pumps installed at the chemical storage tanks. There will be a pneumatic system for moving non-liquid chemical, or the pre-packed quantities of the stored chemicals will be moved by trucks or lifting machines.

Description	Stored quantity
Hydrazine and ammonia storage	
Ammonium hydroxide	1 m^3
Hydrazine	3 t
Hydrogen storage	13 m^3
Chemical storeroom	
Nitric acid	4 m^3
Sulphuric acid	7 m^3
Water treatment plant	
Hydrochloride acid	53 m^3
Sodium hydroxide [3]	40 m^3
Boric acid storage	2 x 3 t

Table 6.7.7-1: Storing chemicals during operation

6.7.8 DIESEL GENERATORS

Emergency power is supplied to the safety systems by 4 diesel generators per power plant unit, each having an output of about 7.5 MW_e, with the fuel heat input being 18.75 MWth. per generator. Each one of the diesel generators is capable of supplying the required amount of electric power in the case of an emergency shutdown. For a safe shutdown, 168 hours of uninterrupted diesel generator operation must be ensured for each power plant unit. Consequently, the total storage capacity required for the operation of one generator (assuming a fuel heat input of 42 MJ/kg; specific weight of 0.83 kg/l and a degree of efficiency of 40%) is about 325 m^3. In order to ensure the level of redundancy necessary for safe fuel supply, each diesel generator device will be equipped with a separate fuel tank capable of holding the amount of diesel fuel required for 168 hours of uninterrupted operation. As a result, storage capacity for holding 8 × 325 m^3 (a total of 2600 m^3) of diesel fuel will be available in the buildings where the diesel generators are installed.

Under normal operating conditions, any planned operation of the diesel generators can take place for test purposes only, meaning an average test run period of 8 hours per generator per month, with each generator tested separately; the maximum duration of test operation is 8×8×12, that is, 768 hours.

6.7.9 SECONDARY BOILER

In order to supply the amount of steam required for the acceleration of unit startup during the implementation phase and the operating period, 2 auxiliary electric steam boilers will be installed, with an output of 15 MW each. Power will be supplied to the boilers via the 10 kV electrical network, and the combined steam supply capacity of the boilers will be 46 t/h at 12 bar and 192°C. [6-11]

6.7.10 HVAC

The purpose of the nuclear power plant's HVAC (Heating, Ventilation and Air Conditioning) systems is to prevent or reduce the spread of radioactive substances within the facility, and to provide the air conditioning key for maintaining the standard conditions necessary for the personnel and/ or equipment.

The ventilation systems designed to reduce the spread of radioactive materials:

- minimize the number of points of emission of aeriform radioactive substances to the open air,
- ensure the integrated controllability of the emissions of aeriform radioactive substances,
- keep the air pressure below atmospheric pressure in the containment structure,
- ensure that the level of ventilation in a given room is proportionate to the level of concentration of airborne radioactive substances in that room,
- ensure that air flows are directed from less contaminated places to more contaminated ones,
- circulate the air in the containment structure in order to increase the efficiency of the hydrogen-regulating system (hydrogen recombination).

In addition to the above features, ventilation systems must meet the following general requirements:

- be optimized against exposure to external effects (external fire or explosion) and climatic conditions (extreme wind velocities, snow, or high air humidity), or clogging by contaminants and the admission of chemical substances into the system,
- be capable of extracting smoke caused by fires, of restoring the original air conditions, if required, and also of preventing the spread of fires, smoke, contaminated air and radioactive contamination through the ventilation systems,
- ensure an adequate level of ventilation in areas where any kind of equipment is operated, and maintain a temperature suitable for the operation of such equipment, also in other areas where work is performed by personnel or any types of electrical equipment is used,
- maintain overpressure in the Control Room in all design basis conditions, in order to prevent contaminated air from infiltrating, should the facility be contaminated.

The HVAC (Heating, Ventilation, Air Conditioning) systems of the turbine building ensure the extraction of chemical fumes from the chemical storage room and laboratories, and also the removal of flammable oil vapour from the storage room of lubricants.

In the buildings where non-safety-related diesel generators are located, the HVAC systems prevent the formation of hazardous concentrations of flammable gases.

Air treatment equipment and heater and fan coil systems are supplied with heating water by the hot/warm water systems.

Areas that pose no safety risk (such as the ventilation systems of offices, electrical rooms and turbine halls) are supplied with cooled water by the central cooled water system.

6.7.11 COMPRESSED AIR SUPPLY SYSTEM

The compressed air required by the primary and secondary circuits is supplied by the compressor substations and air dryer equipment. Generally, compressed air is supplied to the primary and secondary circuits by two compressed air supply stations per unit.

6.7.12 DISTRICT HEATING SYSTEM

Heating for the City of Paks is currently obtained from the turbine branches of the power plant units 2 through 4, using heat exchangers with an approach temperature of 130 / 70°C.

The purpose of the district heating system currently in use at the Paks Power Plant is to:

- supply warm water to the primary circuit of the heat exchangers of the heat distribution centres located at residential districts, thus providing heating for these districts;
- supply the City of Paks with warm utility water and feed warm water into the heating system of the power plant.

The peak heat requirement of district heating is estimated at 30 MW_{th} so the current system is oversized and has some redundant capacity. The system can be fed from the branches of both turbines of units 2 through 4 by installing a 'base' and a 'peak' heat exchanger on each of these units. The 'peak' heat exchanger is followed by a 'super peak' heat exchanger (making it possible to increase the outgoing temperature up to 150°C).

The district heating system was built in a network structure including an outgoing and a return main pipeline (nominal outgoing/return temperature: 130 / 70°C, or in the event of prolonged cold weather: 150 / 70°C), complete with heat exchangers and pumps, as well as valves required for their disconnection.

The district heating system consists of the following three main components:

- Heat distribution centres (heat exchangers);
- Circulation system;
- Replacement-water system.

Within the context of the implementation of the new power plant units, the design of the district heating system to be established will be equivalent to the existing system, that is, from the branches of the newly installed turbines the steam would be conveyed to a common distribution pipe, and heat exchangers would be installed after the manifold depending on heat requirements, subject to an output of approximately 30 MW. The entire system including heat exchangers, circulation and manifold would be installed in a separate building section (separate building). [6-12]

6.8 CONTROL ENGINEERING

The purpose of the control engineering system is to ensure a safe and reliable control of the energy production processes at the power plant. Conventionally, the control engineering system includes the following levels of hierarchy:

Level 0: field equipment (sensors, transmitters, actuators and final control elements)
Level 1: system automation (process control equipment, special control equipment)
Level 2: system monitoring (diagnostic and monitoring systems)
Level 3: top level of control (human-machine interaction, external communication, data processing, data archiving)

Each level can be divided into further subcategories and layers, depending on the specific technological processes and their structure.

In order to ensure safe systems control – i.e., that the probability of breakdowns, malfunctions and incidents is limited to an acceptable level – and also to increase power plant availability, the monitoring, control and protection of the technological and energy production processes rely on multiple redundant and diversified engineering solutions. This principle is applied at all levels of control engineering.

The continuous monitoring of processes and equipment that are required for the operation of the power plant but represent a load / risk for the natural environment and the human population is ensured through the use of monitoring equipment and systems that are controlled independently of the technological processes.

In order to prevent malevolent, undesired or unintentional disruption, and infiltration by malware in the communication between systems assigned to different security classes as well as between the power plant and the outer world, data transmission is only allowed by using IT security equipment suitable for that specific type of data communication.

Any parameters measured, or operational events or interventions observed, or data sent or received, in any of the power plant's technological systems, or in the course of the controlling of such system, will be archived in a systematic and identifiable manner in the IT system, so that they can be retrieved and analysed if necessary.

The control engineering system ensures comprehensive monitoring and automatic control of the technological and energy production processes, generates a warning message when detecting anomalies, and seeks to eliminate such anomalies by applying the appropriate redundant solutions. The operating personnel at the top of the control hierarchy are kept informed of the status of the various processes and events through the control equipment, and take action if necessary.

6.9 TELECOMMUNICATION

The purpose of the telecommunications and IT systems is to support voice and data communication with the same availability and quality as those of the other technological systems of the power plant.

As far as the implementation of the telecommunication and IT system is concerned, the latest technology tested and approved for use in power plants during the design phase will be used.

Offsite telecommunication and IT system: Access to public telecommunication and IT systems can be primarily ensured via optical and microwave connections. Copper-based and VHF radio connections will also be established as a fall-back system.

Onsite telecommunication and IT system: The implementation of the telecommunication and IT systems required for the operation of the power plant will be aligned with the technological system.

The systems serving the power plant's administrative/office requirements differ from the technological systems in their lower availability.

The impact of the applied passive and active telecommunication tools and their operation on the environment is low, commensurate with that of any other telecommunication and IT systems used for industrial or civilian purposes. [6-4]

6.10 ELECTRICAL SYSTEMS

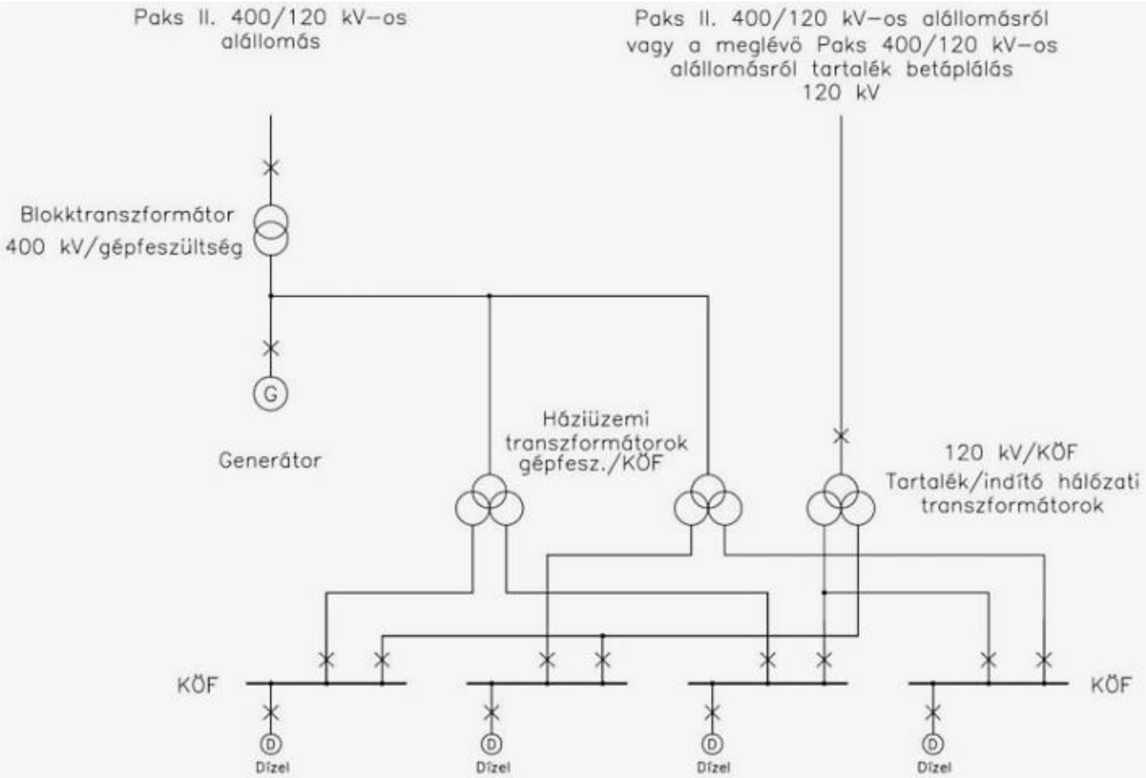
Based on assumptions and analyses made so far, the power plant-side power system of the new units will be set up as follows:

Electric power from the generator of each unit to the planned Paks II substation connecting the power plant unit to the Hungarian public electricity grid will be supplied through the unit transformer (connected to the generator) and the 400 kV unit line.

The two internal use (house service) transformers acting as backups for each other are connected to the medium-voltage trunking busbar of the generator and the unit transformer. It is through these transformers that electric power is supplied to those power consuming installations in the technological process that are required for the uninterrupted operation of the Paks II Power Plant. In addition to normal internal use power supply, a fall-back power supply system will also be established, including a reserve mains (internal use/starting) transformer (which ensures external power supply) and diesel generator-based power supply equipment providing uninterrupted power supply.

Please note that reserve cooling towers will be constructed in the vicinity of the open-air transformer area of the new units. Exposure to the moisture and humidity generated by the cooling towers must be taken into consideration when selecting open-air switching equipment.

Based on current plans and the power systems outlined by the potential suppliers, we believe that the following power supply system would be feasible in relation to a single power plant unit:



Paks II 400/120 kV-os alállomás – Paks II 400 / 120 kV substation
Blokktranszformátor 400 kV/gépfeszültség – Unit transformer 400 kV engine voltage
Paks II 400/120 kV-os alállomásról vagy a meglévő Paks 400/120 kV-os alállomásról tartalék betáplálás – Back-up supply from the Paks II 400 / 120 kV substation or from the existing Paks 400 / 120 kV substation
Háziüzemi transzformátorok gépfesz./KÖF– Internal-use transformers, engine voltage/mean voltage
Generátor – Generator
120 kV/KÖF 120 kV / mean voltage
Tartalék/indító hálózati transzformátorok – Reserve mains / start-up transformers
Diesel – Diesel

Figure 6.10-1*: General plan of a power supply system suitable for the power plant, indicating the main equipment items (for a single power plant unit)*

If the required output is 1200 MW per unit, the unit transformer (also called the main transformer) will be implemented as three single-phase transformers having identical technical specifications.

As far as environmental load is concerned, the power supply system of each unit consists of three single-phase main transformers, two three-phase internal use transformers and one three-phase reserve mains/starting transformer. [6-4], [6-13] Main features of the equipment listed before:

Main transformer

Effective power: min. 1200/3 MW (about 1500/3 MVA)
Quantity: 3 single phase units
Oil quantity: about 90 tons/ single-phase transformer; about 270 tons / 3 singe-phase transformers
Maximum noise load: about 75 dB / transformer

Normal internal use transformer

Effective power: about 70 MW (about 90 MVA)
Quantity: min. 2
Oil quantity: about 33 tons/ transformer; about 66 tons / 2 units
Maximum noise load: about 70 dB / transformer

Reserve mains / start-up transformer

It is recommended to consider the use of at least one transformer for each unit with a power equivalent to that of a normal internal use transformer.
Effective power: about 70 MW (about 90 MVA)
Quantity: 1
Oil quantity: about 33 tons
Maximum noise load: about 70 dB

The estimated total oil quantity of the main, internal use and reserve transformers listed above is about 370 tons/ NPP unit

The total quantity of oil used in the electrical equipment of the 2x1200 MW units is as follows:

Oil quantity of the main transformers: about 540 tons
Oil quantity of the normal internal use transformers: about 132 tons
Oil quantity of the reserve internal use transformers: about 66 tons

There will be secondary containment basins under the transformers to prevent oil spills.

6.11 ARCHITECTURE

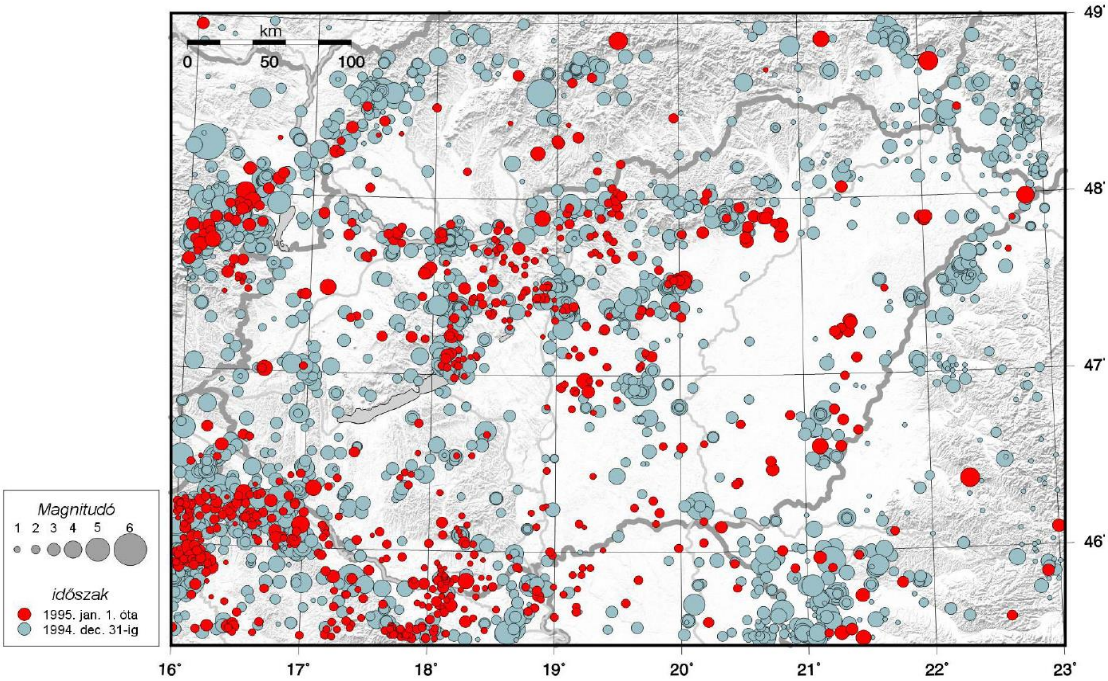
6.11.1 SEISMIC ACTIVITY

In the period between 1986 and 1996, seismic activity was one of the most extensively studied site features that affect the safety of the power plant. The horizontal and vertical acceleration components of an earthquake with a return period of 10,000 years was determined according to international recommendations and under foreign supervision. It was established that the maximum value of horizontal free surface acceleration caused by a design basis earthquake with a return period of 10,000 years is 0.25 g, while that of the vertical component is 0.20 g.

Based on recent studies, the values for a design basis earthquake with a return period of 100,000 years should also be considered in the plans for buildings that are important for nuclear safety. The initial data required for planning should be set down in the design basis.

In accordance with the recommendations of the International Atomic Energy Agency (IAEA), a micro seismic monitoring network was put in place in 1995 in the broader area of the Paks Nuclear Power Plant. Currently there are 8 modern digital measuring stations operating within a 100 km radius of the power plant. A total of 708 earthquakes were registered between 1995 and 2005. The distribution of the earthquakes is rather varied and – with a few exceptions – cannot be connected to known fault lines.

The regional distribution of the epicentres of the earthquakes in the area under investigation shows that the active areas that can be identified on a historical basis practically coincide with the current epicentres. On the basis of observations carried out in the vicinity of the Paks Nuclear Power Plant site there are no signs of change in the level of seismicity, which can still be said to be low.

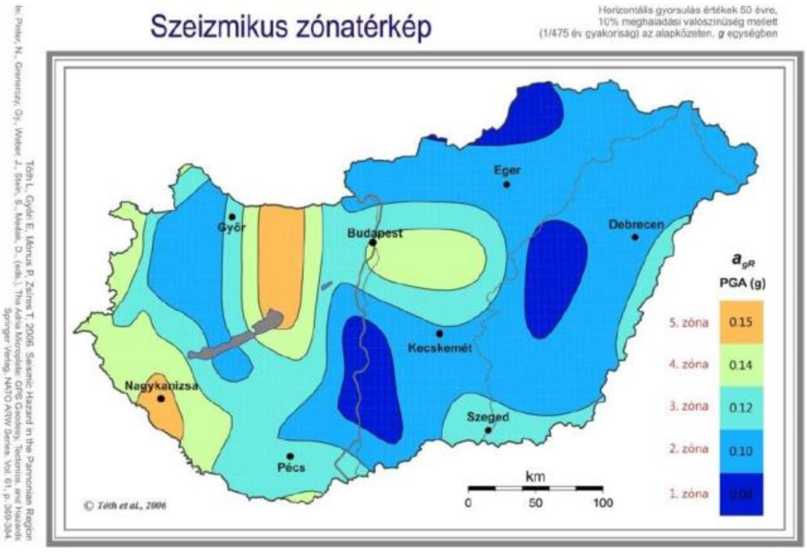


Magnitúdó – magnitude
időszak – period
1995. jan. 1. óta – Since January 1, 1995
1994. dec. 31-ig – Up to December 31, 1994

Figure 6.11.1-1: Epicentres of earthquakes in Hungary and its immediate vicinity (up to 2005) [6-4]

In addition to identifying the design basis earthquake, one of the important findings of the geological research conducted between 1986 and 1996 was the exclusion of the possibility of active faults emerging to the surface in the past 100,000 years as well as the assessment of the possibility of soil flow and the stability of the ground on the basis of the geo-technical studies of the site. According to these studies, layers to a depth of 10 to 20 m may be susceptible to soil flow, which must be taken into account from the point of view of nuclear safety when the foundations are planned.

General basic planning data for buildings that are not part of the safety system are provided by the Seismic Zone Map in the National Annex of standard MSz EN 1998-1 (EUROCODE 8) and other relevant data.



Szeizmikus zónatérkép – Seizmic zone map
Horizontálils gyorsulás értékek 50 évre – Horizontal acceleration values for 50 years
10% meghaladási valószínűség mellett – with a 10% probability of excess
1/475 év gyakoriság az alapkőzeten, *g* egységben – (1/475 years frequency on the base rock, in unit *g*

Figure 6.11.1-2: Seismic zone map MSz EN 1998-1 (EUROCODE 8) National Annex [6-14]

6.11.2 SHALLOW GEOLOGICAL CHARACTERISATION OF THE INSTALLATION SITE

Before the Paks Nuclear Power Plant was built, the height of the original ground surface varied between 91-97 mBf, the surface was very rough, sloping to the east towards the Danube.

Today the surface of the area of the Paks Nuclear Power Plant under investigation is filled up everywhere with material, most of which is natural with soil coming from the bed of the cold-water channel. This material is largely medium or fine-grained sand but silt or clay is also often interbedded. The thickness of the filled-up layers varies between 1.6 and 6.2 m depending on the original ground surface. At certain places some building debris, wrecked concrete and slag can also be found near the surface.

In general, there is arable soil containing humus below the fill with a maximum thickness of 1.5 m but it may also be lacking at some places.

Under the Holocene humus layers there are river flood plan deposit measures consisting of eolian (wind-driven) sandy sediments (old Holocene sand-drift) and Upper-Pleistocene medium and fine-grained sand and rock flour*. The color of the mostly quartz sand drift is ginger and ochre. Its maximum thickness is a few meters.*

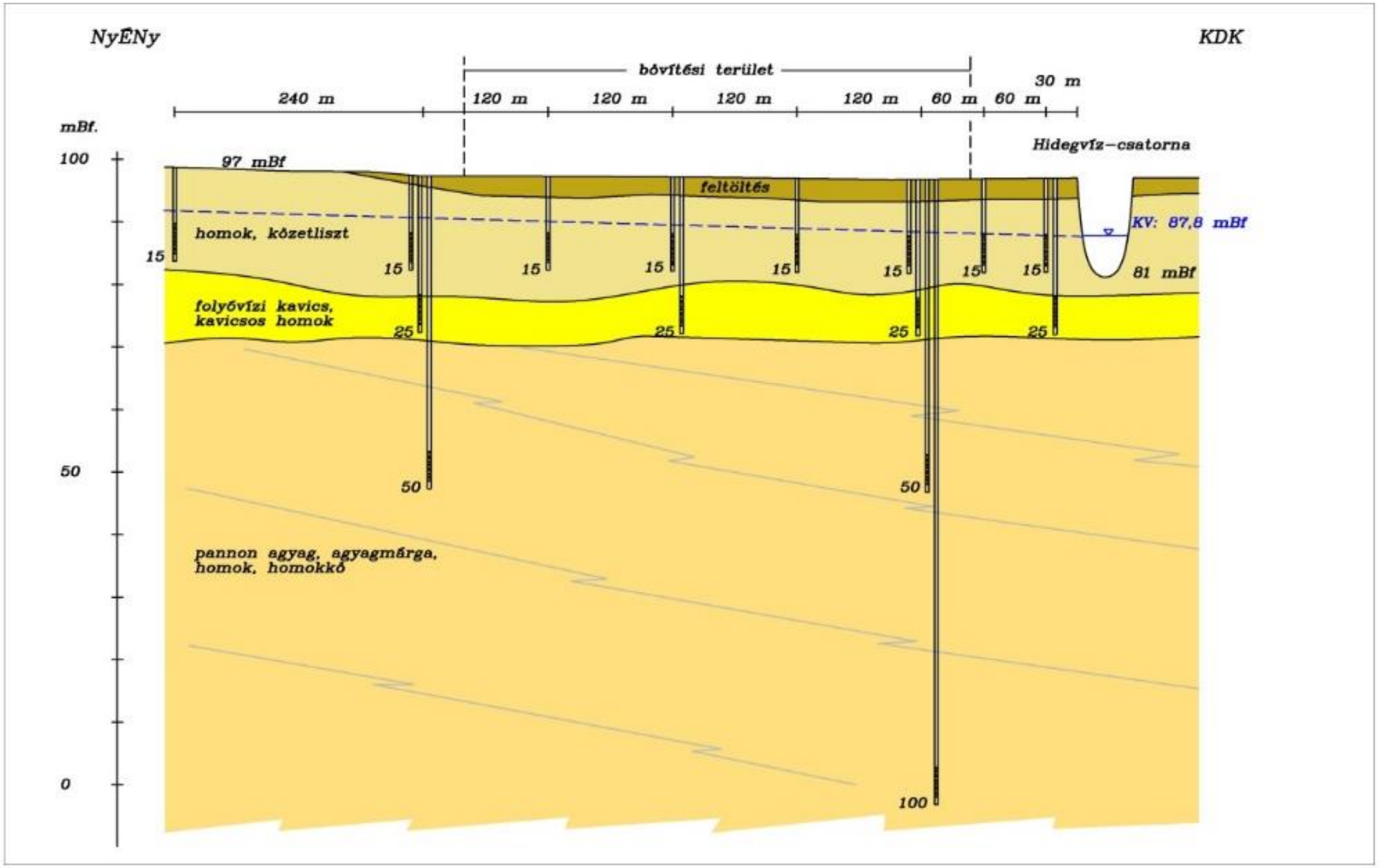
There is a well-classified fine and medium-grained flood sand stemming from floods underneath the sand drift. Its is mostly made up of quartz and quartzite grains, with some feldspar, carbonate (limestone), mica and heavy minerals. However, this sand layer is not homogeneous; it has local fine-grain interbedded layers (muddy fine sand, silt, clay, organic layers). At a depth of 8 to 10 m small pebbly layers appear; choncoidal fractures are quite common here.

Underneath the flood facies, roughly from 15 or 18 m to 25 m there are Upper Pleistocene river bed silts (pebbles, pebbled sand) with erosive discordance on the crumbly river set characterized by constantly changing layers of Upper-Pannonian pelite, sand and sandstone measures.

Underneath the *young Quaternary geological formations there are Upper-Pannonian, fine-grained crumbly sediments, which provide the base stone for the planning area. The sediments are quite varied. The distribution of grains is dominated by flood pelite formations (clay, sludge, silt, and their mixture); the abandoned river loops are filled up with high organic content pelite or perhaps lignite.* The color of the formations is varied too: buff, ochre, isabelline, grey or green-grey.

The top of the eroded Pannon formation forms a wavy surface lying at a depth of 21 to 28 m (69 to 73 mBf) in the design area. [6-15]

The figure below shows the geological profile of the area from west-northwest to east-northeast (Figure 6.11.2-1).



Bővítési terület – Expansion area
Ny-ÉNy – west – northwest
Homok, kőzetliszt – sand, silt
K-DK – east-south-east
Hidegvíz csatorna – Cold-water channel
folyóvízi kavics, kavicsos homok – river pebbles, pebble sand
Pannon agyag, agyagmárga – Pannonian clay, clay marl
Homok, homokkő – sand, sandstone

Figure 6.11.2-1: General geological profile along the expansion area [6-15]

The detailed soil structure of the planned operational site is shown in the 2012 studies, in which profiles (Figure 6.11.2-2) were made on the basis of drillings down to 10 m (Figure 6.11.2-3 to Figure 6.11.2-10).

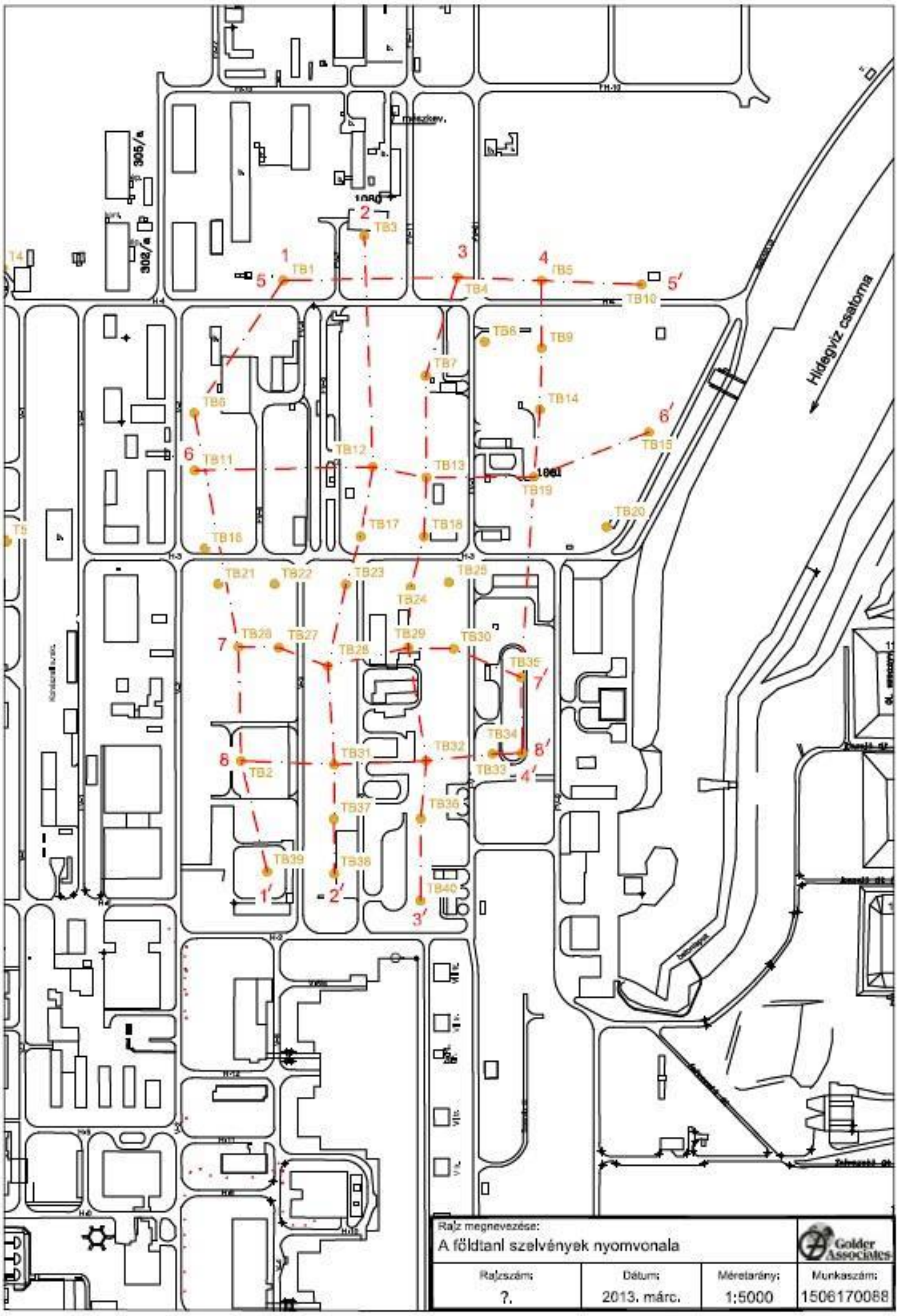
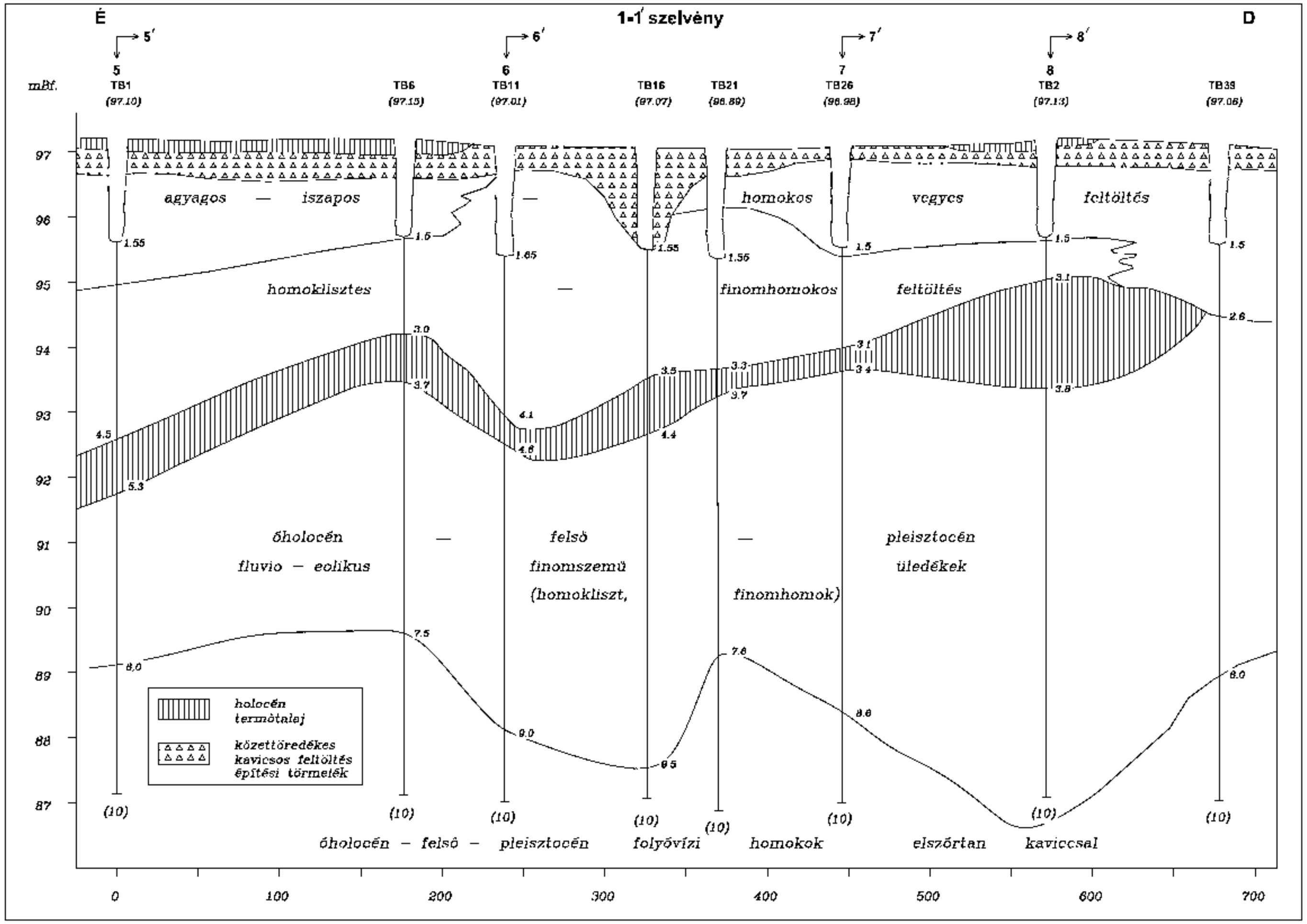


Figure 6.11.2-2: Routes of the geological profiles of the planned power plant site [6-15]

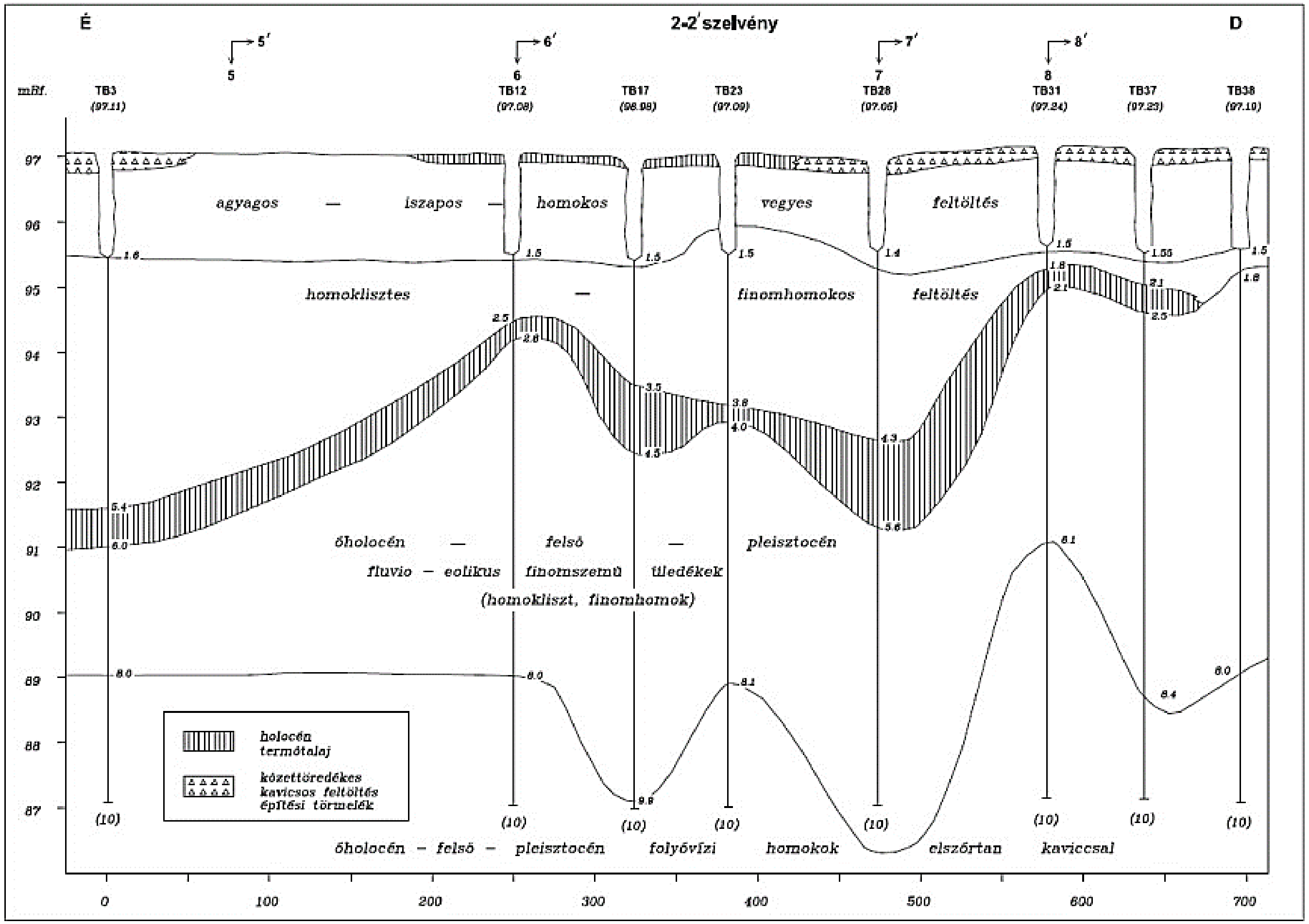
The individual profiles can be seen in the following pictures.



1-1'szelvény – Profile 1-1'
agyagos-iszapos-homokos vegyes feltöltés – mixed filling made of clay, sludge and sand
homoklisztes finomhomokos feltöltés – silt fine grained sand filling
Óholocén – Old Holocene
Felső pleisztocén – Upper-Pleistocene
Fluvio eolikus – fluvio-eloic

Finomszerű homokliszt, finomhomok – (fine-grained silt, fine-grained sand)
Holocén termőtalaj – Holocene fertile soil
Kőzettöredékes kavicsos feltöltés – detrital, pebble filling
Építési törmelék – Construction debris
Óholocén és Felső pleisztocén folyóvízi homok elszórtan kaviccsal –Old Holocene and Upper-Pleistocene river sands mixed with pebbles

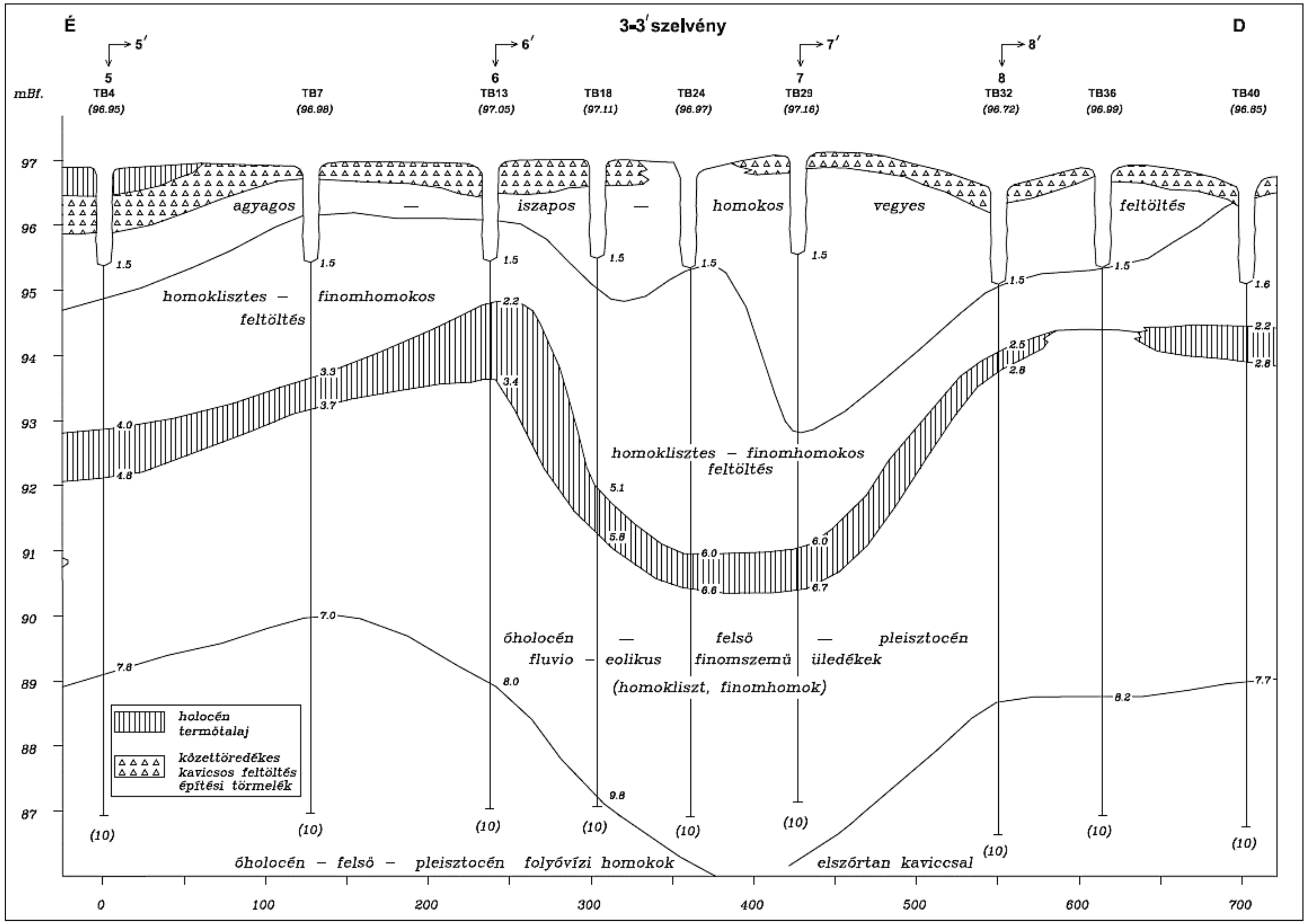
Figure 6.11.2-3: 1-1 geological profile of the planned power plant site [6-15]



2-2'szelvény – Profile 2-2'
agyagos-iszapos-homokos vegyes feltöltés – mixed filling made of clay, sludge and sand
homoklisztes finomhomokos feltöltés – silt fine grained sand filling
Óholocén – Old Holocene
Felső pleisztocén – Upper-Pleistocene
Fluvio eolikus – fluvio-eloic

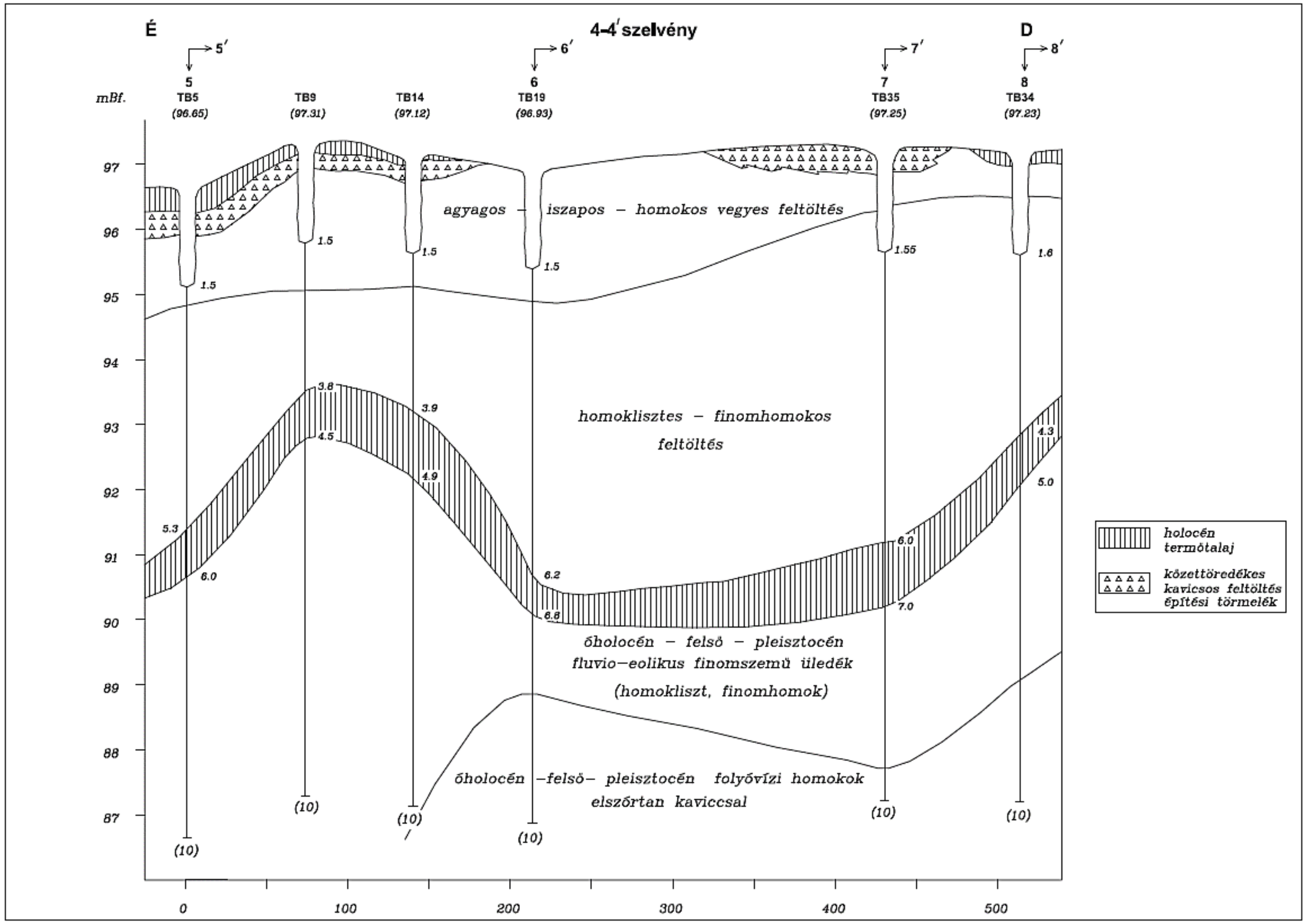
Finomszerű homokliszt, finomhomok – (fine-grained silt, fine-grained sand)
Holocén termőtalaj – Holocene fertile soil
Kőzettöredékes kavicsos feltöltés – detrital, pebble filling
Építési törmelék – Construction debris
Óholocén és Felső pleisztocén folyóvízi homok elszórtan kaviccsal –Old Holocene and Upper-Pleistocene river sands mixed with pebbles

Figure 6.11.2-4: 2-2 geological profile of the planned power plant site [6-15]



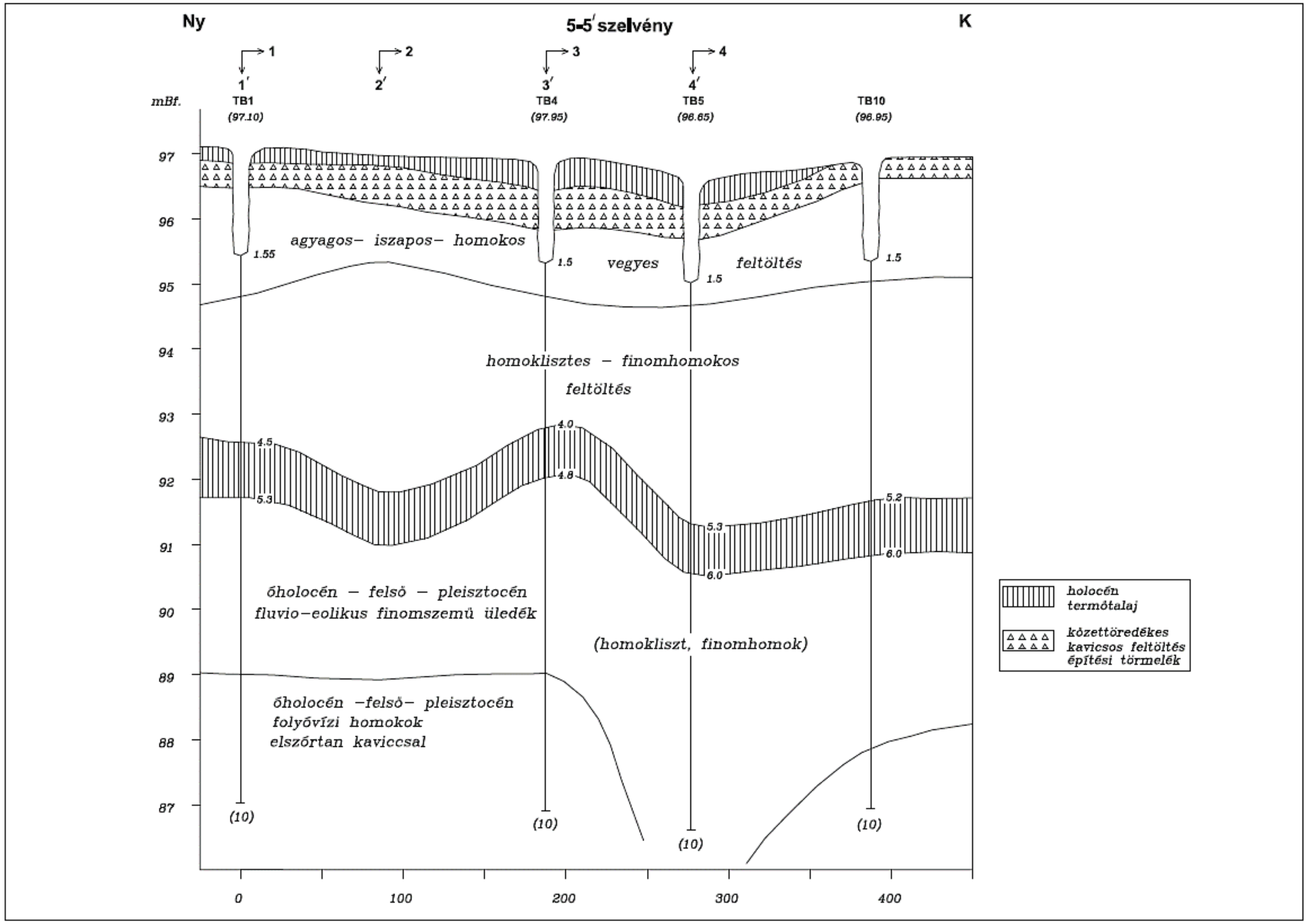
3-3'szelvény – Profile 3-3'
agyagos-iszapos-homokos vegyes feltöltés – mixed filling made of clay, sludge and sand
homoklisztes finomhomokos feltöltés – silt fine grained sand filling
Óholocén – Old Holocene
Felső pleisztocén – Upper-Pleistocene
Fluvio eolikus – fluvio-eloic
Finomszerű homokliszt, finomhomok – (fine-grained silt, fine-grained sand)
Holocén termőtalaj – Holocene fertile soil
Kőzettöredékes kavicsos feltöltés – detrital, pebble filling
Építési törmelék – Construction debris
Óholocén és Felső pleisztocén folyóvízi homok elszórtan kaviccsal –Old Holocene and Upper-Pleistocene river sands mixed with pebbles

Figure 6.11.2-5: 3-3 geological profile of the planned power plant site [6-15]



4-4'szelvény – Profile 4-4'
Agyagos-iszapos-homokos vegyes feltöltés – mixed filling made of clay, sludge and sand
Homoklisztes finomhomokos feltöltés – silt fine grained sand filling
Óholocén – Old Holocene
Felső pleisztocén – Upper-Pleistocene
Fluvio eolikus – fluvio-eloic
Finomszerű üledék – fine-grained filling
Finomszerű homokliszt, finomhomok – (fine-grained silt, fine-grained sand)
Holocén termőtalaj – Holocene fertile soil
Kőzettöredékes kavicsos feltöltés – detrital, pebble filling
Építési törmelék – Construction debris
Óholocén és Felső pleisztocén folyóvízi homok elszórtan kaviccsal –Old Holocene and Upper-Pleistocene river sands mixed with pebbles

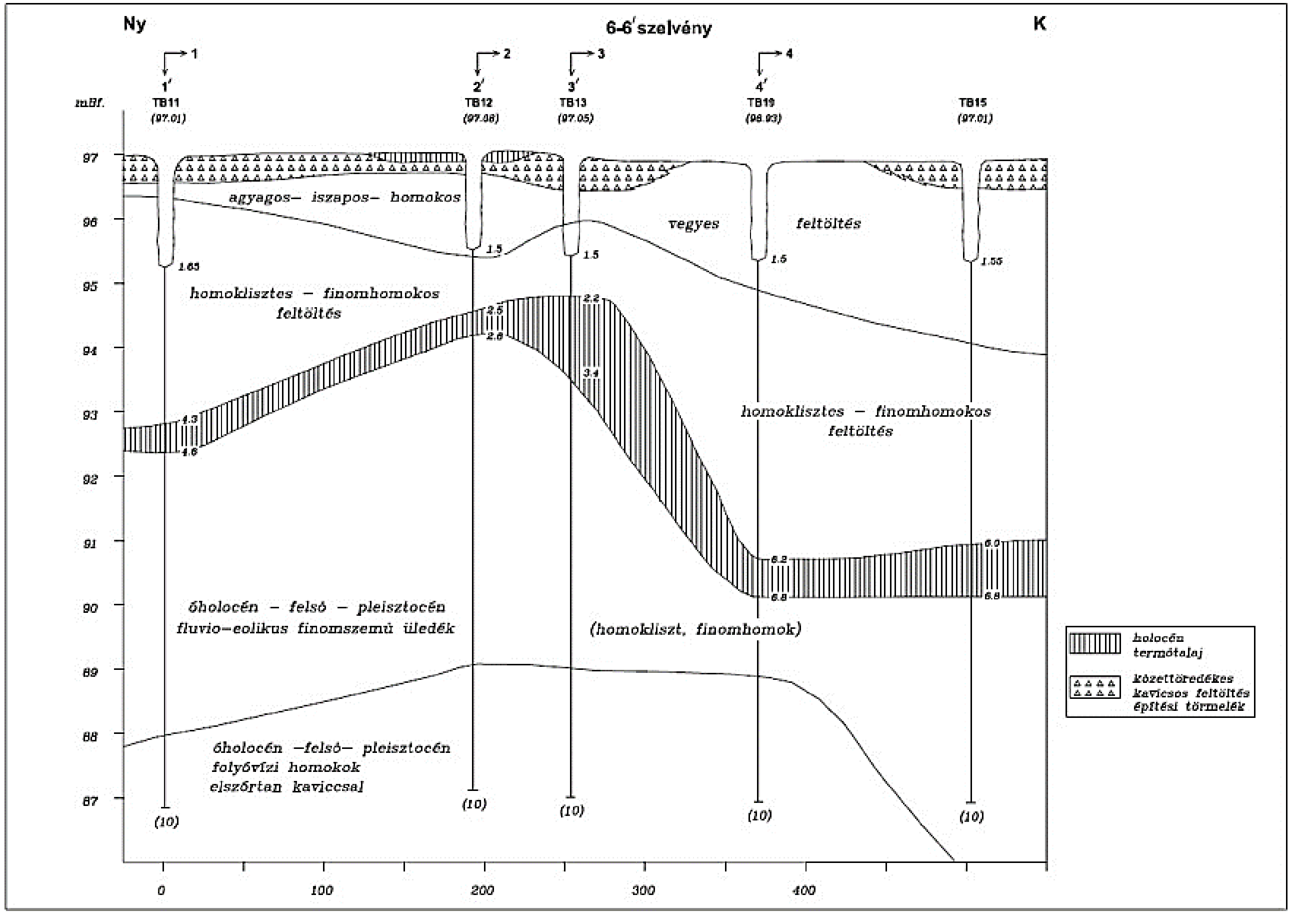
Figure 6.11.2-6: 4-4 geological profile of the planned power plant site [6-15]



5-5'szelvény – Profile 5-5'
agyagos-iszapos-homokos vegyes feltöltés – mixed filling made of clay, sludge and sand
homoklisztes finomhomokos feltöltés – silt fine grained sand filling
Óholocén – Old Holocene
Felső pleisztocén – Upper-Pleistocene
Fluvio eolikus – fluvio-eloic

Finomszerű homokliszt, finomhomok – (fine-grained silt, fine-grained sand)
Holocén termőtalaj – Holocene fertile soil
Kőzettöredékes kavicsos feltöltés – detrital, pebble filling
Építési törmelék – Construction debris
Óholocén és Felső pleisztocén folyóvízi homok elszórtan kaviccsal –Old Holocene and Upper-Pleistocene river sands mixed with pebbles

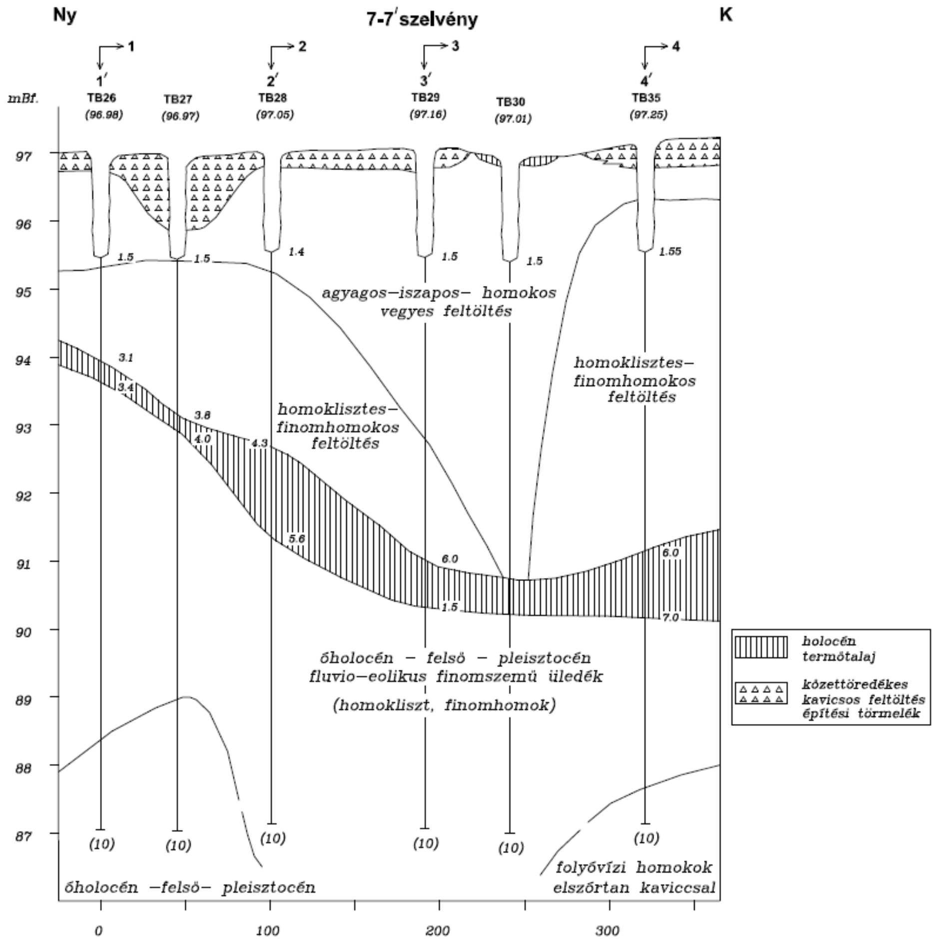
Figure 6.11.2-7: 5-5 Geological profile of the planned power plant site [6-15]



6-6'szelvény – Profile 6-6'
agyagos-iszapos-homokos vegyes feltöltés – mixed filling made of clay, sludge and sand
homoklisztes finomhomokos feltöltés – silt fine grained sand filling
Óholocén – Old Holocene
Felső pleisztocén – Upper-Pleistocene
Fluvio eolikus – fluvio-eloic

Finomszerű homokliszt, finomhomok – (fine-grained silt, fine-grained sand)
Holocén termőtalaj – Holocene fertile soil
Kőzettöredékes kavicsos feltöltés – detrital, pebble filling
Építési törmelék – Construction debris
Óholocén és Felső pleisztocén folyóvízi homok elszórtan kaviccsal –Old Holocene and Upper-Pleistocene river sands mixed with pebbles

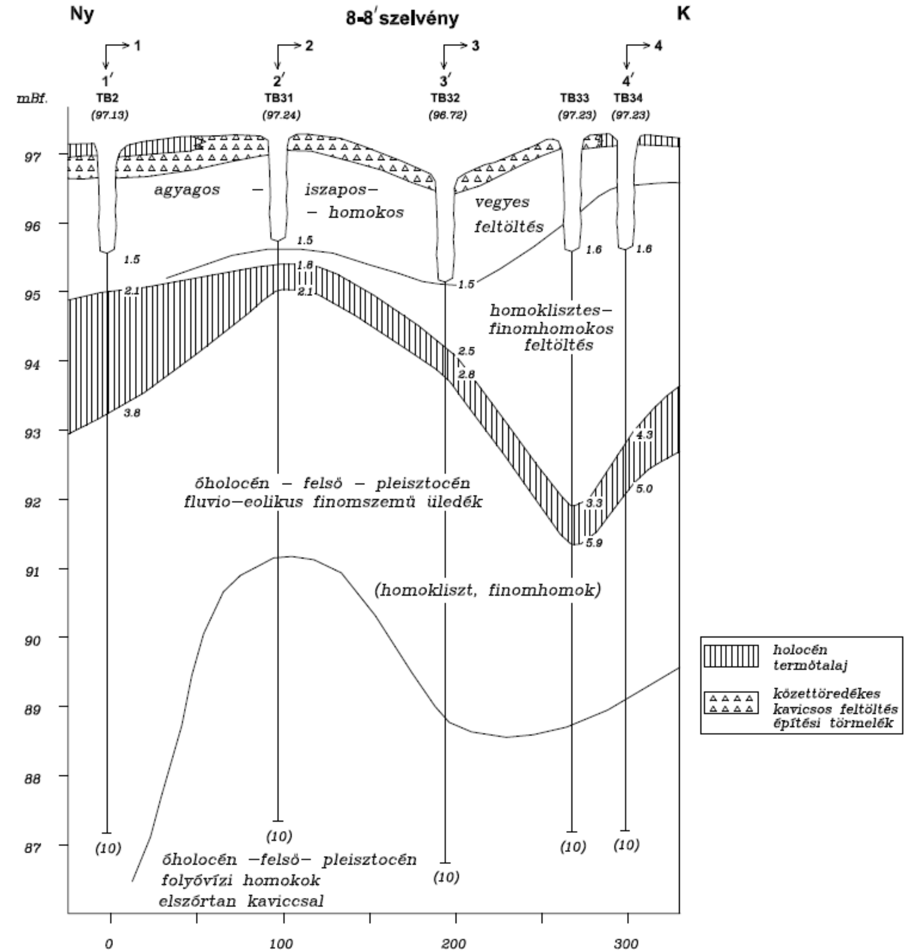
Figure 6.11.2-8: 6-6 geological profile of the planned power plant site [6-15]



7-7'szelvény – Profile 7-7'
agyagos-iszapos-homokos vegyes feltöltés – mixed filling made of clay, sludge and sand
homoklisztes finomhomokos feltöltés – silt fine grained sand filling
Óholocén – Old Holocene
Felső pleisztocén – Upper-Pleistocene
Fluvio eolikus – fluvio-eloic

Finomszerű homokliszt, finomhomok – (fine-grained silt, fine-grained sand)
Holocén termőtalaj – Holocene fertile soil
Kőzettöredékes kavicsos feltöltés – detrital, pebble filling
Építési törmelék – Construction debris
Óholocén és Felső pleisztocén folyóvízi homok elszórtan kaviccsal –Old Holocene and Upper-Pleistocene river sands mixed with pebbles

Figure 6.11.2-9: 7-7 geological profile of the planned power plant site [6-15]



8-8'szelvény – Profile 8-8'
agyagos-iszapos-homokos vegyes feltöltés – mixed filling made of clay, sludge and sand
homoklisztes finomhomokos feltöltés – silt fine grained sand filling
Óholocén – Old Holocene
Felső pleisztocén – Upper-Pleistocene
Fluvio eolikus – fluvio-eloic

Finomszerű homokliszt, finomhomok – (fine-grained silt, fine-grained sand)
Holocén termőtalaj – Holocene fertile soil
Kőzettöredékes kavicsos feltöltés – detrital, pebble filling
Építési törmelék – Construction debris
Óholocén és Felső pleisztocén folyóvízi homok elszórtan kaviccsal –Old Holocene and Upper-Pleistocene river sands mixed with pebbles

Figure 6.11.2-10: 8-8 geological profile of the planned power plant site [6-15]

In sum, the project area soil – similarly to other areas of the Paks Nuclear Power Plant – is formed of anthropogenic fill at the top, down to a depth of 10 m, followed by old Holocene sand drift, and finally Upper-Pleistocene fine and medium-grained flood plane sand at the bottom.

6.11.3 FOUNDATION LAYERS OF THE PLANNED UNITS

The explored layers show that the geological medium at a depth of 10 m is generally made up of fine-grained, low-cohesion, crumbly sediments. The fine-grain sediments are generally compressible layers with varying consistency, low plasticity and low load bearing capacity.

Underneath these layers the flood plain formation is moderately compact, suitable for foundations with proper load bearing capacity but because of its grain distribution it is sensitive to erosion and dynamic effects (e.g. an earthquake) and is susceptible to liquefaction under water.

Muddy clay lenses may block the path of rainwater into the ground, and form so called pendular water lenses. Pendular water lenses are always located higher than the average ground water level.

The general ± 0.00 level of the future Paks II Nuclear Power Plant was taken at 97 mBf.

Taking the assumed initial basic data into account, the estimated foundation depths are as follows:

- ❖ Reactor building complex (nuclear island), turbine building, diesel generators and other buildings that are part of the safety system

  Estimated foundation depth – due to the space required by the technology and the significant dynamic loads of the turbo machine group – is 14 to 20 m. Plate foundation supported by reinforced concrete piles is planned for these places.

- ❖ Other building that are not part of the safety system

  Deepened shallow foundation or plate foundation built on partial soil replacement is planned for other separate buildings that do not contain technological equipment resulting in significant dynamic use. The estimated foundation depth is 2 to 6 m.

6.11.4 LAYOUT – SITE DRAWING FOR INSTALLATION

The installation site layout was prepared for the following criteria:

- be located within the construction area designated for the operating area
  - there should be a distance of at least 100 m from the Paks Nuclear Power Plant in order to accomplish the following:
    - leave enough place around the new units for trucks to travel to facilitate deliveries;
    - simplify the digging of the open foundation pit;
    - minimize the effect of water drainage from the open pit on the operating units;
    - minimize the effect of the works performed after the shut-down of the existing units on the new units;
- the distance between the buildings should be adequate for fire protection;
- designs are based on the building with the largest floor space specified by the supplier;
- delivery routes;
- accessibility of buildings;
- technological order.

On the installation site plan prepared for the environmental impact assessment study (Figure 6.11.4-1 and Figure 6.11.4-2), the buildings and structures were arranged on the basis of technological considerations, taking the technological units with the maximum spatial requirement into account. Due to functional, building physics, structural, seismic design and fire protection considerations the layout and the sizes may be subject to change.

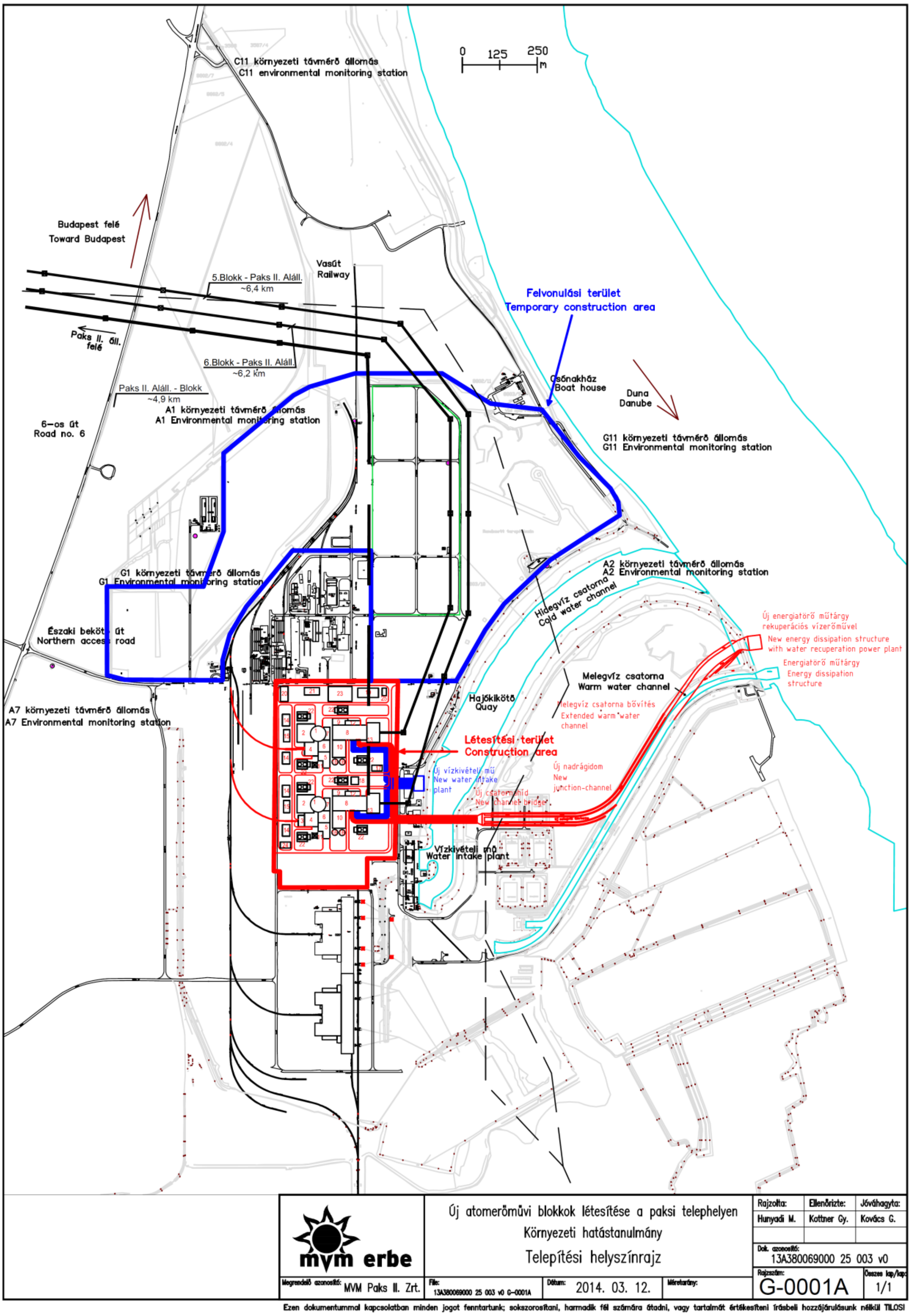


Figure 6.11.4-1: Paks II installation layout – General map including the site of the Paks Nuclear Power Plant

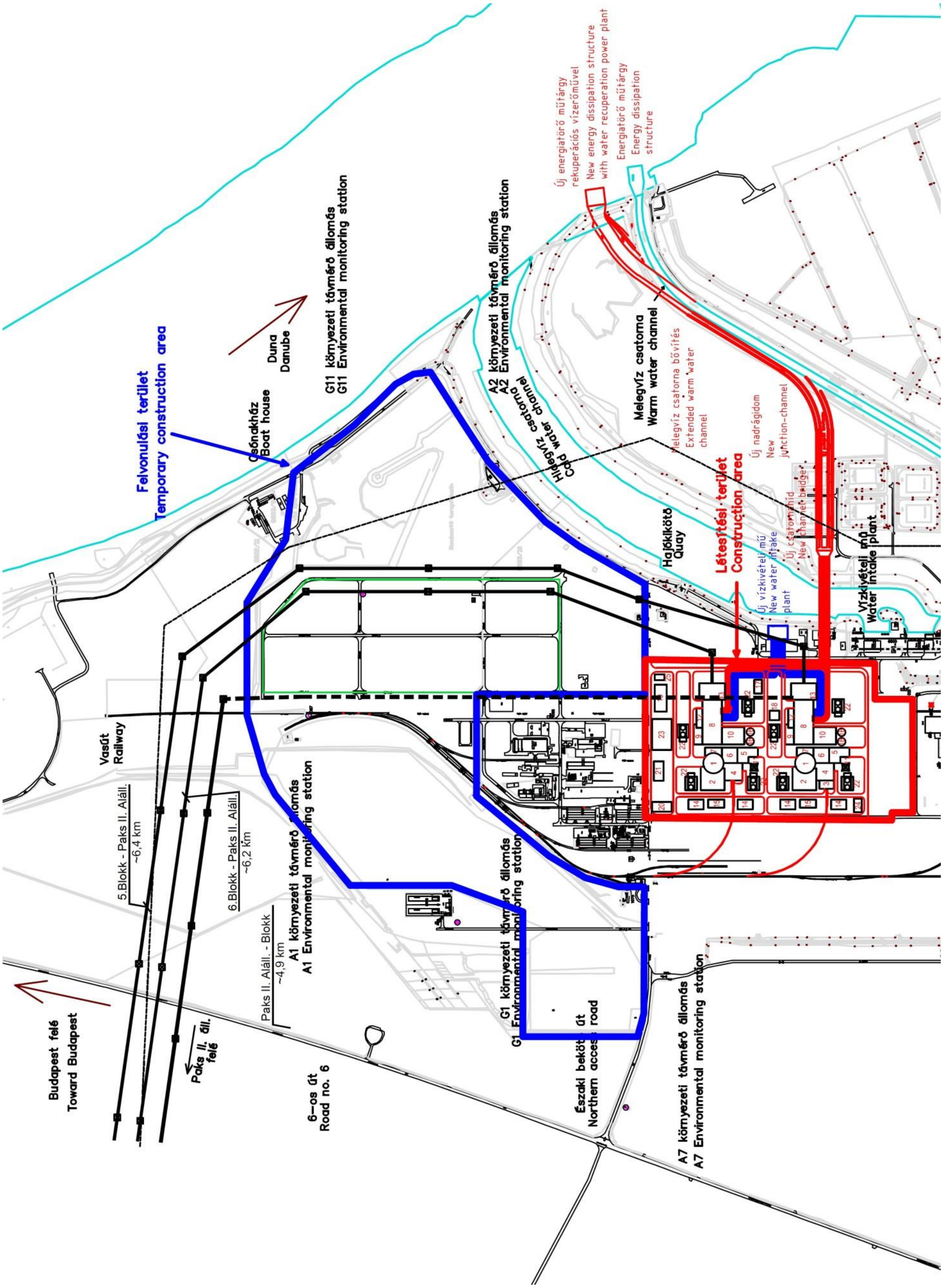
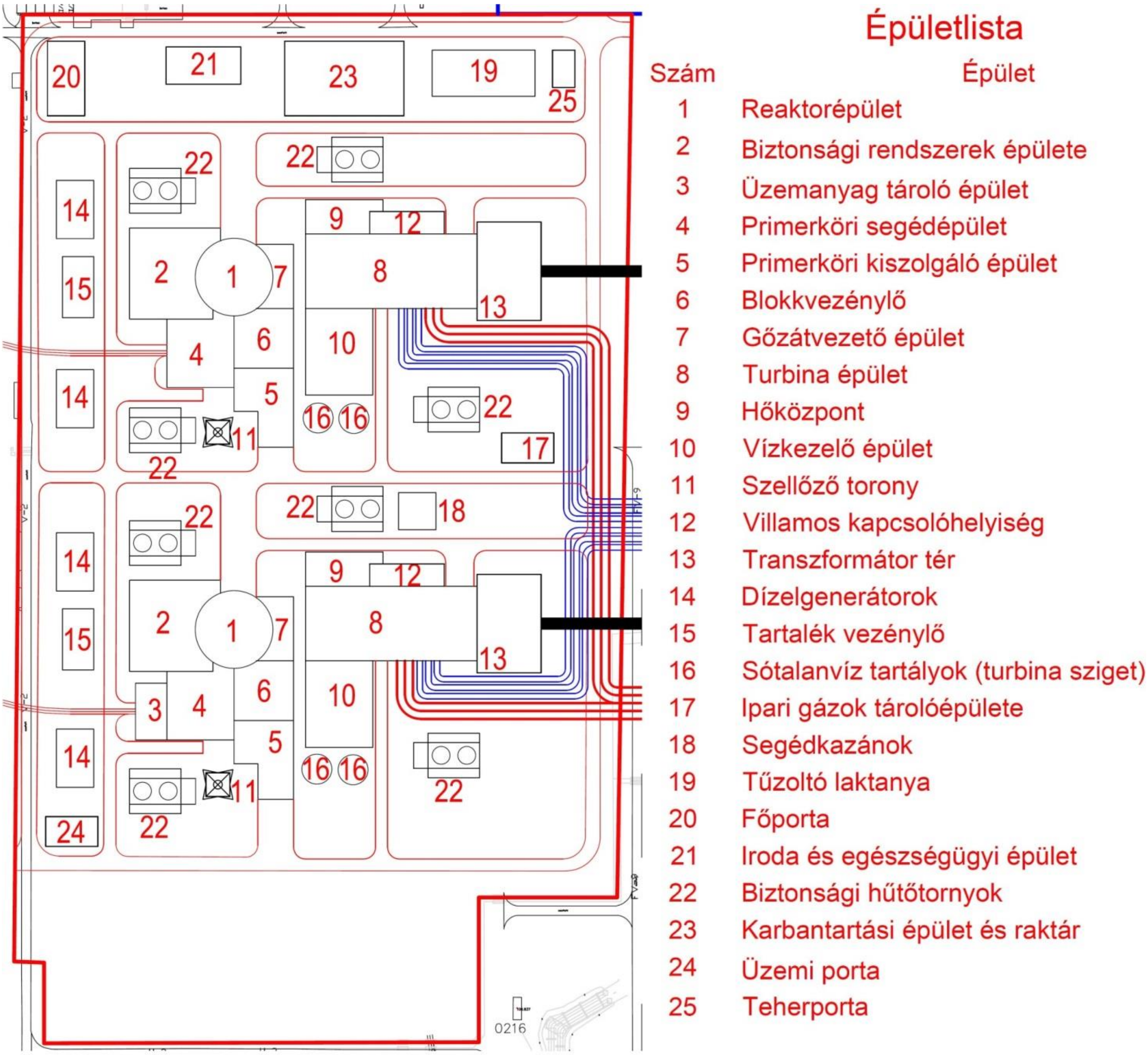


Figure 6.11.4-2: Paks II installation layout – General map

6.11.5 CHARACTERISTIC FEATURES OF PAKS II BUILDINGS AND STRUCTURES



Épületlista – List of buildings
Szám – Number
Épület – Building
1. Reaktorépület – Reactor building
2. Biztonsági rendszerek épülete – Building for safety systems
3. Üzemanyag tároló épület – Fuel storage
4. Primerköri segédépület – Primary circuit auxiliary building
5. Primerköri kiszolgáló épület – Primary circuit service building
6. Blokkvezénylő – Unit control room
7. Gőzátvezető épület – Steam transfer building
8. Turbina épület – Turbine building
9. Hőközpont – Heat centre
10. Vízkezelő épület – Water treatment building
11. Szellőző torony –Ventilation tower
12. Villamos kapcsolóhelyiség – Electrical switch room
13. Transzformátor tér –Transformer area
14. Dieselgenerátorok – Diesel generators
15. Tartalék vezénylő – Reserve control room
16. Sótalanvíz tartályok (turbina sziget) – Desalinating tanks (turbine island)
17. Ipari gázok tárolóépülete – Storage for industrial gases
18. Segédkazánok – Secondary boilers
19. Tűzoltó laktanya – Fire service building
20. Főporta – Main entrance
21. Iroda és egészségügyi épület – Office and healthcare building
22. Biztonsági hűtőtornyok – Emergency cooling towers
23. Karbantartási épület és raktár – Maintenance building and store
24. Üzemi porta – Staff entrance
25. Teherporta – Freight entrance

Figure 6.11.5-1: Location of the Paks II buildings and structures on the installation layout

The following description of the Paks II buildings and structures are detailed to the extent required for determining the basic data of the environmental impact assessment study and are based largely on data provided by the suppliers. Where there were no data, the structures of the existing nuclear power plant were used as a starting point. All the buildings and structures must be adequately sized for fire protection and seismic design. Any sizing criteria beyond these are shown separately for each building. The designation of the buildings and the numbering order agree with those in the installation site plan.

1 Reactor building

This building houses the primary circuit systems and equipment.

The building is sized for overpressure and is airtight to prevent or limit the emission of radioactive substances into the environment.

Dimensions:	*Ø52 m x 71.4 m*
Wall structure:	*double-layer reinforced concrete structure, with the internal side covered by steel sheets*
Roof structure:	*double-layer reinforced concrete dome structure, with the internal side covered by steel sheets*
Foundation:	*plate base supported by reinforced concrete piles*
Estimated foundation depth:	*14 to 20 m*
Other requirements:	*sized against aircraft crash, radiological sizing, sizing for noise and vibration protection.*

2 Safety systems building

There are several redundant safety systems in a nuclear power plant, with each one sufficient to handle a breakdown.

Dimensions:	*61 x 61 x 17.9 m*
Wall structure:	*reinforced concrete*
Roof structure:	*reinforced concrete*
Foundation:	*plate base supported by reinforced concrete piles*
Estimated foundation depth:	*14 to 20 m*
Other requirements:	*sizing for radiological protection, sizing for noise and vibration protection.*

3 Fuel storage building

Used for the management and storage of fresh and spent nuclear fuel

Dimensions:	*38 x 21 x 17.9 m*
Wall structure:	*reinforced concrete*
Roof structure:	*reinforced concrete*
Foundation:	*plate base supported by reinforced concrete piles*
Estimated foundation depth:	*14 to 20 m*
Other requirements:	*sizing for radiological protection*

4 Primary circuit auxiliary building

This building houses the auxiliary systems of the primary circuit, the equipment providing ventilation for the primary system, and storage facilities for liquid radioactive substances.

Dimensions:	*46 x 45 x 28.2 m*
Wall structure:	*reinforced concrete*
Roof structure:	*reinforced concrete*
Foundation:	*plate base supported by reinforced concrete piles*
Estimated foundation depth:	*14 to 20 m*
Other requirements:	*sizing for radiological protection, sizing for noise and vibration protection.*

5. Primary circuit service building

A building used for the performance of maintenance related to the primary circuit, for decontamination, for cleaning the clothes used in the primary circuit, and for access to the primary circuit.

Dimensions: 53 x 40 x 26.2 m
Wall structure: reinforced concrete
Roof structure: reinforced concrete
Foundation: plate base supported by reinforced concrete piles
Estimated foundation depth: 14 to 20 m
Other requirements: sizing for radiological protection,
sizing for noise and vibration protection.

6 Unit control room

A building that contains the equipment required for controlling the power plant during normal operation and during accidents.

Dimensions: 40 x 40 x 36 m
Wall structure: reinforced concrete
Roof structure: reinforced concrete
Foundation: plate base supported by reinforced concrete piles
Estimated foundation depth: 14 to 20 m
Other requirements: sizing for radiological protection,
sizing for noise and vibration protection.

7 Steam transfer building

A safety building containing a system that protects the evaporator from overpressure.

Dimensions: 43 x 25 x 27.3 m
Wall structure: reinforced concrete
Roof structure: reinforced concrete
Foundation: plate base supported by reinforced concrete piles
Estimated foundation depth: 14 to 20 m
Other requirements: sizing for radiological protection
sizing for noise and vibration protection.

8 Turbine building

A building that contains the turbine, the generator and the related auxiliary systems.

Dimensions: 115 x 50 x 33.3 m
Wall structure: reinforced concrete
Roof structure: reinforced concrete
Foundation: plate base supported by reinforced concrete piles
Estimated foundation depth: 14 to 20 m
Other requirements: sizing for noise and vibration protection

9 Heat distribution centre

A building that contains the district heating service provider's heat distribution centre.

Dimensions: 23 x 52 x 25 m
Wall structure: masonry
Roof structure: reinforced concrete
Foundation: flat foundation, strip foundation
Estimated foundation depth: 2 to 6 m
Other requirements: sizing for noise and vibration protection

10 Water treatment building

A facility used for the generation of extra water in the quality and quantity appropriate and required for the primary and secondary circuits.

Dimensions: *45 x 58 x 12 m*
Wall structure: *masonry*
Roof structure: *reinforced concrete*
Foundation: *flat foundation, strip foundation*
Estimated foundation depth: *2 to 6 m*
Other requirements: *sizing for noise and vibration protection*
secondary containment basin

11 Vent chimney

The function of chimneys is to emit radioactive substances to the air at a height of 100 m from the ground. Thus any possible radioactive emissions scatter in a larger airspace and produce less local environmental impact.

Dimensions: *20 x 20 x 100 m*
Outlet diameter: *2.3 m*
Wall structure: *reinforced concrete*
Roof structure: *none*
Foundation: *deep foundation*
Estimated foundation depth: *14 to 20 m*

12 Electric switchboard room

A building that houses electrical switchboards, control engineering equipment and communication devices.

Dimensions: *50 x 15 x 12 m*
Wall structure: *masonry*
Roof structure: *reinforced concrete*
Foundation work: *plate base supported by reinforced concrete piles*
Estimated foundation depth: *2 to 6 m*
Other requirements: *sizing for noise and vibration protection*

13 Transformer area

This is an outdoor place for unit transformers and other power plant transformers.

Dimensions: *66 x 43 m*
Wall structure: *reinforced concrete*
Foundation: *for the walls: flat foundation, strip foundation; for the machines: plate foundation*
Estimated foundation depth: *2 to 6 m*
Other requirements: *sizing for noise and vibration protection,*
secondary containment basin

14 Diesel generators

They provide electric power for the primary circle in the case of any operational breakdown.

Dimensions: *39 x 25 x 15 m*
Wall structure: *reinforced concrete*
Roof structure: *reinforced concrete*
Foundation: *plate base supported by reinforced concrete piles*
Estimated foundation depth: *14 m*
Other requirements: *sizing for noise and vibration protection*
secondary containment basin

15 Backup control room

A building that contains the equipment required for controlling the power plant during normal operation and during accidents in the event of a failure of the unit control room.

Dimensions:	*41 x 21 x 15 m*
Wall structure:	*reinforced concrete*
Roof structure:	*reinforced concrete*
Foundation:	*plate base supported by reinforced concrete piles*
Estimated foundation depth:	*14 m*
Other requirements:	*sizing for radiological protection* *sizing for noise and vibration protection.*

16 Desalinated water tanks (turbine island)

They ensure an undisturbed supply of makeup water for the turbine island in the case of a breakdown of the water treatment plant or other failures.

Dimensions:	*Ø20 m x 15.5 m*
Wall structure:	*masonry*
Roof structure:	*reinforced concrete*
Foundation work:	*plate base supported by reinforced concrete piles*
Estimated foundation depth:	*2 to 6 m*

17 Storage building for industrial gases

Serves for storing hydrogen (in the generator cooling circuit), nitrogen and other gases required for operation.

Dimensions:	*20 x 35 x 12 m*
Wall structure:	*masonry and reinforced concrete*
Roof structure:	*reinforced concrete*
Foundation work:	*flat foundation, strip foundation*
Estimated foundation depth:	*2 to 6 m*
Other requirements:	*sized for explosion*

18 Secondary boilers

These generate the steam required for starting up the power plant.

Dimensions:	*25 x 25 x 15 m*
Wall structure:	*masonry*
Roof structure:	*reinforced concrete*
Foundation work:	*plate base supported by reinforced concrete piles*
Estimated foundation depth:	*2 to 6 m*
Other requirements:	*sizing for noise and vibration protection*

19 Fire service quarters

A building within the boundaries of the power plant, serving as a local premises of the fire service.

Dimensions:	*31 x 69 x 13 m*
Wall structure:	*masonry*
Roof structure:	*reinforced concrete*
Foundation work:	*flat foundation, strip foundation*
Estimated foundation depth:	*2 to 6 m*

20 Main entrance

Provides access to the area of the power plant.

Dimensions: *25 x 50 x 12 m*
Wall structure: *masonry*
Roof structure: *reinforced concrete*
Foundation work: *flat foundation, strip foundation*
Estimated foundation depth: *2 to 6 m*

21 Office and healthcare building

Serves for general office functions and as a healthcare centre.

Dimensions: *50 x 25 x 12 m*
Wall structure: *masonry*
Roof structure: *reinforced concrete*
Foundation work: *flat foundation, strip foundation*
Estimated foundation depth: *2 to 6 m*

22 Emergency cooling towers

Cooling towers used for the emergency cooling of the primary circuit.

Dimensions: *44.25 x 30 x 15 m*
Wall structure: *reinforced concrete*
Roof structure: *reinforced concrete*
Foundation: *plate base supported by reinforced concrete piles*
Estimated foundation depth: *14 m*
Other requirements: *secondary containment basin*

23 Maintenance building and warehouse

Facilities used for the performance of maintenance related to the secondary circuit.

Dimensions: *50 x 80 x 12 m*
Wall structure: *masonry*
Roof structure: *reinforced concrete*
Foundation work: *flat foundation, strip foundation*
Estimated foundation depth: *2 to 6 m*

24 Staff entrance

Provides access to the area of the power plant.

Dimensions: *35 x 20 x 5 m*
Wall structure: *masonry*
Roof structure: *reinforced concrete*
Foundation work: *flat foundation, strip foundation*
Estimated foundation depth: *2 to 6 m*

25 Goods entrance

Provides access to the area of the power plant.

Dimensions: *25 x 15 x 5 m*
Wall structure: *masonry*
Roof structure: *reinforced concrete*
Foundation work: *flat foundation, strip foundation*
Estimated foundation depth: *2 to 6 m*

Building of the water intake structure

The water intake structure will be implemented on the bank of the existing cold-water channel of the Paks Nuclear Power Plant, on an open area about 150 m north of the existing water intake plant. The condenser cooling water system pumps will be located in this water intake structure. The overall dimensions of the water intake structure are about 50 x 34 m, of which only about 5 to 6 m will be above ground level.

Dimensions (width x length x height): 50 x 34 x 30 m
Wall structure: reinforced concrete
Roof structure: reinforced concrete
Foundation: plate base supported by reinforced concrete piles
Estimated foundation depth: 25-30 m
Other requirements: sizing for noise and vibration protection

Building for the energy recovery hydroelectric plant

The energy recovery hydroelectric plant will be implemented on the Danube bank at the mouth of the warm-water channel. The barrage dam, housing the water turbines, the downstream energy dissipation device and the connecting channel, is about 35-45 m wide, with dimensions that are nearly identical with the warm-water channel, and is about 50 to 60 m long.

Dimensions (width x length x height): 60 x 45 x 25 m
Wall structure: reinforced concrete
Roof structure: reinforced concrete
Foundation: plate base supported by reinforced concrete piles
Estimated foundation depth: 20-25 m
Other requirements: sizing for noise and vibration protection

6.11.6 VISUALISATION OF PAKS II

The building complexes of Paks II and the 400 kV line are shown from a bird's eye view and at eye-level on the following three views:

View 1: Viewed from south-west, from the area between the Paks Nuclear Power Plant and Paks II
View 2: Viewed from north-west, from the corner of the temporary construction area
View 3: Viewed from north-east, from the line of the cold-water channel

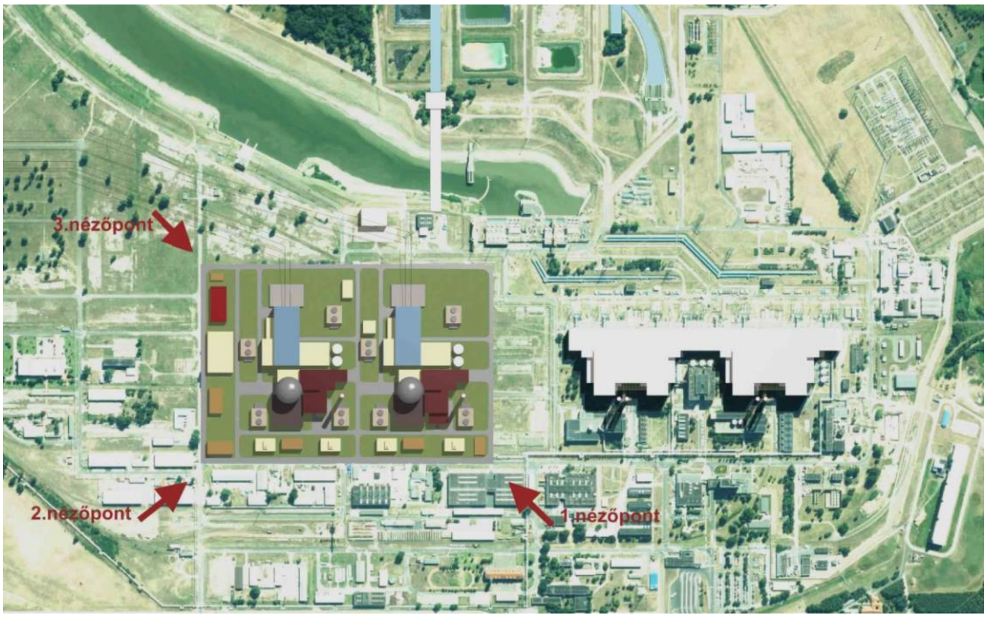


Figure 6.11.6-1: Visual design perspectives

VIEW 1:

Figure 6.11.6-2: The planned units and the 400 kV line from a bird's eye view – south-west

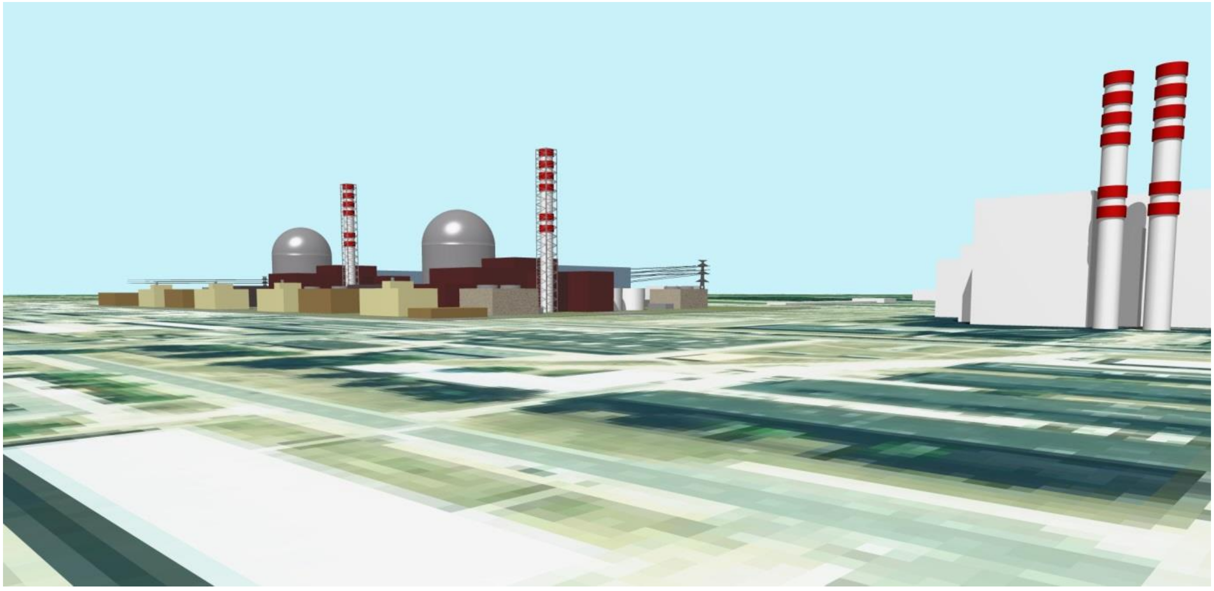


Figure 6.11.6-3: Visual perspective of the planned units and the 400 kV line at eye-level – south-west

VIEW 2:

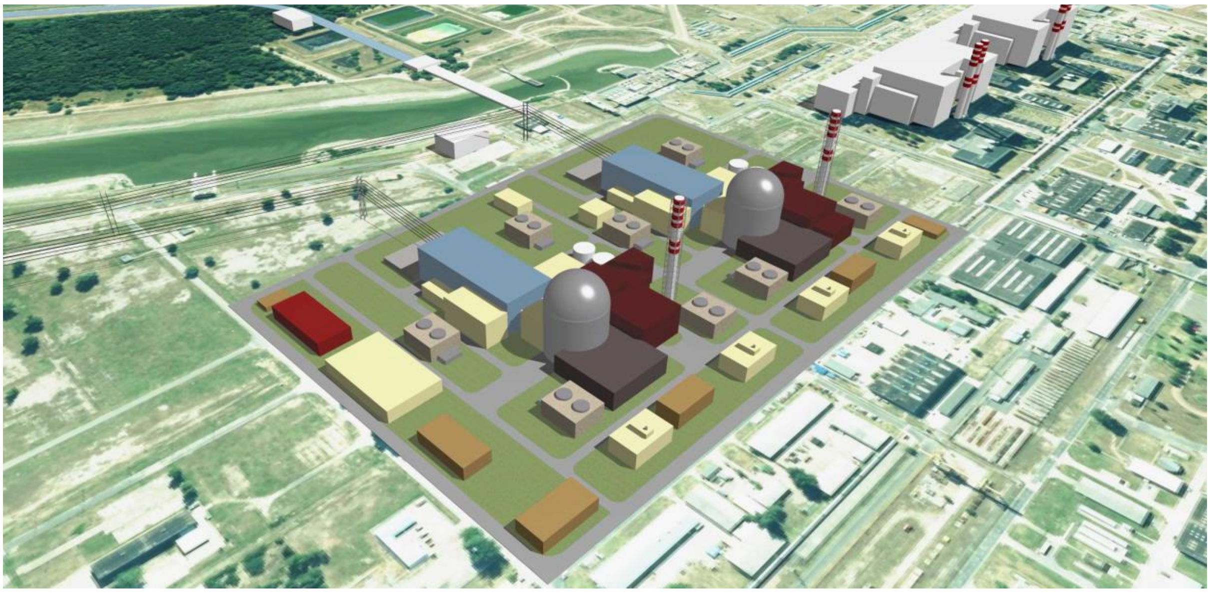


Figure 6.11.6-4: The planned units and the 400 kV line from a bird's eye view – north-west

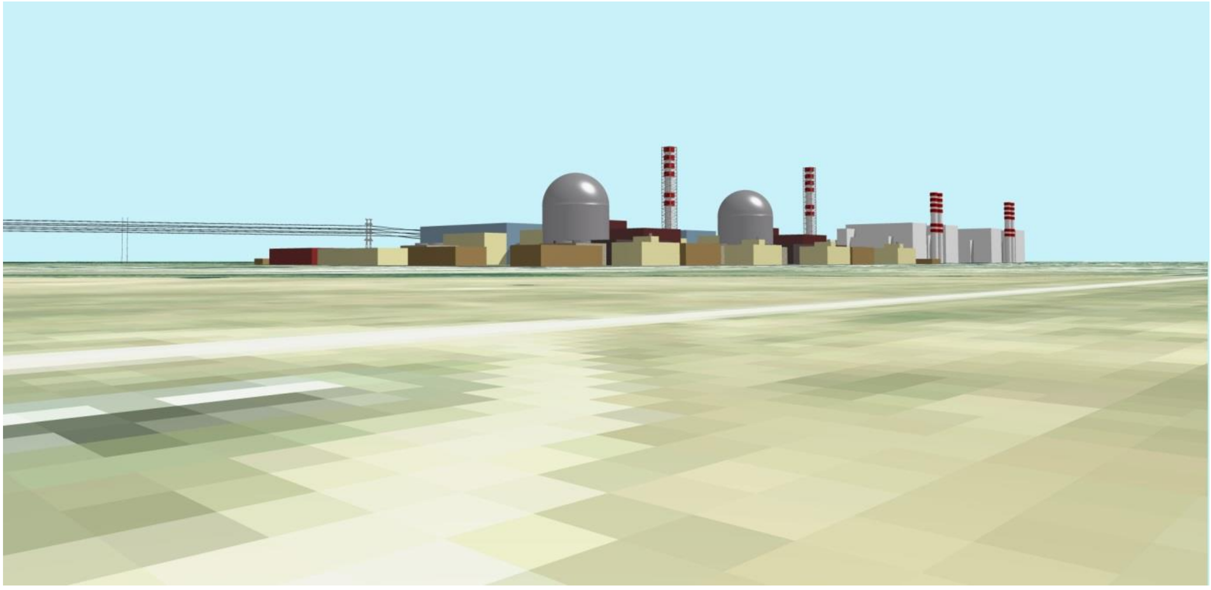


Figure 6.11.6-5: The planned units and the 400 kV line at eye-level – north-west

VIEW 3:

Figure 6.11.6-6: The planned units and the 400 kV line from a bird's eye view – north-east

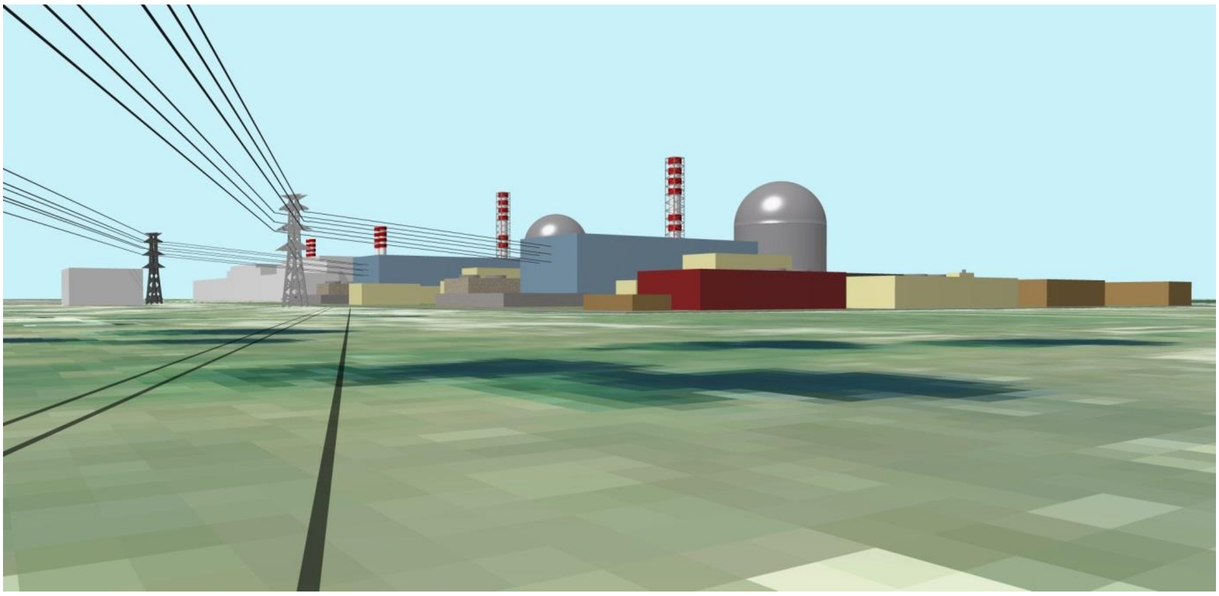


Figure 6.11.6-7: Visual perspective of the planned units and the 400 kV line at eye-level – north-west

6.12 PHYSICAL PROTECTION

During the implementation of the new nuclear power plant units, appropriate physical protection systems must be developed in accordance with the relevant statutory regulations and the decision on the design basis threat, on the basis of the principle of defense in depth. The number, defense capacity and technical parameters of the individual system components are specified in the draft concept of physical protection, the requirements applicable to each particular zone, the DBT decision (Design Basis Threat – the level of threat, as determined by the state, against which effective physical protection must be provided by the party using the nuclear power), and the physical protection plan. The draft concept of physical protection may be included in the physical protection plan.

The possible main system components of the physical protection system include (but are not limited to) the following:

- passive mechanical barriers;
- active mobile mechanical barriers together with their locks;
- intrusion detection and alarm systems;
- video monitoring and assessment system;
- access control system;
- security guards' head office;
- integrated property protection head office.

The physical protection systems are independent of the nuclear power plant systems and system components that are important for nuclear safety and radiation protection. The nuclear safety system components can fully perform their functions regardless of the functioning of physical protection. The physical protection system components do not affect the system components for nuclear safety and radiation protection (there is no interaction between the two systems). Due to the above, the connection point of physical protection system components to the nuclear facilities is included in the active and passive mechanical barriers only to the extent that the latter are part of the structures included in the main contractor's scope of delivery.

6.13 ACCEPTANCE CRITERIA FOR THE INDIVIDUAL MODES OF OPERATION

In agreement with the general safety criteria presented in Chapter 3.4, the acceptance criteria for the individual modes of operation are presented below.

6.13.1 NORMAL OPERATION

Operating condition	Description	Frequency f [1/year])	Exposure of the population to additional radiation	
			Criterion	VVER-1200 projection
TA1/DBC1	Normal operation	1	20 μSv/year	< 2 μSv/year

Table 6.13.1-1: Acceptance Criteria – normal operation [6-16]

6.13.2 DESIGN BASIS CONDITION

Operating condition	Description	Frequency f [1/year])	Exposure of the population to additional radiation	
			Criterion	VVER-1200 projection
TA2/DBC2	Expected operational events	$f \geq 10^{-2}$	100 μSv/year	< 60 μSv/year
TA3/DBC3	Low probability design basis conditions	$10^{-2} > f \geq 10^{-4}$	1 mSv/event	< 1 μSv/event
DBC4	Very low probability design basis conditions	$10^{-4} > f \geq 10^{-6}$	5 mSv/event	< 3.4 mSv/event

According to the NSR, the dose the population is exposed to may not exceed the dose limit (90 μSv), which is less than the criterion set out in the table (100 μSv), but exceeds the forecast value (60 μSv).

Table 6.13.2-1: Acceptance Criteria – Design Basis Condition [6-16]

6.13.3 EFFECTIVE INTERNATIONAL AND HUNGARIAN REQUIREMENTS FOR DESIGN EXTENSION CONDITIONS

EFFECTIVE INTERNATIONAL AND HUNGARIAN REQUIREMENTS (AS PER NSR VALID ON OCTOBER 20, 2014)		
European Utility Requirements (EUR) **Volume 2 - GENERIC NUCLEAR ISLAND REQUIREMENTS** **Chapter 1 - SAFETY REQUIREMENTS**	***Appendix 3 to Government Decree 118/2011. (VII. 11.)*** ***Nuclear Safety Regulations*** **Volume 3: Nuclear power plant design requirements:**	**Decree 16/2000. (VI. 8.) of the** **Minister of Health on the execution of the individual provisions of Act CXVI of 1996 on nuclear energy**
2.5.1 Off-site release Targets for Severe Accidents **2.5.2** Off-site release Targets for Complex Sequences **Appendix B 1.** Criteria for Limited Impact for DEC	**3.2.4.0700** For a new nuclear power plant unit, the limited environmental impact criterion is met if the following items are verified for events resulting in a DEC1 operational state and for events resulting in a DEC2 operational state, also taking into account the provisions of Section 3.2.2.4100. in the latter case:	**Intervention levels applicable to emergency exposure to radiation** *Intervention level:* The value of the avoidable equivalent dose or effective dose which require consideration of the intervention measures when reached. The avoidable dose or its derivative value is exclusively applied to the radiation route or routes at which the particular measure is aimed.
no Emergency Protection Action beyond 800 m from the reactor during releases from the containment *Emergency Protection Action:* Actions involving public evacuation, based on projected doses up to 7 days, which may be implemented during the emergency phase of an accident, e. g. during the period in which significant releases may occur. This period is generally shorter than 7 days.	*a)* beyond a distance of 800 m from the nuclear reactor, there is no need to take early emergency measures, i.e. the population does not need to be urgently evacuated	**Stay-indoors:** 10 mSv effective dose within a period not exceeding 2 days **Rescue:** 50 mSv effective dose within a period not exceeding 1 week **Iodine prevention:** 100 mGy absorbed radiation dose in the thyroid
no Delayed Action at any time beyond about 3 km from the reactor *Delayed Action:* Actions involving public temporary relocation, based on projected doses up to 30 days caused by ground shine and aerosol resuspension, which may be implemented after the practical end of the releases phase of an accident.	*b)* beyond a distance of 3 km from the nuclear reactor, there is no need to take any provisional measures, i.e. the population does not need to be temporarily evacuated;	**Temporary evacuation:** 30 mSv/month effective dose (termination 10 mSv/month effective dose)
no Long Term Action at any distance beyond 800 m from the reactor *Long Term Action:* Actions involving public permanent resettlement, based on projected doses up to 50 years caused by ground shine and aerosol re-suspension. Doses due to ingestion are not considered in this definition.	*c)* beyond a distance of 800 m from the nuclear reactor, there is no need to take late emergency measures, i.e. the population does not need to be relocated permanently;	**Permanent relocation:** >1 Sv/ life effective dose

EFFECTIVE INTERNATIONAL AND HUNGARIAN REQUIREMENTS (AS PER NSR VALID ON OCTOBER 20, 2014)		
European Utility Requirements (EUR) **Volume 2 - GENERIC NUCLEAR ISLAND REQUIREMENTS** **Chapter 1 - SAFETY REQUIREMENTS**	***Appendix 3 to Government Decree 118/2011. (VII. 11.)*** ***Nuclear Safety Regulations*** **Volume 3: Nuclear power plant design requirements:**	**Decree 16/2000. (VI. 8.) of the** **Minister of Health on the execution of the individual provisions of Act CXVI of 1996 on nuclear energy**
limited economic impact: restrictions on the consumption of foodstuff and corps shall be limited in terms of timescale and ground area	*d)* only limited economic impacts are possible outside the area of the power plant.	
Appendix B 2. Release Targets for Design Basis Category 3 and 4 Conditions (1) no action beyond 800 m (2) limited economic impact	**3.2.4.0100.** For processes starting from initial events resulting in a DBC2 to 4 operating state, it shall be verified that the exposure of the reference group of the population does not exceed: *a)* in the case of a new nuclear power plant unit: *aa)* the dose limit applicable in the case of a process that starts from an initial event resulting in a DBC2 operating state (90 μSv/year) *aa)* the 1 mSv/event value applicable in the case of a process that starts from an initial event resulting in a DBC3 operating state, and *aa)* the 5 mSv/event value applicable in the case of a process that starts from an initial event resulting in a DBC4 operating state.	***Appendix 2 to Decree 16/2000. (VI. 8.) of the Minister of Health*** ***I Action levels of dose limits and radon concentrations applicable to employees*** 4.2 The total exposure of the members of the population to external and internal radiation from artificial sources, other than exposures related to medical diagnostic and therapeutic intervention purposes, patient care and voluntary participation in medical research, may not exceed the **1 mSv effective dose rate** per annum. **Under special conditions and for any individual year, OTH may permit a higher dose rate,** provided that for 5 consecutive years following that year, the average individual exposure to radiation does not exceed the 1 mSv effective dose per annum. Irrespectively of the above limit on the effective dose, the annual equivalent dose rate for eye lenses is 15 mSv. The annual equivalent dose rate for skin – averaged for any 1 cm^2 area – and limbs is 50 mSv.

Table 6.13.3-1: Effective international and Hungarian requirements for Design Extension Conditions

6.13.4 OPERATING STATES OF THE UNITS AND THEIR DESIGN BASIS EVENTS

It is possible to define events for each operating state of the planned VVER-1200 units that involve the largest environmental emission within that operating state. Table 6.13.4-1 in Chapter 3.5.3 gives a list of design basis events of the planned units on the basis of preliminary Russian data broken down by operating state. These envelope events can be finally reviewed on the basis of the detailed technical plan.

Operating condition	Description	Design basis condition
TA1 – DBC1	normal operation	There is no design basis condition in normal operation.
TA2 – DBC2	expected operational events	Unintended opening of the steam-generating safety valve, the discharge vale or the valve of the turbine by-pass line and any malfunction arising from it that prevents the closing of the valve
TA3 – DBC3	low probability design basis conditions	small leakage of coolant due to a crack or break in primary circuit pipes with an equivalent diameter of less than 100 mm
TA4 – DBC4	very low probability design basis conditions	significant leakage of coolant due to a crack or break in primary circuit pipes with an equivalent diameter of more than 100 mm, including the leakage of coolant due to a crack or break in the main water cycle pipe
TAK1 – DEC1	design extension conditions	Total loss of power in the non-safety electricity supply system of the units' auxiliary systems
TAK2 – DEC2	Serious accidents	Significant loss of coolant occurring along with the breakdown of the active part of the high or low-pressure zone malfunction cooling system

Table 6.13.4-1: Operating states and design basis events of the units [6-17]

6.13.5 REQUIREMENTS FOR THE PSA RESULTS OF THE RUSSIAN UNITS

Annex 3 ("Design criteria for nuclear power plants) to Government Decree 118/2011 (VII. 11.) contains, among other things, the following in the chapter "General design Criteria":

> *3.2.3.1600. Level 1 and level 2 probability safety analyses must be carried out for the design of the nuclear power plant units which takes into account every possible operating condition, system configuration and all assumed initial events for which there is no other method to verify that their contribution to risk is insignificant.*
>
> *3.2.3.1700. The probability safety analysis must consider all material functional and on-site dependencies that are based on the physical location of the system components and arise from operation, maintenance and other failures with a common cause, in particular, the effects of flying objects, liquids and steam jets, internal fire and flooding as well as the system disturbances of nearby industrial facilities and the effects of human activity. Extreme weather conditions and seismic events must also be assessed.*

The analysis of the consequences of possible failures as initial events is performed in a complex way in the probability safety analysis, going beyond the initial event and taking into account additional equipment failures and human errors, which occur either due to the initial event or independently of it. This study identifies the series of events leading to damage to a zone in level 1 probability analysis and to serious accidents due to large radioactive emission in level 2 analysis, and determines their frequency (probability) of occurrence. This way, these studies include the entire range of design basis failures as well as beyond design extension processes, the latter including complex processes as well as serious accidents.

Under level 1 and level 2 PSA

- damage to a zone or fuel rod (level 1), large radioactive emission (level 2) and the annual average probability of the failure to drive the residual heat into the final heat absorber are identified, including their probability by operating condition;
- all the possible operating conditions, system configurations and radioactive emission sources of the power plant are taken into account (including the fuel pond);
- all the initial events are analysed in detail for which it cannot be verified that their contribution to risk is insignificant.

The investigations include the possible consequences of initial events of a technological nature (internal events) as well as internal and external risks (internal fire and flooding, external human and natural impacts, earthquakes) among the

PSA initial events. The events with a verifiably insignificant frequency or consequences are filtered out of the detailed impact study. Probabilistic and/or deterministic methods and criteria are used for filtering.

Finally, the analyses identify the entire risk and its components that the nuclear power plant poses. The goal of the assessment of the results is to verify that the acceptance criteria of the PSA results are met, to present the balanced nature of the power plant design and to assess compliance of the design extension. The PSA is an integral part of the design process of the nuclear power plant, which is scheduled in the design phase of the power plant and is carried out in such detail so that – along with the deterministic analyses – it can be used for risk-based decision, the modification of the design and other PSA applications. These applications include, among others, classification of system and system components into safety classes, instructions for managing serious accidents, scheduling and optimizing maintenance work, establishing operating limitations, scheduling of tests and trials, etc. Compliance with the acceptance criteria of the PSA results is verified by taking into account the effect of maintenance work, tests and supervisions on the reliability of the system and system components.

The new version of the current Nuclear Safety Regulations **expected to come into effect with amendments** will specify the following quantitative criteria for new nuclear power plant units, which the supplier will have to verify by probability safety analyses:

3a.2.1.1300.	They must ensure that the residual heat is driven into the final heat absorber in such a way that the frequency of loss of the heat absorption function is less than 10^{-7}/year.
3a.2.2.0400.	Probability safety analyses must be used to verify for every design basis condition that the product of the frequency of a given initial event and the probability of the failure of any safety function required for meeting the acceptance criteria of TA4 operating states does not exceed the value of 10^{-6}/year during the transient caused by the given initial event.
3a.2.2.5100.	The following may be filtered out of the assumed initial events: • an internal initial event stemming from the failure of systems, system components or human error or both, if its frequency is less than 10^{-6}/year; • an event stemming from external human activity typical of the site, the frequency of which is less than 10^{-7}/year, or if the risk factor is at such a distance that it can be proved that it will probably not have any influence on the NPP unit; and • any initial event stemming from an external environmental effect that is repeated with a frequency of less than 10^{-5}/year.
3a.2.2.7300.	At least the following events must be practically excluded by means of design solutions or preventive accident management capabilities, that is, it must be demonstrated that their occurrence is impossible or their frequency of occurrence can be safely estimated at less than 10^{-7}/year: • break in the reactor pressure vessel; • immediate critical reactivity accidents, including cases of heterogeneous boron dilution; • any short or long-term load which may put the integrity of containment at risk, especially drop of heavy masses, steam or hydrogen explosion, interaction of fuel melt with concrete load bearing structures, and containment overpressure; • loss of cooling during the storage of radiated fuel rods which may lead to the damage of the fuel rod; and • loss of coolant with open containment, which may result in the zone becoming dry.
3a.2.3.1800.	Level 1 and level 2 probability safety analyses must be carried out for the design of the nuclear power plant units, including the fuel storage and management systems, which take into account every possible operating condition, system configuration and all assumed initial events for which there is no other method to prove that their contribution to risk is insignificant.
3a.2.3.1900.	The probability safety analysis must consider all the material functional and on-site dependencies that are based on the physical location of the system components and arise from operation, maintenance and other failures with a common cause, in particular, the effects or flying objects, liquids and steam blast, internal fire and flooding as well as the system disturbances of nearby industrial facilities and the effect of human activity. Events evoked by external natural risk factors must also be assessed.
3a.2.4.0600.	For the chain of events stemming from all the assumed initial events – except for sabotage – the aggregate frequency of events resulting in the total or partial meltdown of the zone may not exceed the frequency of 10^{-5}/year.
3a.2.4.0800.	Events involving large or early emission must practically be excluded. The frequency of the chain of events aggregated for all the operating conditions resulting in a large or early emission – except for sabotage – may not exceed 10^{-6}/year. Compliance with the criteria must be demonstrated by Level 2 probability safety analyses.

6.14 CHARACTERISTICS OF ESTABLISHING PAKS II

6.14.1 INSTALLATION AREAS OF PAKS II. AND ASSOCIATED FACILITIES

In the course of implementing the new nuclear power plants, the construction of the technological part of the power plant and the associated facilities required for operation will affect the following areas:

Paks II Nuclear power plant

Service area for the construction of the power plant: *temporary construction site*
Construction area of the new nuclear units: *operating area*

Associated facilities

Freshwater removal from the Danube: *cold-water channel, water intake structure*
Drainage of warmed-up coolant: *area enclosed by the cold and warm-water channels ("island") for the recovery hydroelectric plant*

Unit lines and transmission lines:

Route of the 400 kV unit line and 120 kV transmission line to the new substation

6.14.2 PLANNED STAGES IN THE IMPLEMENTATION OF PAKS II

The process of implementing the new nuclear power plant units consists of the following main steps, which can be started in possession of the required and effective implementation and construction permits:

❖ Activities preceding construction

(preparation of the area, deployment, creation of other conditions related to the construction)

- Preparation of the temporary construction area, landscaping
- Demolition of the buildings, structures and pavings at the construction site
- Replacement / dismantling of the line facilities on the construction site
- Removal / transfer of plants from the construction site
- Removal / selective disposal of the topsoil
- Infrastructure building
- Building offices and sanitary units for the constructors

❖ Building and installation activities

- Excavation of the construction pit
- Building the cutoff wall and / or the sheet-pile wall
- Foundation work
- Dewatering the construction pit to the degree that piling and foundation works can be performed above the groundwater
- Building the reactor complex (nuclear island) and the connected turbine building
- Construction of separate buildings not containing technological equipment
- Construction of the water intake structure
- Building the associated facilities
- Extension of the cold- and warm-water channels
- Building a new warm-water channel branch
- Building an energy recovery hydroelectric plant
- Building cooling cells
- Building unit power lines
- Transmission line construction
- Technological fitting and installation
- Landscaping and earthworks at the premises of the power plant

- Processes preceding operation
    - Commissioning
    - Test runs
        - Individual tests of equipment (safety and non-safety)
        - (Complex) test runs of technological (safety and non-safety) systems
    - Insertion of the first charge / tests
    - Unit test runs
    - Grid connection
    - Test run
    - Warranty measurements

The associated facilities subject to separate licensing (the new electrical substation, the spent fuel interim storage) will be implemented in adjustment to the time schedule of unit implementation.

6.14.3 DRAFT TIME SCHEDULE FOR THE IMPLEMENTATION OF PAKS II

The expected dates during the implementation period are given in Table 6.14.3-1, presuming an undisturbed licensing and that 5 years pass between the implementation of the two units:

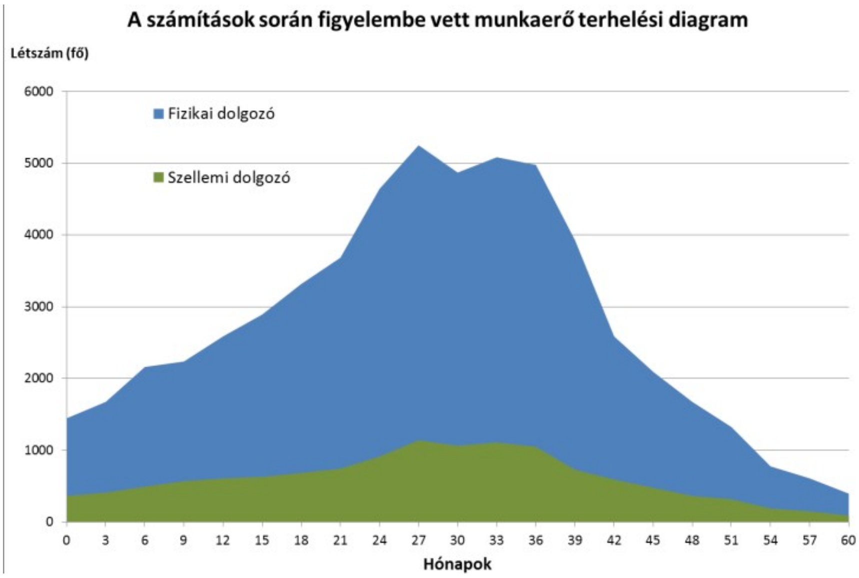
Activity	Paks II	
	Unit 1	Unit 2
Start of environmental licensing	2014	
Demolition on the implementation site	2017-2022	
Preparation of construction and implementation plans for licensing	2018-2019	
Landscaping, earth moving	2018-2019	
Obtaining the permits and licenses required for the start of implementation	2018-2020	
Start of implementation	2020	2025
Foundation work	2020-2021	2025-2026
Building and fitting structures	2022-2023	2027-2028
Tests and commissioning	2024	2029
Insertion of the first charge	2024	2029
First grid connection	2024	2029
Test run start date	2025	2030
Start of commercial operation	2025	2030

Table 6.14.3-1: Installation time schedule of the Paks II units

6.14.4 HUMAN RESOURCE REQUIREMENTS DURING THE IMPLEMENTATION PERIOD

The headcount estimates applicable to the implementation period and the staffing time schedule related to the construction period are based on the relevant previous analyses, which assumed up to 1700 to 7000 persons in the peak period. The time required for the implementation of a unit is about 5 years, so the starting date of the implementation of the second unit was set 5 years after the first unit. In our calculations we assumed (based on reports from the supplier of the technology) that 5250 persons will be needed for the implementation of one unit.

In respect of the time schedule of employment, we relied on the distribution given by PÖYRY ERŐTERV, which resulted in the workload diagram shown in Figure 6.14.4-1.



Létszám (fő) – Headcount (persons)
Fizikai dolgozó – Blue collar
Szellemi dolgozó – White collar
Hónapok – Months

Figure 6.14.4-1: Site staff workload diagram considered for calculations [6-10], [6-18], [6-19]

6.15 CHARACTERISTIC FEATURES OF THE OPERATION OF PAKS II

6.15.1 DRAFT TIME SCHEDULE FOR THE OPERATION OF PAKS II

Unit 1 of Paks II will start commercial operation in 2025 and Unit 2 will start commercial operation in 2030.

The scheduled life of the planned nuclear power plant units is 60 years.

Based on current practice, the 60-year operating time may be extended, provided that the relevant conditions are met. In the case of the new units, the planned 60-year operating time may thus be extended to even 100 years.

The current established practice of nuclear energy generation includes at least one replacement of the sub-systems and technological components required for heat generation and electric power generation over the operating period. This does not apply to the reactor vessel. The operational and service buildings and equipment, the reactors and connected safety systems of the new nuclear power plant units analysed in this EIAS are assumed to remain in service during the full planned 60-year operating period.

Presumably, an extension procedure will be conducted for the operating time of units 1 and 2 of Paks II, however in this study the related impacts are not discussed.

Activity	Paks II	
	Unit 1	Unit 2
Start of commercial operation	2025	2030
End of the 60-year life	2085	2090

Table 6.15.1-1: Operating time schedule of the Paks II units

Operating periods

Activity	Time interval
Simultaneous operation of units 1 to 4 of the Paks Nuclear Power Plant and unit 1 of Paks II	2025-2030
Simultaneous operation of units 1 to 4 of the Paks Nuclear Power Plant and units 1 to 2 of Paks II	2030-2032
Final shutdown of units 1 to 4 of the Paks Nuclear Power Plant when the extended operating time of units 1 to 4 ends	2032-2037
Simultaneous, separate operation of units 1 to 2 of Paks II after the shutdown of units 1 to 4 of the Paks Nuclear Power Plant	2037-2085
End of the operating time of unit 1 of Paks II	2085
Following the shutdown of unit 1 of Paks II Stand-alone operation of unit 2 of Paks II	2085-2090
End of the operating time of unit 2 of Paks II	2090

Table 6.15.1-2: Operating periods of the Paks II units and their joint operation with the existing units of the Paks Nuclear Power Plant

6.15.2 HUMAN RESOURCES REQUIRED FOR THE OPERATION OF THE NEW NUCLEAR POWER PLANT UNITS

Based on the analysis of ERBE, if one unit is in operation, 600 people may be employed as permanent staff, including 400 employees working in core time and 200 employees working in shifts. Of the 200 shift workers, assuming 5 shifts and a 3-shift daily work schedule, 120 employees/day are required in addition to the core time employees. So we can reckon with 520 employees being on site every day.

Following the commissioning of unit 2, 800 employees will be required for the operation of the two units, of whom 300 employees will be working in shifts and 500 employees will be working in core time during the day. Of the 300 shift workers, assuming 5 shifts and a 3-shift daily work schedule, 180 employees/day are required in addition to the core time employees. So we can reckon with 680 employees being on site every day.

The operator headcount does not include those who perform maintenance duties because considering the current practice a significant part of these tasks will be outsourced.

Based on the data provided by the nuclear power plant supplier, the additional headcount demand for the major repair of each unit expected to be carried out every ten years is approximately 1000, which includes 200 core time employees during the day and 800 shift workers. Assuming 5 shifts and a 3-shift daily work schedule, 480 employees/day are required in addition to the core time employees. So during the maintenance period we can reckon with 680 employees being on site daily in addition to the operator headcount. [6-10], [6-18], [6-19]

6.15.3 OPERATIONAL PROPERTIES OF THE NEW NUCLEAR POWER PLANT UNITS

6.15.3.1 Controllability, availability and maintenance

The electrical output of the new nuclear power plant units will be controllable between 50 and 100%, and it will be able to operate both in load-follow and island modes. The load change speed of the units is 5% (60 MW) / minute in both the up and down direction. The expected annual availability of the new nuclear power plant units will be >90 %, including also the annual minor repairs and the transfer time of spent fuels. Overhauls are expected to be performed every 10 years, each requiring about 1 month. The expected time requirement of annual maintenance is 20 calendar days (fuel transfer and minor repairs), while the expected time of major stoppages is 30 calendar days (overhaul of secondary and primary circuits).

6.15.3.2 Annual power engineering data of the new nuclear power plant units

Description	Unit of measure	Value/unit
Peak capacity usage hours	h/year	8,147
Installed electrical output (gross)	MW	1200
Self-consumption	MW	87
Electric power generated per unit	GWh p.a.	9,776
Electricity delivered per unit	GWh p.a.	9,068

Table 6.15.3-1: Annual power data

6.15.4 ANNUAL MATERIALS AND ENERGY BALANCE OF THE NEW NUCLEAR POWER PLANT UNITS

The annual materials and energy balance was determined by taking into account the annual operating time (8147 hours) relative to the technical availability and full load for 2 x 1200 MW_e units. Depending on the main equipment selected, the values in the table may be subject to change.

Description	Unit of measure	Value
Annual gross electric power generation	GWh p.a.	19,552
Self-consumption of electricity	GWh p.a.	1,418
Annual net electric power generation	GWh p.a.	18,136
Fuel requirement	t/18 months	64.6
Fuels required (fuel + cassette)	t/18 months	96
Strategic fuel charge	t	225.6
Oil consumption		
Bulk oil in steam turbines	m^3	about 240
Bulk oil in transformers	t	about 804
Oil for main transformers	t	about 540
Oil for normal internal use transformers	t	about 132
Oil for reserve internal use transformers	t	about 66
Lubricant and hydraulic oils	t/year	20
Diesel generators	m^3/168 hours	2,600
Generator hydrogen cooling	m^3	8
Lubricant grease	kg/year	about 280
Water requirement		
Technological water requirement		
Condenser cooling water (including technological cooling water)	million m^3/year	about 3900
Desalinated water	thousand m^3	640
Communal water requirement	m^3 per year	25,276
during maximum requirement (first unit is operative, second units is being built)	m^3 per year	235,790
Consumption of chemicals		
Hydrochloric acid (33% HCl)	m^3/year	640
Sodium hydroxide (100% NaOH)	m^3/year	480
Ammonium hydroxide	m^3	15
Hydrazine	t	32
Nitric acid	m^3	51
Sulphuric acid	m^3	80
Boric acid	t	62
Other chemicals of the water pre-treatment plant (chlorine removal chemical, antifouling agent)	t/year	25
Technological waste water		
Waste water from the water pre-treatment plant	thousand m^3per year	200
Primary circuit technological waste water beyond balance	thousand m^3 per year	88
Turbine building and auxiliary facilities, liquid waste water	thousand m^3 per year	350
Communal waste water	m^3 per year	24,012
during maximum generation (first unit is operative, second units is being built)	m^3 per year	224,110
Wastes		
Radioactive wastes		
Low-activity radioactive waste	m^3 per year	140
Medium-activity radioactive waste	m^3 per year	22
High-activity radioactive waste	m^3 per year	1.0
Large-size, radioactive waste which can not be handled (generated in the course of maintenance/improvement)	m^3 per year	10
Conventional, non-radioactive wastes		
Non-hazardous waste	t/year	800
Hazardous waste	t/year	100

Table 6.15.4-1: Materials and energy balance for the operation of Paks II

6.16 DECOMMISSIONING THE NEW NUCLEAR POWER PLANT UNITS

6.16.1 INFORMATION ON THE DISMANTLING AND DECOMMISSIONING OF THE PAKS NUCLEAR POWER PLANT

At the end of the operating life of the Paks Nuclear Power Plant, before the commencement of its decommissioning and dismantling, it is required to conduct an environmental impact analysis procedure according to Government Decree 314/2005 (XII.25.) on the procedural rules of performing environmental impact analyses and issuing integrated permits for use of the environment, and in compliance with the provisions set out in section 6.5 of environmental permit registration no. K6K8324/06 for the extension of the operating time of MVM Paksi Atomerőmű Zrt. (DdkTVF, Pécs). This procedure is to be performed in the future taking into account the actual status and the then current legislative environment. [6-20]

After the expiry of its planned 30-year operating life, Unit 1 of the Paks Nuclear Power Plant was granted a permit for an extension of 20 years. Authorisation for the extension of the operating life of Units 2 to 4 is pending. The operating period of the nuclear power plant units is summarized in the following table.

MVM Paks Atomerőmű Zrt.	Date of commissioning	End of the 30-year operating life (start date of the extension of operating life)	End of the 50-year operating life
unit 1	1982	2012	2032
unit 2	1984	2014*	2034
unit 3	1986	2016	2036
unit 4	1987	2017	2037

Note:
* Extension of the operating life is pending.

Table 6.16.1-1: Operating life of units 1 to 4 of the Paks Nuclear Power Plant [6-21]

Possible options for the dismantling of Units 1-4, the lifetime of which was increased by the extension of their operating time:

- *Immediate dismantling*
- ***Delayed dismantling with protected preservation of the reactor***
- *Delayed dismantling with protected preservation of the entire primary circuit*

The chosen dismantling strategy is the “delayed dismantling with protected preservation of the entire primary circuit for 20 years”. [6-20]

The process of dismantling can be characterized by the following activities:

I. dismantling phase:

- processing the operational radioactive waste and transportation it to storage;
- delivery of spent fuels to the SFIS;
- removal of operating media;
- dismantling unnecessary inactive and reusable equipment;
- demolishing unnecessary, inactive buildings;
- conservation of equipment to be used later (ventilation, special duct system, etc.);
- maintaining and monitoring barriers preventing emission;
- supervision of locked buildings and facilities,

II. dismantling phase:

- the parts of the power plant containing radioactive materials and equipment remain closed;
- maintenance of barriers preventing emission during long-term protected preservation.

III. dismantling phase:

- decontamination;
- gradual dismantling of the equipment, including the reactor, and the remaining support systems,
- demolition of vacant buildings;
- processing the radioactive waste produced during decontamination and dismantling;
- processing inactive waste;
- final checking, cleaning of the site and landscaping;
- preparing the Final Dismantling Report;
- termination of authority supervision;
- handing over the site for further use.

6.16.2 DECOMMISSIONING STRATEGY TO BE FOLLOWED DURING THE DISMANTLING OF THE NEW NUCLEAR POWER PLANT UNITS

In this EIAS the immediate dismantling option is considered for the decommissioning of Paks II taking into account the international trends and the following considerations:

- current legal regulations guarantee that the resources needed for dismantling will be available at the end of the operating period
- final placement can be ensured for the radioactive waste produced during dismantling within the available time span
- there is no reason to worry that the knowledge required for dismantling will be lost.

The process of dismantling a nuclear power plant is long and complex. The works can be divided into the following parts:

Preparations for future dismantling. These include preparation of the Preliminary Dismantling Plan (PDP), development of a dismantling strategy (at site and facility level), regular review of the PDP (including authority activities), creation of a dismantling database, its continuous maintenance (including the conduct of radiation protection surveys, continuous tracking of hazardous materials and the design and implementation plans of the power plant) and continuous processing of operational waste.

Conduct of the future dismantling environmental impact assessment and carrying out the licensing procedure.

Direct administrative and technical preparations for the actual dismantling activity, including preparation of the safety report of dismantling, setting up a management organisation for dismantling, planning the headcount reduction, preparing the documentation providing the basis for obtaining a permit for the final shutdown, and for the related authority proceedings. The scope of technical preparations covers activities of expressly technical nature which take place during the (transitional) period of a few years preceding the shutdown of the reactor unit.

Preparations for the actual dismantling activities starting with the shutdown of the unit. These cover the finalisation of the dismantling plan, including the conduct of the survey of radiation protection and the related authority proceedings which provides grounds for a possible transfer of the beneficiary title of the permit. This is followed, within the scope of actual dismantling activities, by works having radiation protection implications and traditional environmental impact. This includes such operations and activities as decontamination, dismantling and removal of radioactive materials, waste, and components, dismantling of building structures, and the management of produced inactive and radioactive waste. The performance of such works makes it possible to terminate the authority supervision of the facilities or detached buildings and demolish, by traditional construction industrial tools, the decontaminated facilities or buildings. The last steps of actual dismantling activities include the final radiation protection inspection of the site, the preparation of the Final Dismantling Report and the termination of the authority supervision of the site.

The scope of the actual dismantling tasks, their planning and detailed elaboration are always specific of the site or facility and significantly depend on the strategy chosen for the dismantling of the facility.

The following key factors need to be considered for examining possible alternatives for the dismantling strategy of a nuclear facility, for selecting a single strategy, and for fleshing it out:

- special features of national projects related to radioactive waste management (waste streams, storages, timing),
- the national dismantling policy,
- special features of the facility to be dismantled,
- safety and health regulations,
- compliance with environmental requirements,
- requirements for the continued use of the site,
- political, economic and social impacts as well as acceptance by the population,
- the requirement of the availability of technology, feasibility of dismantling,
- the costs of the dismantling procedure and the available resources,
- the risks of the dismantling process.

The above factors should be analysed and considered in relation to each other, should be weighted and balance off against each other.

The dismantling strategy finally used after the shutdown of the units will be determined later, based on detailed analyses with a far broader horizon. The shutdown strategy will have to be optimized within the framework of the development of the national program in compliance with Directive 2011/70/Euratom of the European Council. [6-22]

The licensing of decommissioning and dismantling - at least in 60 years but no later than in about 2180 - will have to be carried out for the actual status, taking into account the legislative environment at the time.

We assume that the future waste storage facilities will have been completed with the adequate extension of the National Radioactive Waste Storage (NRHT/NRWS) as stated in the document entitled *The eleventh medium- and long-term plan of Radioaktív Hulladékokat Kezelő Közhasznú Nonprofit Kft. for the activities to be financed from the Central Nuclear Financial Fund*:

"...the design, scale and time schedule of the implementation and operation of the facility must be aligned with the requirements of the Paks Nuclear Power Plant and also extension options should be considered during the design." High-level and/or long-lived radioactive waste can be stored provisionally in the technological systems of the new units until the start of the dismantling works. If a provisional storage facility of spent fuel is built for the new units, it will remain operable for the full operating time of the new units plus the resting time requirement that may arise while the units are dismantled. Availability of the necessary funds to finance the dismantling process is prescribed and safeguarded by law in Hungary (Article 62 (1) of Act CXVI of 1996 on Nuclear Energy). [6-23]

6.16.3 FINANCING THE DISMANTLING ACTIVITIES, COSTS

According to Article 62 (1) of Act CXVI of 1996 on Nuclear Energy the costs of dismantling nuclear facilities are to be disbursed from a separate state fund, the Central Nuclear Financial Fund (KNPA/CNFF).

The body managing the Central Nuclear Financial Fund is the ministry directed by the appointed minister.

In the course of the implementation of the new units preparations should be made for the transformation of the CNFF, which would allow among others the financing of the dismantling of the new units.

The costs of dismantling can only be estimated according to the present level of knowledge. Supplier forecasts suggest that the dismantling of the new units will presumably be simpler and produce less waste than current reactors. [6-23]

6.17 REFERENCES

[6-1] Sándor Nagy, Nuclear capacity maintenance, licensing duties, Budapest, 04/23/2014

[6-2] http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Russia--Nuclear-Power

[6-3] VVER-1200 unit plan (02-01-01; Fig. 1.1 - Principle process diagram of the power unit)

[6-4] MVM Magyar Villamos Művek Zrt. Implementation of new nuclear power plant units, Preliminary consultation documentation, PÖYRY ERŐTERV, 10/05/2010

[6-5] MIR.1200 Preliminary data and information for safety and environmental licensing, Report, 2010. А.Н.Обысова

[6-6] MVM Paks II. Zrt.

[6-7] Analysis of various alternatives for condenser cooling water extraction and return in relation to the new nuclear power plant units, MVM ERBE Zrt. 2014

[6-8] Units 1 to 4 of the Paks Nuclear Power Plant, Final Safety Report, 2013, Chapter 2, Description of the Site, Paksi Atomerőmű Zrt. 2013 (Design base Danube water levels)

[6-9] Preliminary water rights licensing documentation for the use of Danube waters for the new NPP units of Paks, MVM ERBE Zrt.

[6-10] Decision support analysis of the various aspects of drinking water supply to the new NPP units of Paks, and of sewage handling, MVM ERBE Zrt. 2013

[6-11] Elpanneteknik references, Finland's Olkiluoto 3 Nuclear plant

[6-12] Analysis of the Items Outside ERBE's Main Contracting Scope, 2013.

[6-13] Lévai Project, Implementation of the new nuclear power plant, Feasibility Study for Decision-Making, PÖYRY ERŐTERV Zrt.

[6-14] Seismic zone map MSz EN 1998-1 (EUROCODE 8), National Annex

[6-15] Elaboration and execution of the survey and evaluation programs that provide the basis of the environmental impact assessment analysis, MVM ERBE Zrt. 2012.

[6-16] MIR-1200 Preliminary data and information for safety and environmental licensing, report, 2010. 09. 29., А.Н.Обысова

[6-17] Data for NPP environmental impact analysis (AES-2006 with VVER-1200), Rusatom Overseas JSC, 2014.09.23.

[6-18] Analysis for the definition of the staffing requirements of the new nuclear power plant units, MVM ERBE Zrt. 2013

[6-19] MVM Zrt. Implementation of new nuclear power plant units, Assessment of building, commissioning and operating staff requirements, Vol. 1/2, PÖYRY ERŐTERV Zrt. January, 2012

[6-20] Extension of the operating time of the Paks Nuclear Power Plant, Environmental Impact Assessment Study, ETV-ERŐTERV Rt., 20/02/2006

[6-21] Environmental licence No. K6K8324/06 for the extension of the operating life of the MVM Paksi Atomerőmű Zrt., 10/25/2006 South-Transdanubian Environmental, Nature Conservation and Water Management Supervisory Authority, (Dél-dunántúli Környezetvédelmi, Természetvédelmi és Vízügyi Felügyelőség, DdKTVF, Pécs)

[6-22] Directives; Directive 2011/70/Euratom of the Council, EU, 19/07/2011

[6-23] Eleventh medium and long-term plan of the Radioaktív Hulladékokat Kezelő Közhasznú Nonprofit Kft. for the activities to be financed from the Central Nuclear Financial Fund, RFK Kft., August 2011

7 CONNECTION TO THE HUNGARIAN POWER GRID [7-1], [7-2]

This section presents the power engineering tasks and network development needs identified by current assessments and necessary for the implementation of the Paks II Power Plant. Their joint environmental impact is insignificant compared to the entire environmental impact of the power plant to be established. Note that subject to later studies and decisions, the location and building of the station, the route of the transmission lines and the placement of the towers may change.

7.1 COMPATIBILITY OF THE NEW UNITS WITH THE HUNGARIAN POWER SYSTEM

The currently operating units of the Paks Nuclear Power Plant will be connected to the Hungarian power system through the 400 kV switching equipment of the 400 / 120 kV substation owned by MAVIR Zrt as Transmission System Operator.

The preliminary study of the required electrical network developments on which decisions can be based was prepared for decision-making by PÖYRY ERŐTERV Zrt under MVM identifier No. “530303A 00031 ERA final” as part of the Lévai Project in connection with the preparations for the implementation of the Paks II Nuclear Power plant. The feasibility study prepared for decision-making examined the station sites and the required changes of the transmission lines in several versions. The present documentation is based on previous studies taking into account new criteria arising in the meantime that affect the site of the nuclear power plant.

Preliminary network calculations have been performed to see what conditions are required for the transmission of the generated amount of power with units of net 1200 MW capacity under regular operating conditions and in case of a system disturbance. The new power plant units can be integrated into the power grid only by the implementation of new network connections.

The results of the study confirmed the need for the following developments:

- The connection of the new units to the power grid requires the implementation of a new 400 / 120 kV substation (Paks II substation).
- The findings of the studies on double outage states and the reserve supply for the new Nuclear Power Plant require the installation of a third 400 / 120 kV transformer in the region.
- The installation of a Paks-Albertirsa dual-system transmission line is a basic and indispensible condition for the expansion.

In order to ensure the required stability of the power grid, the unplanned loss of the grid’s largest unit capacity generator should be replaceable in a short time. In Hungary it is the responsibility of MAVIR Zrt as the system operator. The unit capacity of the new power plant units will likely be around 1200 MW, making them the largest in the Hungarian power system. Before the first unit of the Paks II Nuclear Power plant is commissioned, a tertiary reserve capacity equivalent to that of the new unit should be ensured. This need will have to be met by sourcing power through the import power transmission route and/or by creating a new tertiary reserve capacity in a fast start-up domestic power plant.

The studies showed that by implementing the above developments and expansions, the power generated by the new units can be safely connected to and used in the Hungarian power grid. [7-1]

7.2 INSTALLATION SITE OF THE NEW 400 / 120 KV PAKS II SUBSTATION

By taking into account the installation criteria of typical MAVIR stations, the special goals and requirements for the MAVIR transmission network station, and the special criteria of the Paks II Nuclear Power plant for connection to the grid, several possible locations have been identified for the Paks II substation. The substation site optimal from the points of view of feasibility and safety is located along the transmission line routes going north-west in the area between the roads going from Paks to Nagydorog and Kölesd, where the Kölesd road crosses the 400 kV power line, 6 km from the planned site of the new units, near the 2 km section of road 6233, on the north side of the road, next to the existing transmission line corridor.

Based on received data, we considered this site as the starting point for our investigation, but it should be noted that the designation of the final location for the Paks II substation is the competence of MAVIR Zrt as the future owner of the substation, and to our knowledge the final decision has not yet been made.

In accordance with current practice in Hungary, the Paks II substation will be a typical MAVIR 400 / 120 station with a one-and-a-half breaker arrangement and air insulated switches. In its final stage, up to 4 normal and 2 double width 400 kV field lines will have to be installed, in addition to a longitudinal bus sectionalizer.

The Paks II substation and the related transmission lines (except for the unit lines) will be owned by the Transmission System Operator (MAVIR Zrt) and will be part of the public grid. In addition to selecting the location of the substation, the connection point must also be identified by the Transmission System Operator. On the basis of preliminary network investigations, the grid connections of the new substation must be created along the following criteria:

- One system of the new 400 kV Paks-Albertirsa transmission line must be connected to the new substation along the route bypassing the power plant from the east, while the other system must be connected to the existing substation. A 120 kV interconnect line should be installed to connect the two substations through the remaining dual-system aerial line between the two substations.
- 400 kV unit lines should be installed from the new units to the new substation along a route on independent aerial lines.
- The currently operating 400 kV transmission lines leading to Martonvásár should be cut near the new substation site and connected to the new substation.
- With this connection a second interconnect will be created between the two Paks stations.
- The currently operating 400 kV transmission lines leading to Litér and Toponár should be routed through the new substation near the new substation site.
- This, and the previous line cut makes the remaining section of the transmission lines to Litér and Toponár an out-of-operation reserve.
- If the above mentioned studies justify the installation of additional transmission line connections, the new transmission lines should be connected to the new substation.
- Due to the installation of the new units and the implementation of the Paks II substation, the remaining 120 kV substation transmission lines should also be upgraded.

For the start-up of the new units and to provide a fall-back (reserve, internal use) power supply for them, a 120 kV incoming feed for each unit should be installed between the existing substation and the new units or between the new substation and the new units. If a new substation is built on the planned site, the network connection should be installed by combining the transmission line and the cable section in such a way that an overhead transmission line is installed outside the power plant and an underground cable line is installed within the power plant. The required capacity will presumably be around 90 MVA per unit, which will be received by one or two 120 kV/medium voltage transformers per unit with a capacity of at least 90 MVA each.

7.3 THE 400 KV UNIT LINE AND THE 120 KV TRANSMISSION LINE

In Hungary all 400 kV transmission lines are overhead lines.

7.3.1 DESIGN CRITERIA OF THE LINE ROUTES

In addition to the general technical and economic criteria for the installation of high-voltage power lines, the following should also be considered during the planning of the power line routes.

Technical criteria

- install the power lines on a separate tower line, at a safe distance, without crossing each other;
- minimize interference of the route of the unit lines and the transmission lines with on-site construction work at the power plant, shipment from the quay and use of the deployment area;
- cross the M6 motorway perpendicularly;
- match existing and planned facilities.

- The possibility to build the Paks II – Albertirsa transmission line in the area between the Paks Nuclear Power Plant and the River Danube should remain an option.

Criteria regarding to protection of the built environment and nature conservation

- keep away from inhabited areas;
- keep away from areas under nature protection;
- minimize environmental impact;
- keep away from protected natural sites;
- avoid existing facilities;
- avoid temporary and final facilities of future developments.

Based on the specifics of the development area and on technical, economic and environmental criteria, the power lines directly linked to the power plant can be installed as follows:

- the 400 kV unit lines will be overhead type;
- the 120 kV line providing fall-back power will be an underground cable within the site of the power plant and an overhead power line outside it.

7.3.2 400 KV UNIT LINES

The power generated in the units of the Paks II Nuclear Power plant will be transmitted through 400 kV unit lines (generator lines) to the future Paks II substation, which will connect the new power plant units to Hungary's national power grid.

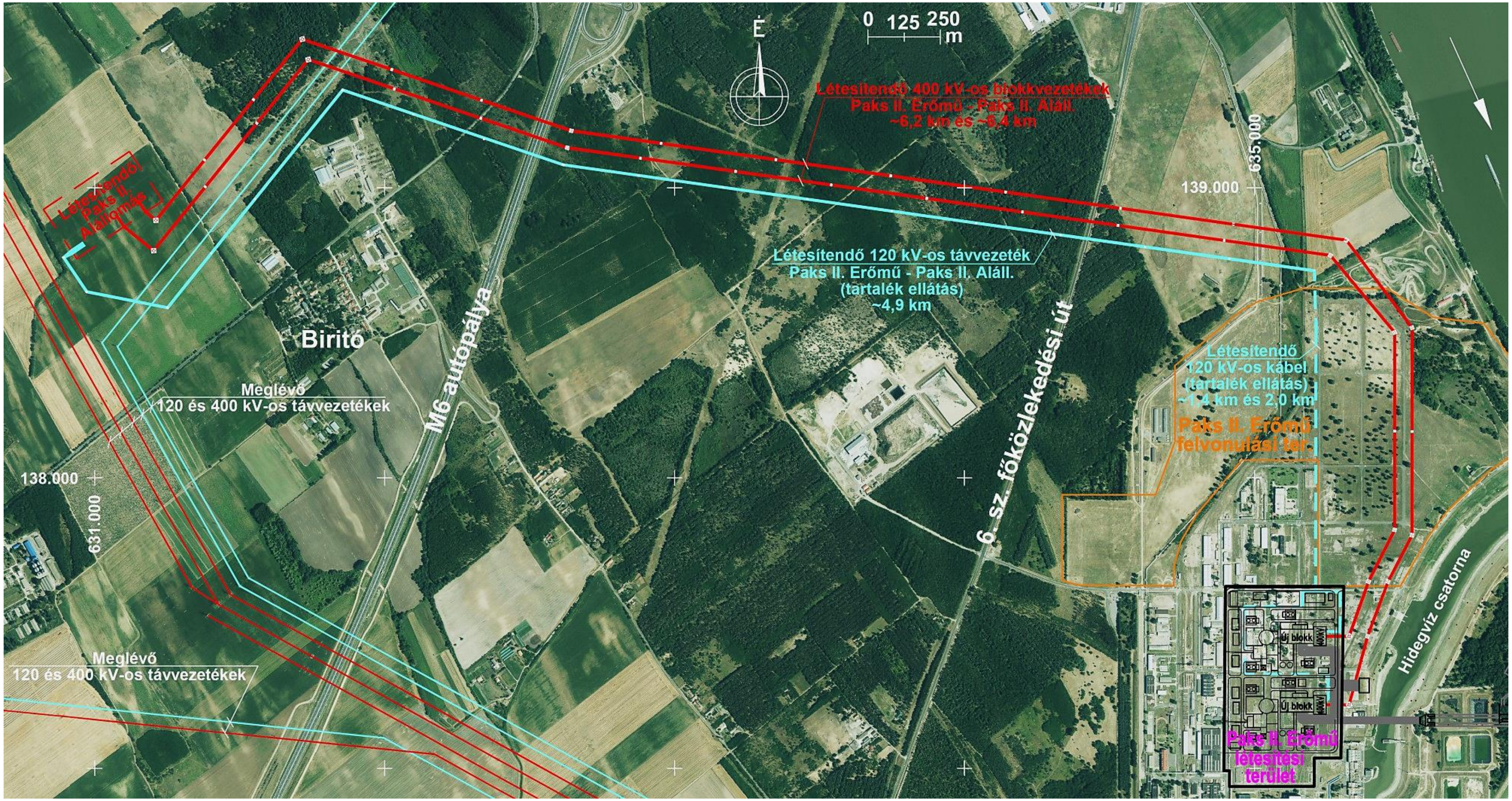
The unit lines will be installed between the unit transformer and the receiving station. The starting point of the unit lines will be the line exit portal structure of the "Transformer Space" 400 kV stations to be installed on the operating premises of the units, and their terminal point will be the supporting structure of the entry field portal to be installed at the Paks II substation.

The route of the unit line is shown in Figure 7.3.2-1 and its legend in Figure 7.3.2-2

The outgoing unit lines starting out from the power plant transformer space will be going east, turning north after the first tower along the road by the River Danube, running in parallel with the road. The two unit lines will be going in parallel for about 1.5 km, touching the deployment area, and then will turn west towards the Paks II substation, going around the power plant site. Still running in parallel, the unit lines will connect to the Paks II substation from north-east, keeping away from inhabited and built-in areas. The unit lines will cross railway tracks, the main road No. 6, the M6 motorway and road No. 6233.

The unit line that belongs to the unit to be built in the first phase will bypass the deployment area, ensuring that this area can be used without any limitation during this period. The unit line that belongs to the unit to be built in the second phase will slightly touch the eastern section of the deployment area.

The power generated in the two new nuclear power plant units will be transmitted to the Paks II substation by a transmission line installed on separate lines of towers for each unit. The use of separate overhead lines along this relatively short route increases operational safety.



Létesítendő 400 kV-os blokktávvezetékek – 400 kV unit lines to be built
Létesítendő 120 kV-os távvezeték – 120 kV transmission line to be built
Paks II Atomerőmű – Paks II Nuclear Power Plant
Paks II alállomás – Paks II substation
M6 autópálya – Motorway Main Road No. 6
Létesítendő 120 kV-os kábel (tartalék ellátás) – 120 kV cable (reserve supply) to be built
Paks II Atomerőmű felvonulási tér – Paks II Nuclear Power Plant temporary construction area
Meglévő 120 és 400 kV-os távvezetékek – Existing 120 and 400 kV transmission lines
Hidegvíz csatorna – Cold-water channel
Paks II Erőmű létesítési terület – Construction area of Paks II Power Plant

Figure 7.3.2-1: Route of the unit lines between the Paks II Nuclear Power plant and the Paks II substation (Site 2).

Jelmagyarázat – Legend
Létesítendő 400 kV-os blokkvezeték nyomvonala – Route of the 400 kV unit line to be built
Létesítendő 120 kV-os vezeték (tartalék ellátás) nyomvonala – Route of the 120 kV unit line (reserve supply) to be built
Létesítendő 120 kV-os kábel (tartalék ellátás) nyomvonala – Route of the 120 kV unit cable (reserve supply) to be built
Meglévő 400 kV-os távvezeték nyomvonala – Route of the existing 400 kV transmission line
Meglévő 120 kV-os távvezeték nyomvonala – Route of the existing 120 kV transmission line
Paks II Erőmű létesítési terület határa – Boundary of the Paks II construction area
Paks II erőmű felvonulási terület határa – Boundary of the Paks II temporary construction area
Paks II Alállomás határa – Boundary of the Paks II substation

Figure 7.3.2-2: Legend for the route drawing of the unit line on drawing No. V-01195 ERBE

Route lengths

Paks II. 400 kV unit lines between the Paks II Power Plant and the Paks II substation: about 6.4 km and 6.2 km

Salient specifications of the unit lines

Tower type:	*PINE*
Phase conductor:	*2×500 / 65 ACSR per unit*
Number of systems:	*two, connected in parallel (for each unit)*
Number of towers:	*supporting towers: 12 and 11, total of 23* *(line, corner, terminal) strain towers: 8 and 9, total of 17*
Footprint of the towers:	*supporting towers: 40 m^2 / piece* *strain towers: 142-229 m^2 / piece (depending on their function)*
Material of the towers:	*steel with duplex surface protection*
Material of the foundation:	*reinforced concrete*
Material of the insulators:	*glass or composite (plastic)*
Width of the safety zone:	*34.4 m in each direction from the axis of the route, for a total width of 68.8 m (for each unit line)*

In case of two parallel unit lines, the total width of the safety zone is 128.8 m.

Subject to later studies and decision, the technical solution for the unit lines and their tower type may change with a view to provide increased safety. [7-1]

Landscape appearance

The transmission line concerned will be going along a nearly flat area. The route will mainly cut across agricultural land and woods outside the power plant site. We wish to use, as appropriate and as circumstances permit, all the methods that worked well for previous overhead transmission lines to facilitate compatibility of the new transmission lines with the environment and reduce any disturbance caused to the environment (e.g. parallel routes; painting the towers green; installing bird nests on the towers and devices that enhance the visibility of the lines for birds).

The type of towers planned to be used for the transmission lines connecting to Paks II has been used in the past in Hungary for a network; some examples are shown in the following photos.

Figure 7.3.2-3: The Martonvásár-Győr 400 kV overhead transmission line with PINE towers

Figure 7.3.2-4: The Pécs-National Border 400 kV overhead transmission line with PINE towers, line corridor

Impacts of the operation of the transmission line

Electrical and magnetic field strengths

An electromagnetic field is generated near high-voltage transmission lines. The limits of electrical filed intensity and magnetic induction to be considered for physiological effects have been specified by the International Radiation Protection Association (IRPA) working under the UN World Health Organisation. The Hungarian requirements (MSZ 151-1-2000/15.6.3.) are in line with the recommendations of the international association adopted worldwide.

Time that can be spent under the transmission line	Electrical field strength E (kV/m)	Magnetic induction B (μT)
a few hours per day	10	1000
unlimited	5	100

Table 7.3.2-1: Permissible values of electrical field strength and magnetic induction

Typical values of electrical field strength and magnetic induction in the vicinity of existing transmission lines:

	Values measured at a height of 1.8 m above ground under 120 to 750 kV lines in Hungary	
	electrical field strength [**kV/m**]	**magnetic induction** [μ**T**]
under the overhead power lines	2-17*	10-37
at the edge of the safety zone	0.2-1.1	1-9

* note
A value higher than 10 kV/m is measured under the conductor of a 750 kV transmission line only.

Table 7.3.2-2: Measured values of electrical field and magnetic induction

By selecting the necessary height of the transmission line above the ground when planning installation it can be ensured that the value of electrical and magnetic field strengths measured under the most adverse conditions will be under the limit specified in the WHO recommendation. We wish to repeat here that the route of the transmission line concerned will avoid inhabited areas.

According to previous research findings, the electrical and magnetic field strengths in the vicinity of overhead transmission lines does not have any demonstrable harmful effects on health.

Corona discharge (ionizing effect, radiofrequency effects, radiation loss)

One of the most noticeable phenomena for the environment that occurs on overhead power lines is corona discharge (in short: corona). This can be observed especially in rainy, foggy weather if the inhomogeneous electrical field generated on the surface of the power conductor cable exceeds the value of 30 kV/cm. In this case, the air around the conductor becomes ionized and a discharge occurs, which can be seen in darkness, accompanied by crackling noise.

Corona may have the following direct environmental effects:

- crackling, fizzing noise due to the ionizing effect of high local field strength;
- high-frequency electromagnetic waves are generated, which may disturb radio and TV reception in the vicinity of the power lines;
- a loss occurs in the power line due to the corona.

Ionizing effects

Due to corona, especially on overhead power lines above 400 kV, mainly ozone (O_3) and nitrogen oxide (NO_x) are formed, but the values are below the measurable limit and are insignificant compared to any other source.

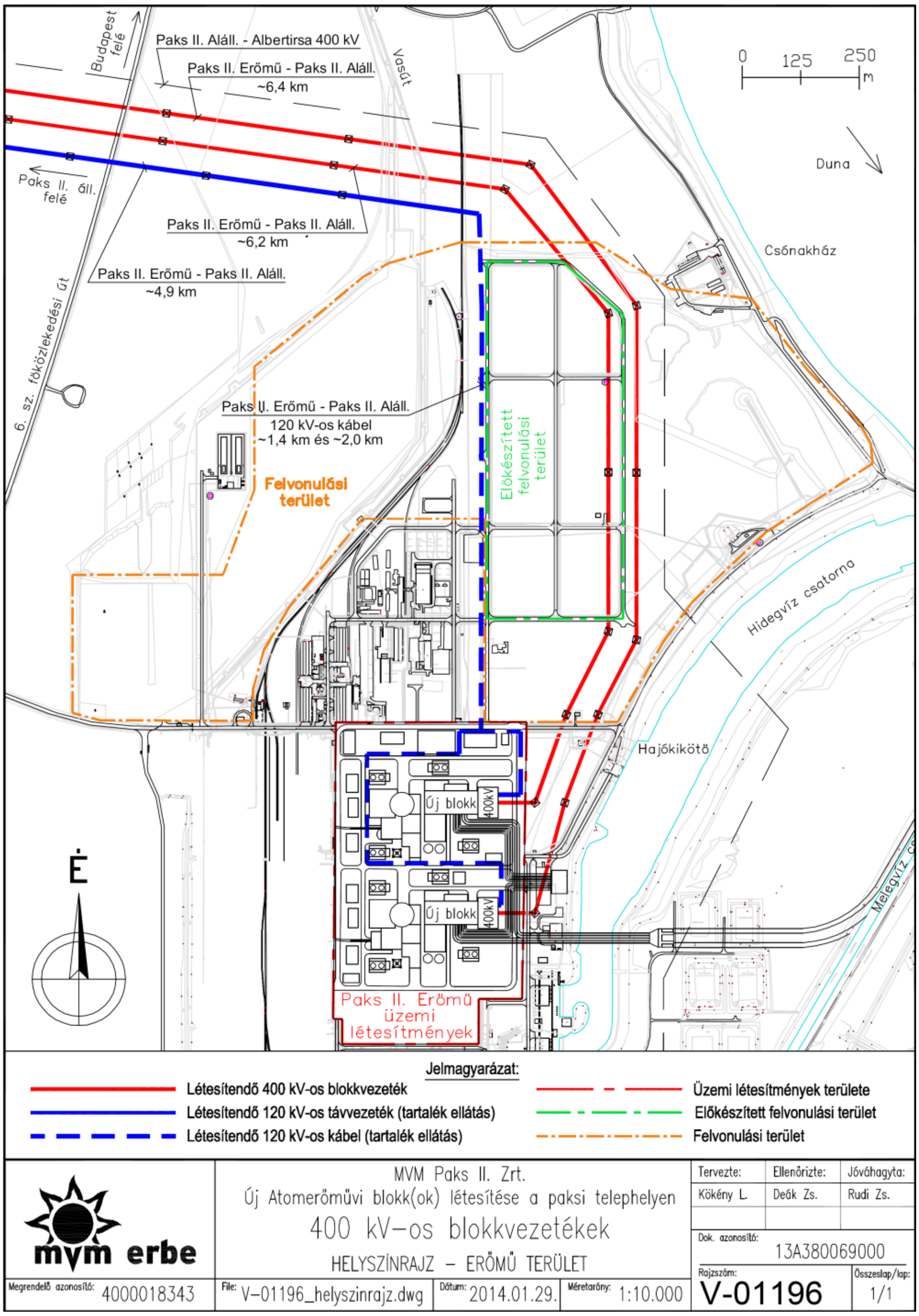
Noise

On the basis of previous measurements, the noise emission in the immediate vicinity of the 400 kV overhead transmission lines is between 30 and 35 dB. The noise emission of the 120 kV fall-back power lines used as reserve supply will be insignificant.

Maintenance

Periodic maintenance will be required on the installed overhead transmission lines, in accordance with their operating instructions. Mainly the existing roads will be used for access for maintenance work, minimizing traffic in the safety zone. The operator will perform maintenance work by choosing the most suitable time and technology causing the least disturbance to the environment.

We have examined several route versions for the 1.5 km section of the route crossing the power plant in order to keep away from the deployment area designated for the construction of the power plant. As a result, we propose the route shown in Figure 7.3.2-5.



Paks II Alállomás határa – Boundary of the Paks II substation
Létesítendő 400 kV-os blokkvezeték – 400 kV unit line to be built
Létesítendő 120 kV-os távvezeték (tartalék ellátás) – 120 kV transmission line to be built (reserve supply)
Létesítendő 120 kV-os kábel (tartalék ellátás) – 120 kV cable to be built (reserve supply)
Üzemi létesítmények területe – Area of operational facilities
Előkészített felvonulási terület – Prepared temporary construction area
Felvonulási terület –Temporary construction area
Duna – Danube
hidegvízcsatorna – cold water channel
hajókikötő – ship port
új blokk – new unit
Paks II Erőmű üzemi létesítmények – plant facilities of Paks II Power Plant
Új Atomerőművi blokk(ok) létesítése a paksi telephelyen – construction of new power plant unit(s) at the Paks site
400 kV-os blokkvezetékek – 400 kV unit lines
helyszínrajz – erőmű terület – site map – power plant area
Tervezte – Designer, Ellenőrizte – Supervisor, Jóváhagyta –Approved by, Dokumentum azonosító – Doc. ID, Megrendelő azonosító – Customer ID, Dátum – Dated, Méretarány – Scale, Rajzszám – Drawing No., Oldalszám – Pages:

Figure 7.3.2-5: Proposed route of the unit line on the site of the power plant

7.3.3 120 kV TRANSMISSION LINE

The task of the 120 kV transmission line will be to supply the Paks II Nuclear Power plant with fall-back power from the future Paks II substation.

The starting point of the transmission line will be the line exit portal of the future Paks II substation's 120 kV section and its terminal point will be the line entry field portal of the 120 kV section to be installed in the operating premises of the power plant units.

The transmission lines will exit the Paks II substation going south-west and then turn south-east after the first tower. When reaching the existing 120 kV transmission line near the station, the new power line will continue to run in parallel with them (and the unit lines) toward the north-east. From here, it will follow the route of the unit lines and enter the site of the Nuclear Power Plant.

The overhead power line will end before the deployment area and from the last tower one 120 kV cable system for each unit will connect to the power plant transformers bypassing the prepared deployment area from the west, ensuring the undisturbed use of the area.

Route lengths

Paks II. The 120 kV transmission line between the Paks II Power Plant and the Paks II substation:

- overhead line section: about 4.9 km
- cable sections: about 1.4 km and about 2.0 km

Key specifications of the overhead section of the 120 kV transmission line

Tower type:	*SZIGETVÁR*
Phase conductor:	*2×3×250 / 40 ACSR*
Number of systems:	*two*
Number of towers:	*supporting towers: 13* *(line, corner, terminal) strain towers: 6*
Footprint of the towers:	*supporting towers: 14 m^2 / piece* *strain towers: 23 m^2 / piece*
Material of the towers:	*steel with duplex surface protection*
Material of the foundation:	*reinforced concrete*
Material of the insulators:	*glass or composite (plastic)*
Width of the safety zone:	*15.6 m in each direction from the axis of the route, for a total width of 31.2 m*

Subject to later studies and decision, it may be necessary to install the 120 kV fall-back power lines on separate tower lines for each unit in order to increase the safety of the units. In addition, the type and the number of the towers may also change.

Source: Lévai Project, Implementation of the new nuclear power plant, Feasibility Study for Decision Support, PÖYRY ERŐTERV Zrt. [7-1]

7.3.4 COMMON SAFETY ZONE

If the two 400 kV unit lines and the 120 kV transmission line providing fall-back power run parallel, the total width of the safety zone will increase to 170 m.

7.3.5 CONSTRUCTION OF THE TRANSMISSION LINE

The main phases of construction are as follows:

- preparatory work, routing
- groundwork
- assembling the towers and the insulation chains
- tower erection
- wire stringing and adjustment

Preparatory work, routing

Before the construction work, the contractor obtains the necessary licenses. The places of the towers will be marked out on the basis of the coordinates contained in the licensed construction plan. Tower positions and route access roads will be designated in a walkthrough.

Groundwork

Much larger foundations will be made for the strain towers than for the supporting towers.

Tower foundation depths largely depend on the structure and the load-bearing capacity of the soil. The foundations will be designed by taking into account the results of soil mechanics studies carried out at the marked-out tower places. Foundation depths will generally vary between 2.5 and 4.0 m. A deeper foundation is required only when the soil's load bearing capacity is low.

After the machine excavation of the pit, a concrete assembly slab is prepared at the bottom of the pit on which an iron plate formwork is built. After the reinforcement is completed, the required quantity of concrete is transported to the site by mixer trucks, on a designated route. The poured concrete is compacted by machines. The concrete base will rise about 0.5 m above ground level at the feet of the tower. When the concrete is hardened, the formwork is removed and the soil is filled back around the concrete base in line with the land recultivation plan. The soil that cannot be used for recultivation is removed.

Assembling the towers and the insulation chains

The bases fully harden in about two weeks, during which the pre-fabricated components of the towers are transported to the site. The pre-fabricated tower parts are made of galvanized steel and are painted for double surface protection. The green color of the paint matches the environment. Assembling one tower on site takes about 1 to 2 days.

The insulation chains and their fittings are also assembled on site. The insulators are generally mounted on the towers before the towers are erected but it may also be done afterwards.

Tower erection

The assembled towers may erected in two ways:

- They are assembled on the ground and are erected with the help of a crane. This method is mostly used for supporting towers.
- If there are several pieces, the towers are erected with the help of a crane at the tower site: first the lower tower sections are assembled either on the ground or at the tower site, then the upper section/sections is/are lifted on them. This method is mostly used for strain towers.

Tower erection will take about a half day or one full day per tower.

Wire stringing and adjustment

The conductor wires are also installed on site from drums. The strain towers placed along the route represent the endpoints of tensioning sections. Special machinery is required for tightening and adjusting the wires at the endpoints. Wire stringing is best done in good weather. In rainy weather stringing is preferably postponed, if possible, in order to spare the affected areas. During wire stringing the traffic on crossed roads is maintained.

Required space

The construction of a transmission line requires a 3 to 5 m wide strip of land. However, this strip is not necessary for tower spans where the towers can be accessed from existing roads. During stringing, traffic between such towers is limited to some extent. When arable soil is used for construction work, a pedological expert opinion is prepared for recultivation, on the basis of which the temporary alternative use of the arable soil is licensed by the competent land registry.

The overall dimensions of the towers above the ground depend on whether a supporting or a strain tower is installed but also on the cross-section and the number of conductors fitted on the towers.

The space required for onsite assembly and erection of the towers should also be considered when calculating the space needed for construction, which, depending on the type of tower and the installation site, is as follows:

for 400 kV towers: about 60x40 m

for 120 kV towers: about 40x40 m

These strips of land are temporarily withdrawn from cultivation in the case of arable soil.

The following photo shows tower assembly during a previous installation of a transmission line.

Figure 7.3.5-1: Martonvásár-Győr 400 kV overhead transmission line, space required for the assembly and erection of towers

Scheduling of workflows

The three transmission lines of Paks II can be built at the same time or staggered. In case of staggered construction, the 400 kV and the 120 kV transmission lines for unit 1 must be built first, followed by the 400 kV line for unit 2.

Time required for construction work:

Landscaping, earth moving: 2 working days/km

Groundwork: 2 weeks/km

Tower assembly and erection: 1 week/km

Wire work: 1-3 weeks/km

The work processes outlined above partly overlap, so the estimated implementation time is about 8-10 months. In case of staggered construction, the time required for implementation may be significantly longer. During this time the environment is not disturbed at the same time along the entire length of the power lines. Equipment is used on the work area only for the time that is absolutely necessary, going from one tower site to the next. Construction involves both machinery and manual labor as required for the installation technology.

7.4 REFERENCES

[7-1] Lévai Project, Implementation of the new nuclear power plant, Feasibility Study for Decision-Making, PÖYRY ERŐTERV Zrt.

[7-2] MVM Magyar Villamos Művek Zrt. Implementation of new nuclear power plant units, Preliminary consultation documentation, PÖYRY ERŐTERV, 10/02/2010

8 POTENTIAL IMPACT FACTORS OF PAKS II, IMPACT BEARERS AND IMPACT MATRICES

8.1 POTENTIAL IMPACT FACTORS

The first step of the environmental impact assessment is to determine the potential impact factors related to creating the conditions of nuclear energy production, and to the operation of the plant, resulting from the technological parameters detailed above.

This study examines all potential impact factors that may reasonably play a role in the Paks II project. Whether the listed potential impact factors actually impact any impact bearer, i.e. whether they are impact factors at all, will be determined in the evaluation phase of the study.

The impact factors related to the planned nuclear units are grouped thematically around (1) location, (2) time and (3) characteristic types of impacts.

Constructing and operating the new nuclear units may affect the following ***locations***:

Paks II Nuclear Power Plant

- *Operation site of the new nuclear units*
- *The building yard*

Paks II Nuclear Power Plant – Connected Facilities

- *Cold water canal*
- *Warm water canal*
- *Area enclosed by the cold and warm water canals (“island”)*
- *Site of the power recovery water plant*

Unit line and transmission line

- *Route of the 400 kV unit line and 120 kV transmission line to the new substation*

Transport Routes

- *Roads affected by transportation to and from the plant*

The potential ***temporal*** impact factors of the new nuclear units and their facilities (preparations/construction/installation, operation, and decommissioning) are grouped chronologically with respect to the various sites affected.

Preparations, construction and installation: Approximately 5 years of construction work, in addition to preparation activities, in 2 quasi consecutive cycles for 2 units, adding up to about 10 years altogether.

Operation: The assumed operation time of the planned new nuclear power plant unit is 60 years, which, in view of the procedure of prolonging the operation time of the 4 current units, can be divided into several periods

- Joint operation of units 1to 4 of the Paks Nuclear Power Plant and unit 1 of Paks II between 2025 and 2030
- Joint operation of units 1 to 4 of the Paks Nuclear Power Plant and units 1 to 2 of Paks II between 2030 and 2032
- Joint operation of units 1 to 2 of Paks II after the closure of units 1 to 4 of the Paks Nuclear Power Plant between 2037 and 2085
- Independent operation of unit 2 of Paks II after the expiry and closure of unit 1 of Paks II between 2085-2090
- End of operation of Paks II, unit 2 in 2090

Decommissioning: At the determined expiry time, first unit 1 and then unit 2 of Paks II is closed (based on article 31, appendix 1 of Government Decree No. 314/2005, this activity also requires an environmental impact study).

The **typical impact factors** for each of the above mentioned periods are also examined in this study. Considering the character of the facility, emissions and wastes are divided into two groups: common, non-radioactive types and radioactive types.

- **Use of the environmental elements**
- **Emission of pollutants**
  - *Common, non-radioactive pollutants*
  - *Radioactive pollutants*
- **Wastes**
  - *Generation and management of common, non-radioactive wastes*
  - *Generation and management of radioactive wastes*
- **Spent fuels**
  - *Handling and storage of fuels removed from the reactor zone*

Tests were run for both normal operation and service breakdowns, as well as emergencies and design basis conditions.

8.1.1 POTENTIAL IMPACT FACTORS RELATED TO THE CONSTRUCTION AND INSTALLATION OF THE NEW UNITS OF THE NUCLEAR POWER PLANT

8.1.1.1 Normal operation

8.1.1.1.1 Typical impact factors

- Use of the environmental elements
  - site occupation
  - removal and disposal of topsoil
  - water supply
- Emission of pollutants
  - common, non-radioactive pollutants
  - radioactive pollutants
- Wastes
  - generation and management of common, non-radioactive wastes

8.1.1.1.2 Use of the environmental elements

Site occupation (building yard, operation site, “island”, unit line and transmission line)

Size of the building yard: 976,114 m^2
Size of the operation site: 270,330 m^2
Size of the area to be used (for two sections of the warm water canal + for the power recovery water plant) on the island: 22,521 m^2
(21,512 + 830 + 179)
Total size of safety zone for the two 400 kV unit lines and the fall-back 120 kV transmission line: 833,000 m^2
(4,900m x 170m)
Footprint the towers of the two 400 kV unit lines and the fall-back 120 kV transmission line: 4,031 m^2
(400 kV 40 m^2/piece x 23 = 920 m^2+ 229 m^2/piece x 17 = 3,893 m^2)
(120 kV 14 m^2/piece x 13 = 182 m^2+ 23 m^2/piece x 6 = 138 m^2)

Removal and disposal of topsoil (building yard, operation site, “island”, unit line and transmission line)

At the operation site: 54,066 m^3 (270,330 m^2 x 0.2m of topsoil)

At the building yard: 60,000 m^3 (300,000 m^2 x 0.2m of topsoil)

On the island: 4,504 m^3 (22,521 m^2 x 0.2m of humus)

At the places of the towers for the unit lines and transmission line: 806 m^3 (4,031 m^2 x 0.2m of topsoil)

Water supplied from the Csámpa Water Works

Maximum quantity of drinking water needed: 646 m^3/day

Ensuring water supply during construction and installation

8.1.1.1.3 Sources of emissions during implementation

Sources of emissions of common, non-radioactive pollutants

Building yard

Removal/transplantation of flora from the building yard
Removal and disposal of topsoil
Groundwork for substructures

Operation site of the power plant

Demolition/replacement of facilities, pavements and lineal structures at the nuclear power plant’s operation site
Removal/transplantation of flora from the installation site
Removal and disposal of topsoil
Excavating the construction pit
Dewatering the construction pit
Groundwork for substructures
Building a nuclear island
Erecting buildings and structures
Technological fittings and installation
Landscaping works

Cold water canal and its surroundings

Removal and disposal of topsoil
Expansion of the cold water canal
Groundwater emission from dewatering the construction pit

Warm water canal and its surroundings

Removal and disposal of topsoil
Expansion of the warm water canal
Discharging purified communal waste water into the warm water canal

Area enclosed by the cold and warm water canals (“island”)

Removal/transplantation of flora from the site of the new warm water canal
Removal and disposal of topsoil
Earth moving at the segment of the new warm water canal and building its bed at its new section
Removal/transplantation of flora from the site of the power recovery water plant
Removal and disposal of topsoil
Excavating the construction pit for the power recovery water plant
Constructing the substructures
Constructing the main structure
Technological installation

Route of the 400 kV unit line and 120 kV transmission line to the new substation

Removal of flora at the place of the towers for the transmission line
Removal and disposal of topsoil
Constructing the substructures
Erecting the transmission line towers
Wire work

Transportation routes

Transporting construction materials and technological equipment
Transporting the workforce
Transporting waste (non-radioactive)

Sources of emissions of radioactive pollutants

Operation site of the power plant

Radiographic tests

8.1.1.1.4 Sources of waste during implementation

Generation of common, non-radioactive wastes

Building yard

Groundwork for substructures

Operation site of Paks II

Demolition/replacement of facilities, pavements and lineal structures at the nuclear power plant's operation site
Excavating the construction pit
Groundwork for substructures
Building a nuclear island
Erecting buildings and structures
Technological fittings and installation

Cold water canal and its surroundings

Expansion of the cold water canal

Warm water canal and its surroundings

Expansion of the warm water canal

Area enclosed by the cold and warm water canals ("island")

Earth moving at the segment of the new warm water canal and building its bed at its new section
Excavating the construction pit for the power recovery water plant
Constructing the substructures
Constructing the main structure
Technological installation

Route of the 400 kV unit line and 120 kV transmission line to the new substation

Constructing the substructures
Erecting the transmission line towers
Wire work

Generation of radioactive wastes

No radioactive waste is generated during construction.

8.1.1.2 Service breakdowns and emergencies

8.1.1.2.1 Typical impact factors at times of service breakdowns and emergencies

- Emission of pollutants
  - *emission of non-radioactive, common pollutants*
- Wastes
  - *generation of common, non-radioactive wastes*

8.1.1.2.2 Sources of emissions at times of service breakdowns and emergencies

Damage to the diesel tank
Service breakdown of the communal waste water purification plant causing an emergency
Leakage of motor oils and fuels from machinery during use, storage or breakdown
Service breakdowns or accidents during collecting, moving, storing or transporting wastes

8.1.1.2.3 Sources of waste generation at times of service breakdowns and emergencies

Elimination of damage from service breakdowns and emergencies

8.1.2 POTENTIAL IMPACT FACTORS RELATED TO THE OPERATION OF THE NEW UNITS OF THE NUCLEAR POWER PLANT

Impact factors related to the operation of Paks II are also divided into two groups: common, non-radioactive and radioactive.

Operation is basically divided to two major conditions:

- Normal operation:
  - *Common, non-radioactive pollutants*
  - *Radioactive pollutants*
- Abnormal operation:
  - *Service breakdowns and emergencies resulting in common, non-radioactive pollutant emissions*
  - *Design basis conditions resulting in radioactive emissions*

8.1.2.1 Normal operation

8.1.2.1.1 Typical impact factors

- Use of the environmental elements
  - site occupation
  - cooling water intake and other technological demands
- Emission of pollutants
  - emission of non-radioactive, common pollutants
  - Radioactive pollutants
- Wastes
  - generation and management of common, non-radioactive wastes
  - generation and management of radioactive wastes
- Spent fuels

8.1.2.1.2 Use of the environmental elements during normal operation

Site occupation (operation site, “island”, unit line and transmission line)

Final occupation of the Paks II operation site, deep foundations

Size of the operation site: 270,330 m^2

Final occupation of the path of the warm water channel

Size of the area to be used (for two sections of the warm water canal + for the power recovery water plant) on the island: 22,521 m^2
(21,512 + 830 + 179)

Final occupation of the 400 kV unit line and 120 kV transmission line path to the new substation

Total size of safety zone for the 400 kV unit lines and the 120 kV transmission line: 833,000 m^2

Total footprint of the towers of the 400 kV unit lines and the 120 kV transmission line: 4,031 m^2

Water extraction from the Danube for technological use

Technological water demand (cooling the condenser, safety cooling water, supplementary cooling, other technological uses), maximum: 132 m^3/ó

Water supplied from the Csámpa Water Works

Drinking water requirement: 70 m^3/day (Max. quantity during general maintenance every 10 years: 100 m^3/day)

8.1.2.1.3 Sources of pollutants during normal operation

Sources of common, non-radioactive pollutants

Operation site of the power plant

Operation and maintenance of the Paks II Nuclear Power Plant
Air pollutants and noise resulting from the operation of diesel generators

New warm water canal, with the power recovery plant at its end

Discharge of warm cooling water into the Danube
Discharge of waste waters used in technological preparatory procedures
Discharging purified communal waste water into the warm water canal
Drainage of rainwater
Operation and maintenance of the power recovery water plant

Route of the 400 kV unit line and 120 kV transmission line to the new substation

Operation of the 400 kV unit line and 120 kV transmission line
Removal of trees and bushes, as well as mowing the grass in the safety zone of the electricity lines

Transportation routes

Transportation of the operating staff
Periodic delivery of supplies, tools, machinery and equipment related to operation
Transporting waste (non-radioactive)

Sources of radioactive pollutants during normal operation

Operation of Paks II Nuclear Power Plant
Temporary storage of solid and solidified radioactive wastes at the site

During normal operation of the new units, the power plant will emit pollutants into the environment via two routes. Both liquid and gaseous emissions will be emitted in a controlled manner.

Isotopes will be emitted into the air via two emission points, the venting chimney and the turbine hall.

The technological water use of the units generates waste water, which is collected in tanks and then discharged in a controlled manner into the warm water canal leading to the Danube.

8.1.2.1.4 Sources of waste generation during normal operation

Generation of common, non-radioactive wastes

Operation site of the power plant

Operation and maintenance of the Paks II Nuclear Power Plant
Operation of the existing communal water purification station

New warm water canal, with the power recovery plant at its end

Operation and maintenance of the power recovery water plant

Path of the 400 kV unit line and 120 kV transmission line to the new substation

Maintenance of the 400 kV unit line and 120 kV transmission line

Generation and management of radioactive wastes

Operation site of the power plant

Operation and maintenance of the Paks II Nuclear Power Plant

Low to medium activity solid and solidified radioactive wastes generated during energy production are packed into unified casings and, after classification, are sorted according to place and time of temporary and final storage.

High activity radioactive wastes generated during normal operation stay at the site until its closure and are provided with proper physical and biological protection.

8.1.2.1.5 Sources of spent fuel cassette generation during normal operation

Operation site of the power plant

Operation of the Paks II Nuclear Power Plant
Temporary storage of spent fuel cartridges at the site

Transportation routes

Transportation of spent fuels

Spent fuels removed at the time of replacement are first rested and then stored at a dedicated storage site for several decades (perhaps even beyond the plant's operation time) before they are relocated to a final storage site outside the power plant.

8.1.2.2 Abnormal operation

8.1.2.2.1 Typical impact factors during abnormal operation

- Emission of pollutants
  - emission of non-radioactive, common pollutants
  - Radioactive pollutants
- Wastes
  - generation of common, non-radioactive wastes
  - generation and management of radioactive wastes
- Spent fuels

8.1.2.2.2 Sources of pollutants during abnormal operation

Sources of common, non-radioactive pollutants during service breakdowns and emergencies

Hazardous substances used and malfunctions occurring in supplementary systems, equipment and technology may lead to service breakdowns accompanied by non-radioactive emissions.

Malfunctions of the oil system of the turbine
Malfunctions of the transformer
Malfunctions of the diesel oil tank, machine oil tank or their pipelines
Malfunctions of the supplementary oil system
Malfunctions of tanks, pipelines and unloading equipment
Malfunctions of the industrial waste water tank and pipeline
Damage to the communal waste water pipeline
Improper operation of the industrial waste water purification system, discharging unpurified waste water into the tank
Improper operation of the communal waste water purification system, discharging unpurified waste water into the tank
Operation of diesel generators during disruptions of external power supply
Forest fires in the proximity of the electric transmission line
Service breakdowns or accidents during collecting, moving, storing or transporting wastes
Spillage of hazardous substances due to accidents during their delivery to the site

Sources of radioactive emissions during design basis conditions

Occurrence of design basis conditions (with the containment building remaining intact)
Summarized radiological impact (BDC4)

As provided for by the Nuclear Safety Regulations (NBSz), design basis conditions include the following:

- Assumable service events (DBC2)
- Low incidence service breakdowns (DBC3)
- Very low incidence service breakdowns (DBC4)

For each individual operational state of the VVER-1200 units, the events resulting in the highest environmental emission within the particular operating state can be determined. Preliminary Russian data concerning the design basis condition of the planned units are presented in chapter 6.13.4.

Based on section 3.2.2.3300 of the Nuclear Safety Regulation (NSR) promulgated by Government Decree 118/2011. (VII.11), internal initial events resulting from malfunctions of systems or their elements, or from human errors, or both, can be removed from the list of hypothetical initial events at new nuclear units, if their incidence is lower than 10^{-6} occurrences per year.

In defining the impacts and impacted areas related to design basis conditions, Appendix 3, Section 3.2.2.0200 as well as Appendix 10, Section 163 of the Nuclear Safety Regulation (NBSz) require to consider design basis conditions with very low incidence (Tervezési Alap 4 or DBC4: design basis conditions, assumable service breakdowns with very low incidence: $10^{-4} > f > 10^{-6}$ [1/year]).

In examining design basis conditions, we used Russian preliminary data concerning DBC4 (Design Basis Category 4 Conditions).

Description	Service condition	Highest risk event
Assumable service events	TA2 – DBC2	Unintentional opening of the safety valve or discharge valve of the steam generating turbine, or of its bypass duct, resulting in damages that prevent the closure of the valves
Low incidence service breakdowns	TA3 – DBC3	Small-scale spillage of cooling agent caused by the fissure or fracture of ducts (with an equivalent diameter of less than 100 mm) in the primary circuit
Very low incidence service breakdowns	TA4 – DBC4	Large-scale spillage of cooling agent caused by the fissure or fracture of ducts (with an equivalent diameter of more than 100 mm) in the primary circuit, including that of the main cooling water duct

Table 8.1.2-1: Service conditions of the units and events carrying the highest risk in the given categories [8-1]

8.1.2.2.3 Sources of waste generation during abnormal operation

Sources of non-radioactive waste generation during service breakdowns and emergencies

Elimination of damage from service breakdowns and emergencies

Sources of radioactive waste generation during design basis conditions

Tools and equipment damaged and polluted during design basis conditions and their recovery (with the containment building remaining intact)
Accidents during the transportation of radioactive wastes

8.1.2.3 Environmental emissions during operation

Expected emission values, as well as the basic data necessary for running the various model tests, and the lists of isotopes for various time intervals are contained in the chapters focusing on the various special fields.

8.1.3 POTENTIAL IMPACT FACTORS OF DECOMMISSIONING AND DISMANTLING THE NEW NUCLEAR POWER PLANT UNITS

Although the lists of potential impact factors related to the construction and operation of the new units of the nuclear power plant are based, to a certain degree, on estimations, the impact factors of decommissioning (closure) and dismantling are even more uncertain.

Concerning the major systems of the planned facility, we may only make assumptions based on our knowledge. The decommissioning of the new units is such a far away event in time, especially considering the present rate of development f technology, that it is impossible to describe it with any certainty. [8-2]

Typical impact factors of decommissioning

- transportation requirement of dismantling and the environmental impacts thereof (depending on the mode and extent of dismantling)
- transportation of waste (non-radioactive wastes)
- common emissions
- radioactive emissions (depending on the technological solutions of dismantling)

Major sources of emissions:

Draining radioactive and non-radioactive systems and their pipelines
Demolition of buildings and structures, setting up a temporary disposal site
Preparation of radioactive and hazardous wastes for transporting from the site
Transportation of radioactive and hazardous wastes to the designated handler or storage site
Removal of non-radioactive wastes generated in the controlled zone from official supervision
Dispatching dismantled parts and equipment
Handling and disposal of unremoved tools, equipment and systems
Draining ground waters springing up during demolition into surface waters
Operating the communal water purification station
Environmental emissions and waste volumes

8.1.4 ENVIRONMENTAL EMISSIONS AND WASTE VOLUMES

For expected emission values identified on the basis of the technological parameters detailed above, for the basic data necessary for running the various model tests, and for the volumes of waste generated please refer to the chapters dealing with the various special fields.

8.1.5 IMPACT BEARERS

The second step of the environmental impact study is to appraise and define the impact processes triggered by the impact factors related to the implementation and operation of Paks II, including the events related to its construction, service and decommissioning. Based on these processes, it is possible to define **the scope of environmental elements and systems where** the processes triggered by the impact factors (use and straining of environmental resources) **may lead to direct** and **indirect effects.**

During the construction, operation and decommissioning of the new nuclear units, the following elements and systems of the environment are to be taken into account as impact bearers:

Surface waters – Danube
Geological formation, underground water (operation site, Danube valley)
Air
Inhabited environment (noise, radioactive pollutants, wastes)
Biosphere, ecosystem
Artificial environment, engineering objects
Population (common and radioactive pollutants)

8.2 POTENTIAL IMPACT MATRICES

The second step of the environmental impact study is to appraise and define the potential impact processes triggered by the potential impact factors related to the construction, operation and decommissioning of Paks II. The impact factors as well as the impact bearers during the construction, operation and decommissioning, as well as for abnormal service conditions (service breakdowns, emergencies and design basis conditions) during all three phases have been identified. The assumed impacts of potential impact factors on the affected parties are summed up in the matrices below.

For more detailed descriptions, please refer to the chapters dealing with each field.

Impact factors	***Impact bearers***								
	Environmental elements/systems								
	Surface water	*Geological formation, underground water*		*Air*	*Inhabited environment*	*Biosphere, ecosystem*	*Cultural heritage*	*Population*	*Built environment*
	Danube	*Site*	*Danube valley*						
Installation									
Demolition of buildings	-	U	-	S	S	S	-	U,S	U,S
Site occupation	U	U	-	S	U	S	-		U
Transportation	-	-	-	S	U,S	S	S	S	U,S
Construction of the facility	U	U	-	S	U,S	S	-	S	U,S
Installation of technology	U	U	-	S	U,S	S	-	S	U,S
Related activities	U	U	-	S	U,S	S	-	S	U,S
Service breakdowns, emergencies	S	S	-	S	S	S	S	S	S
Operation									
Technology	S	U	S	S	U,S	S	-	S	U,S
Related activities	-	-	-	S	U,S	S	-	S	U,S
Transportation	-	-	-	S	U,S	S	S	S	U,S
Service breakdowns, emergencies	S	S	-	S	S	S	S	S	S
Decommissioning									
Disassembling technology	-	S	-	S	U,S	S	-	S	S
Demolition of buildings	-	S	-	S	U,S	S	-	S	S
Transportation	-	S	-	S	U,S	S	-	S	S
Related activities	S	S	-	S	U,S	S	-	S	S
Landscaping	-	S	-	S	U	S	-	S	U
Service breakdowns, emergencies	S	S	-	S	S	S	S	S	S

Legend:
U – Use of the environment
S – Straining of environmental resources

Table 8.2-1: Summary impact matrix – identifying the types of impact factors, as well as impact bearers

Impact factors	***Impact bearers***								
	Environmental elements/systems								
	Surface water	*Geological formation, underground water*		*Air*	*Inhabited environment*	*Biosphere, ecosystem*	*Cultural heritage*	*Population*	*Built environment*
	Danube	*Site*	*Danube valley*						
Installation									
Demolition of buildings	-	U	-	C	C	C	-	C, U	C, U
Site occupation	U	U	-	C	U	C	-		U
Transportation	-	-	-	C	U, C	C	C	C	U, C
Construction of the facility	U	U	-	C	U, C	C	-	C	U, C
Installation of technology	U	U	-	C	U, C	C	-	C	U, C
Related activities	U	U	-	C	U, C	C	-	C	U, C
Service breakdowns, emergencies (E)	C	C	-	C	C	C	C	C	C
Operation									
Technology	E+D	U	C	E+D	U, E+D	E+D	-	E+D	U, E+D
Related activities	-	-	-	C	U, C	C	-	E+D	U, C
Transportation	-	-	-	C	U, E+D	E+D	C	E+D	U, E+D
Service breakdowns, emergencies (E) Design-basis conditions (D)	E+D	E+D	-	E+D	E+D	E+D	C	E+D	E+D
Decommissioning									
Disassembling technology	-	E+D	-	E+D	U, E+D	E+D	-	E+D	E+D
Demolition of buildings	-	E+D	-	E+D	U, E+D	E+D	-	E+D	E+D
Transportation	-	E+D	-	E+D	U, E+D	E+D	-	E+D	E+D
Related activities	C	E+D	-	C	U, E+D	E+D	-	E+D	E+D
Landscaping	-	C	-	E+D	U	E+D	-	E+D	-
Service breakdowns, emergencies (E) Design-basis conditions (D)	C	E+D	-	E+D	E+D	E+D	E+D	E+D	E+D

Legend:

C – Common environmental impacts
R – Radiological impacts

Table 8.2-2: Summary impact matrix, identifying common and radiological impacts

8.3 REFERENCES

[8-1] Data for NPP environmental impact analysis (AES-2006 with VVER-1200), Rusatom Overseas JSC, 2014.09.23.

[8-2] ETV-ERŐTERV Rt.: Extension of the operating life of the Paks Nuclear Power Plant, Environmental Impact Assessment Study, 01/23/2026