OPERATIONAL STATUS
OF KRŠKO
NUCLEAR POWER PLANT

Ime Priimek, 22.10.2021.

www.nek.si

Contents

- Nuclear Power in Europe
- Management and Organisation of NEK
- Plant Design
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- Plant Safety Upgrade
- Goals for the Future
- Conclusions

A MINUTE FOR SAFETY

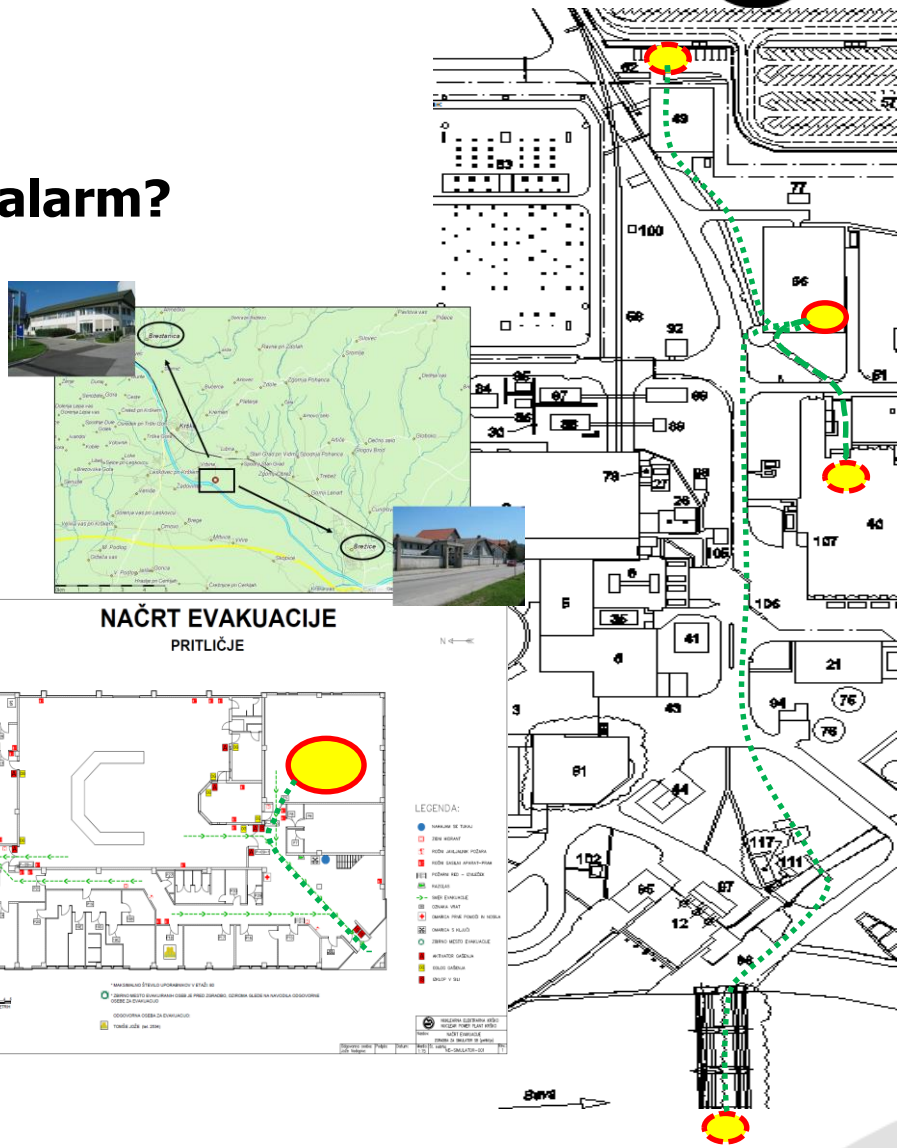
How to act in case of the evacuation alarm?

Evacuation in case of an emergency:

Assembly point (only one):
Main entrance or
Sava River dam

Evacuation in case of a fire:

Assembly point:
Hall by the dining room, Bldg. AD2



Nuclear Europe

Worldwide: (IAEA, August 2021)
448 units in **33** states in operation
51 units under construction in **19** states
28 new states wanted to embark nuclear
19 023 reactor-years of operation

180 units in operation in Europe, (**108** EU)
15 units under construction
(IAEA, August 2021)

Installed electric net capacity: **159.5 GWe**

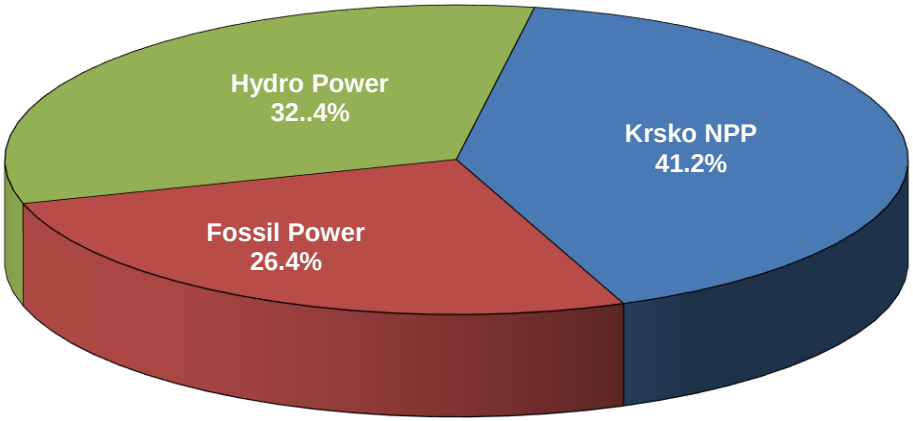
- **EU-27, electricity production by sources:**
  - Combustible.....45.5%
  - Nuclear.....25.8%
  - Hydro..... 13.0%
  - Wind.....11.3%
  - Solar..... 4.1%
  - Geothermal.....0.2%
  - Others.....0.2% (Eurostat 2018)
- **Nuclear share:** (IAEA, August 2021)

France 70.6%	Slovakia 53.1%
Ukraine 51.2%	Hungary 48.0%
Bulgaria 40.8%	Belgium 39.1%
Slovenia 37.8%	Czech Rep. 37.3%
Finland 33.9%	Switzerland 32.9%
Sweden 29.8%	Spain 22.2%

- **Under Construction:**

Belarus 1, Finland 1, France 1, Slovakia 2, Russia 3, Ukraine 2, Turkey 3, UK 2

Krško NPP – Important Producer of Electrical Energy - 2020



HE (Hydro Power) = 4746.8 GWh

TE (Fossil Power) = 3872.2 GWh

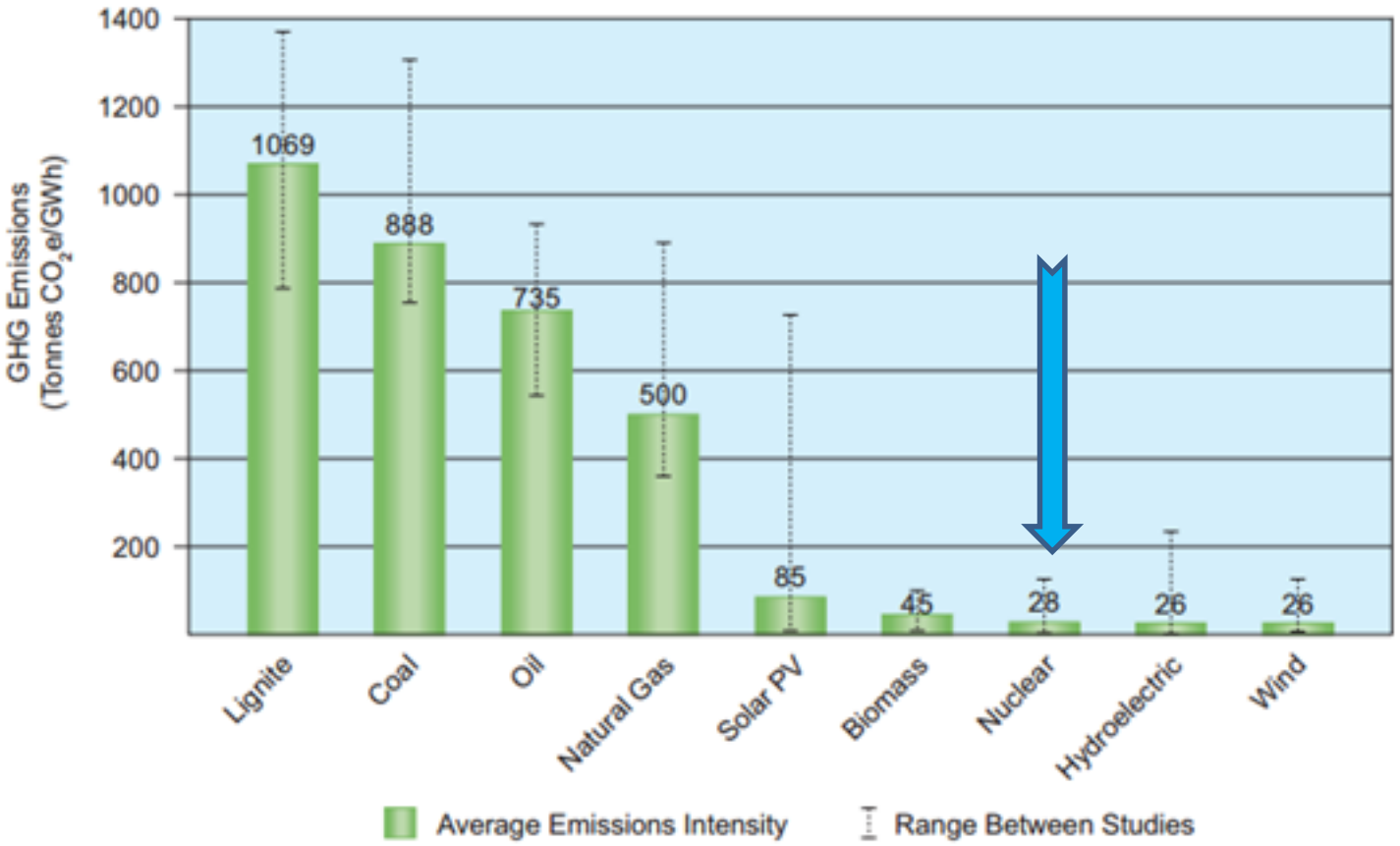
Krško NPP = 6040.1 GWh *

Total = 14659 GWh

* Total Krško NPP Production

Source: ELES, Monthly Report on the Power System for December and year 2020, January 2021

Nuclear is supporting the need for low life cycle emissions



Source: World Nuclear Association meta study, incl. IPCC 2014

Nuclear is supporting United Nations Sustainable Development Goals

Nuclear energy is an affordable and clean energy source that allows coherent development and transition to climate neutrality.

- Krško NPP is the main source of low-carbon energy production in Slovenia; at the European level, nuclear power plants generate half of low-carbon energy.

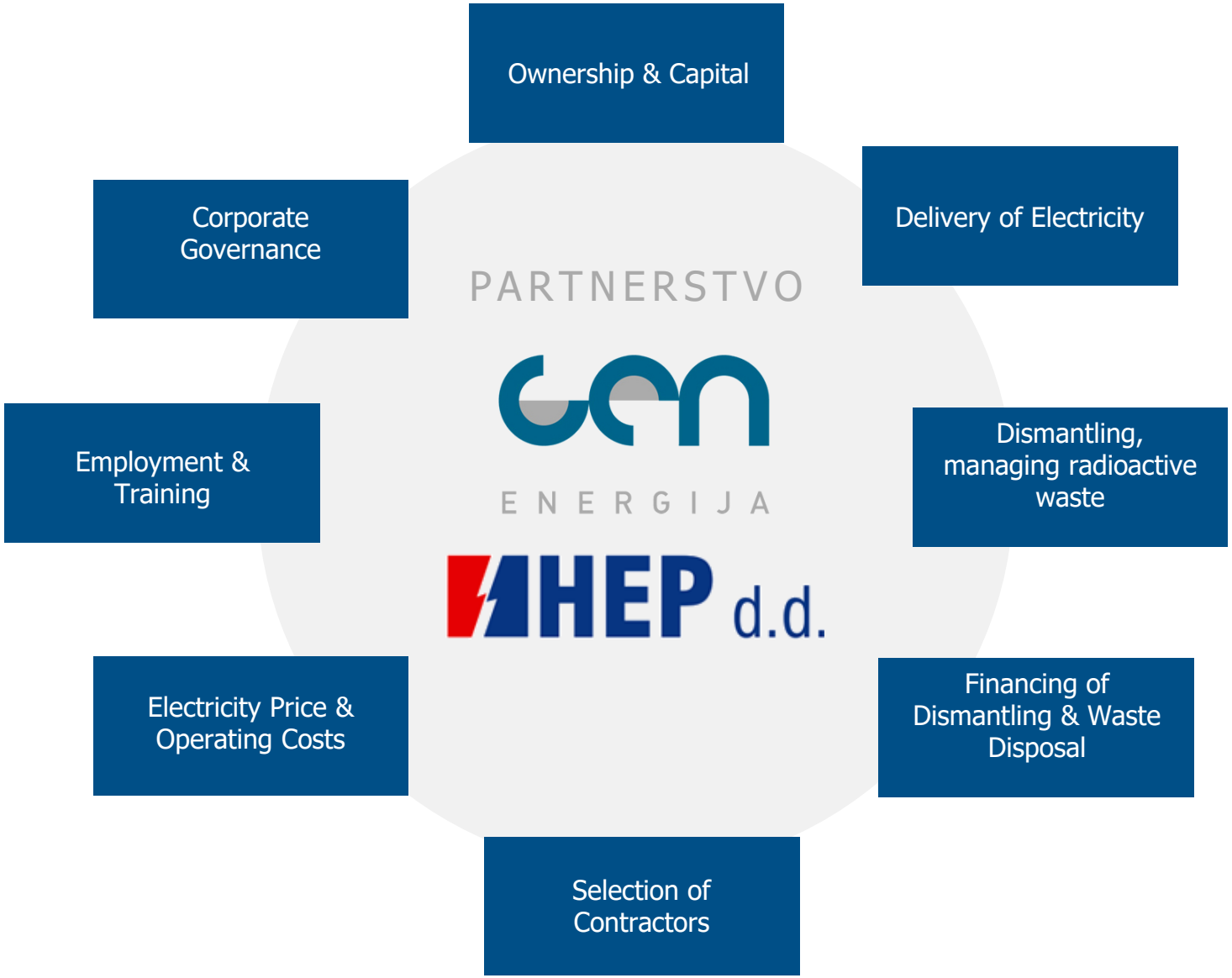
- Krško NPP is improving carbon footprint of the Slovenian energy system generating 40% of energy and less than 3% of total carbon footprint of the system.

- Krško NPP attains high operating stability 24 hours per day throughout the year and is therefore the main factor in reliable supply of electrical energy – a requirement for normal functioning of a modern society.

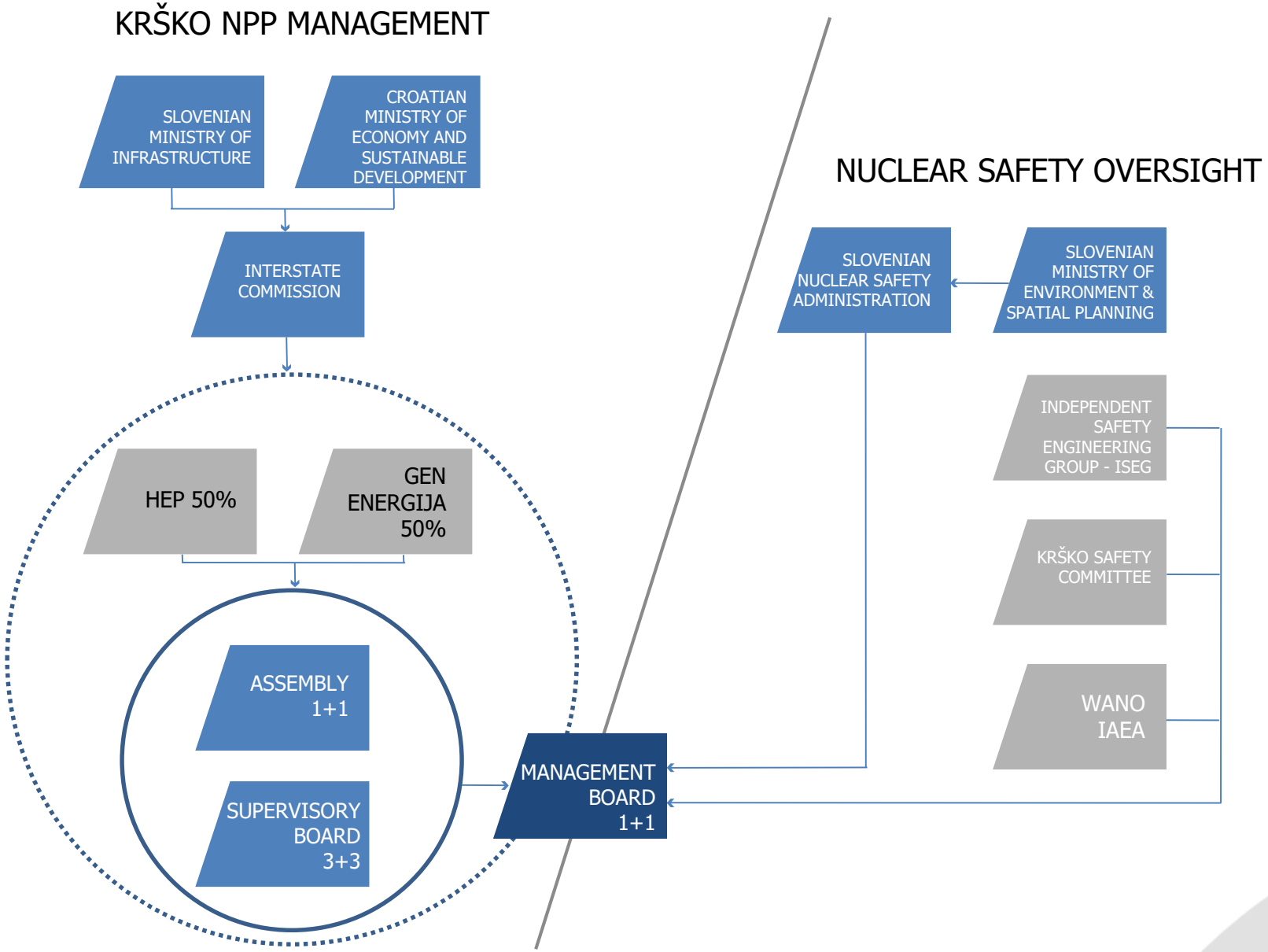
Krško in Brief

- Owners: **GEN-energija 50%, HEP 50%**
- Operator: **Krško Nuclear Power Plant**
- NSSS Supplier: **Westinghouse**
- Reactor Type: **PWR, 2-loop**
- Engineering: **Gilbert Architect Engineer**
- Construction Permit: **1975**
- First Criticality: **1981**
- Commercial Operation: **1983**
- Bilateral Agreement: **2003**
- Renewed Operating License: **2012**
- Operating Life Time: **40+10+10+... years**
- No. of Employees: **~630**
- Gross Plant Output: **727 MW**

Agreement between Slovenia and Croatia



Independent Functions of Management & Supervision



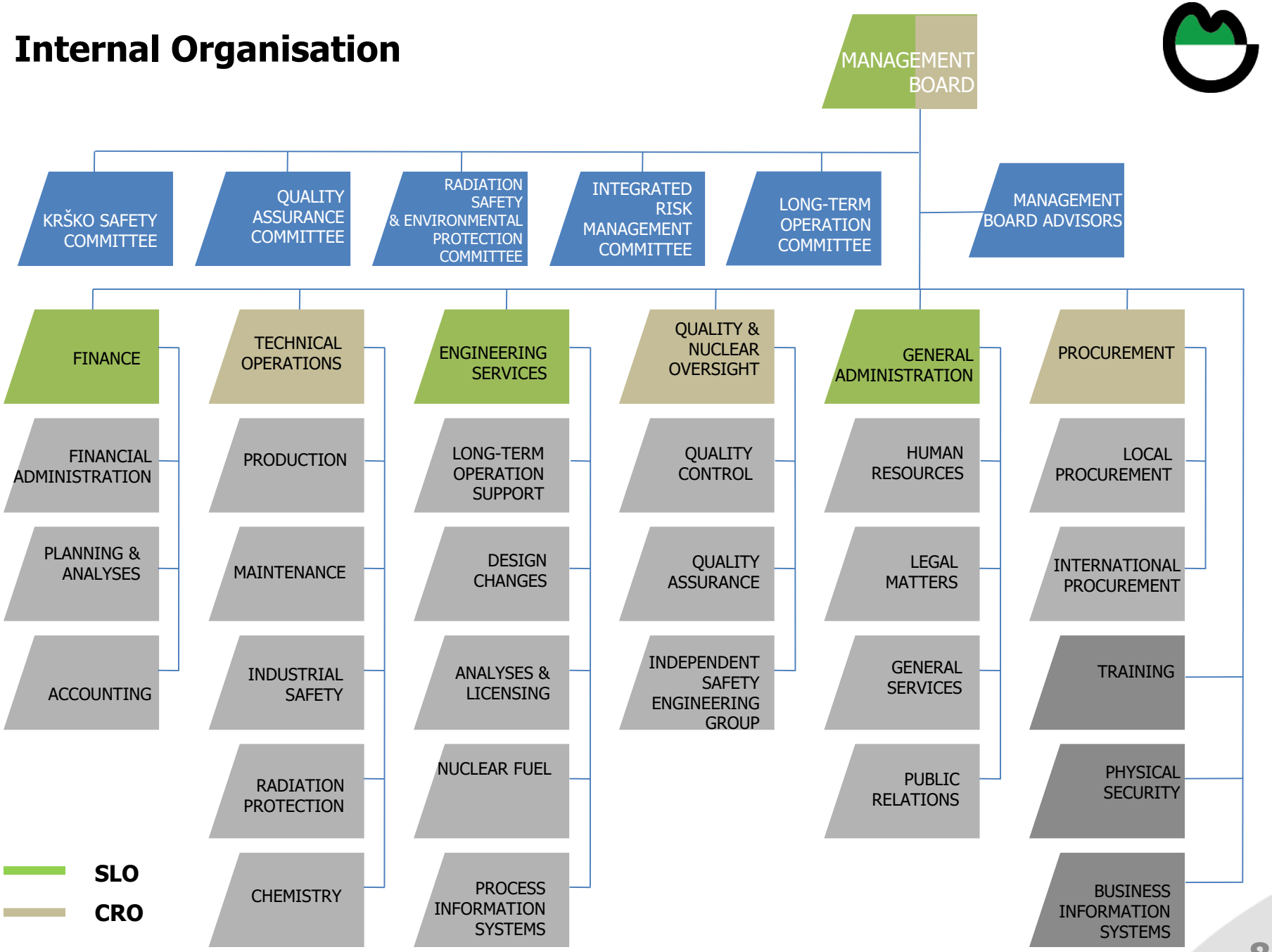
Our Vision & Mission

Vision

Biti zgled jedrske varnosti
in odličnosti na globalni ravni
(World-wide leader in nuclear safety and excellence)

Mission

Internal Organisation



Structure of Employees

- Free employment of job applicants from Slovenia & Croatia
- Management positions covered by SRO's
- High Stability, Low Turnover
- 85.7% male, 14.3% female
- Systematic Approach to Training

	2016	2017	2018	2019	2020
Total No. of Employees	617	608	633	628	**630**
University Degree (+VI/2nd level)	255	254	283	286	**282**
College, High School Degree	311	305	327	322	**320**
New Employees	1	0	36	5	**14**
Staff Turnover (%)	3.9	1.5	1.7	1.6	**1.9**
Scholarships	7	10	11	18	**18**
RO	23	23	21	18	**17**
SRO	50	50	51	52	**51**

SRO … Senior Reactor Operator
RO … Reactor Operator

The plant management together with the operating crew ensure operational stability & nuclear safety

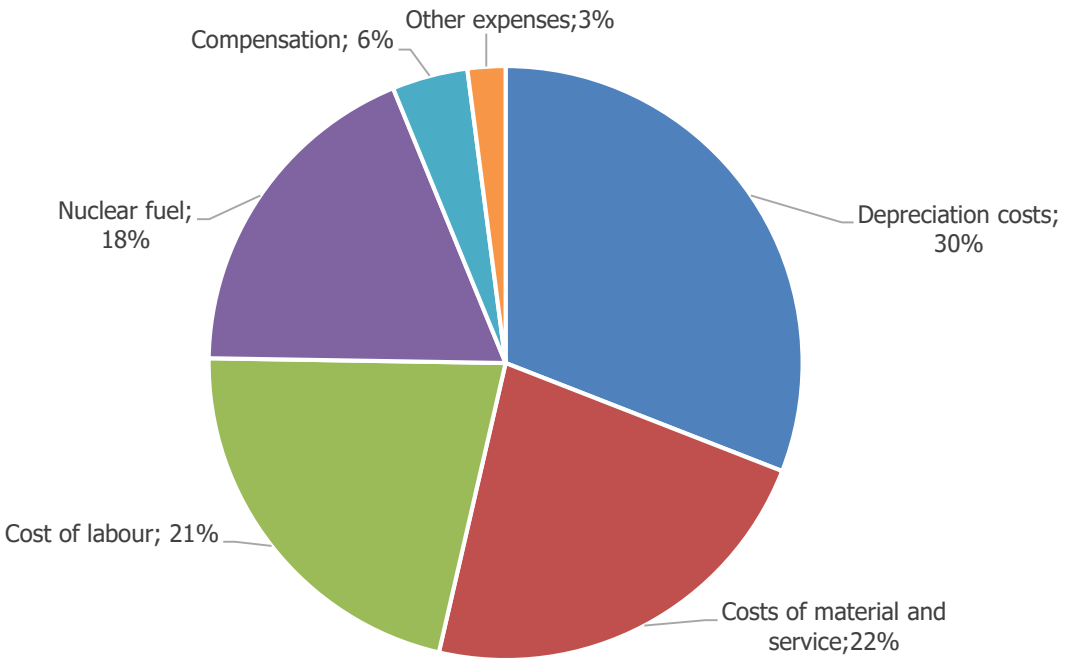
Safety culture is our platform for action.

Principles:

- Personal responsibility
- Management‘s attitude towards nuclear safety
- Effective communication
- Respectful workplace
- Freedom in reporting
- Effective Decision-making
- Work processes
- Questioning attitude
- Experience-based learning
- Corrective Action Management

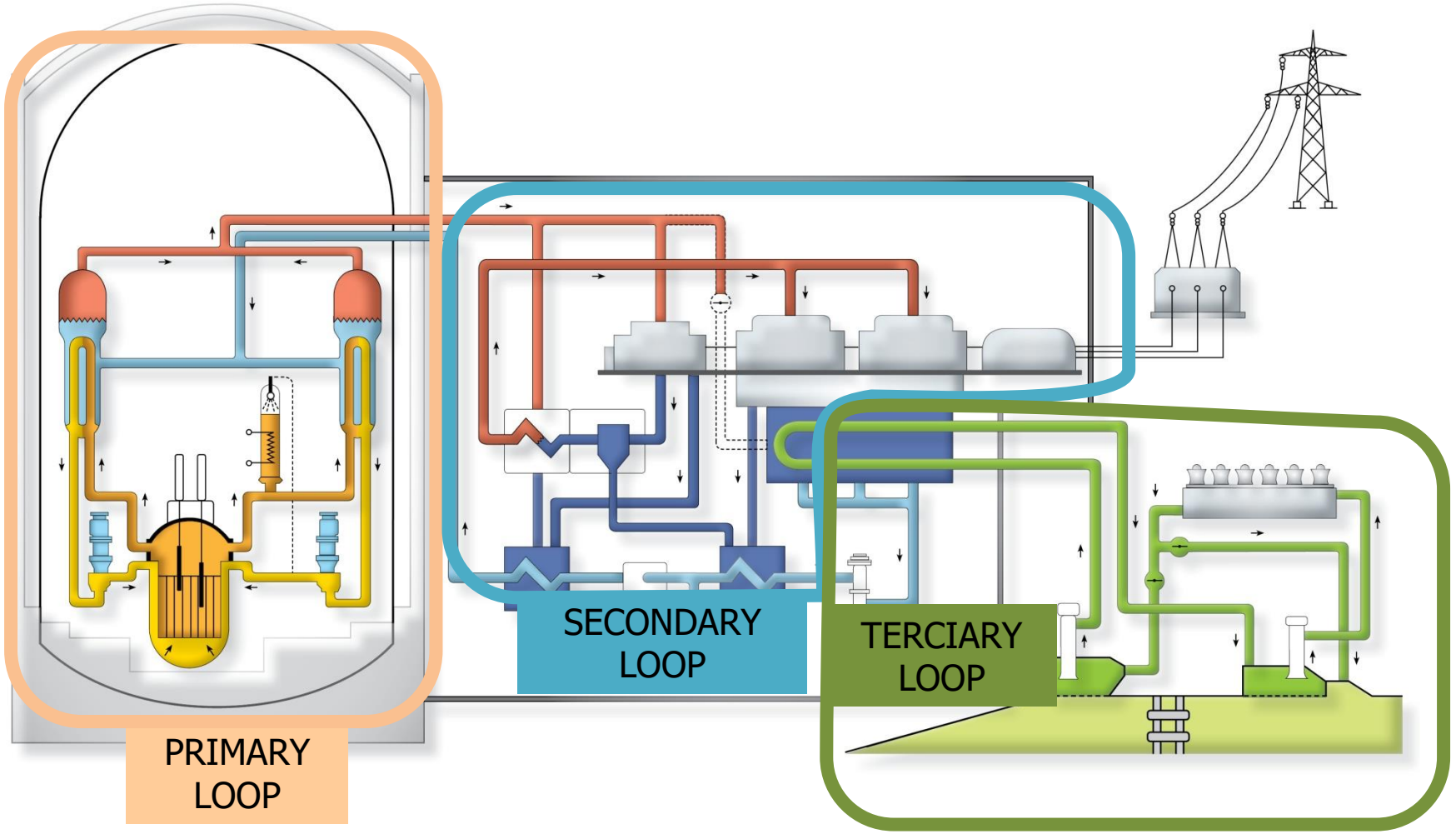
Structure of expenses in 2020

- Depreciation cost 30%
- Cost of material and service 22%
- Costs of labour 21%
- Nuclear fuel 18%
- Compensation and water use fee 6%
- Other expenses 3%

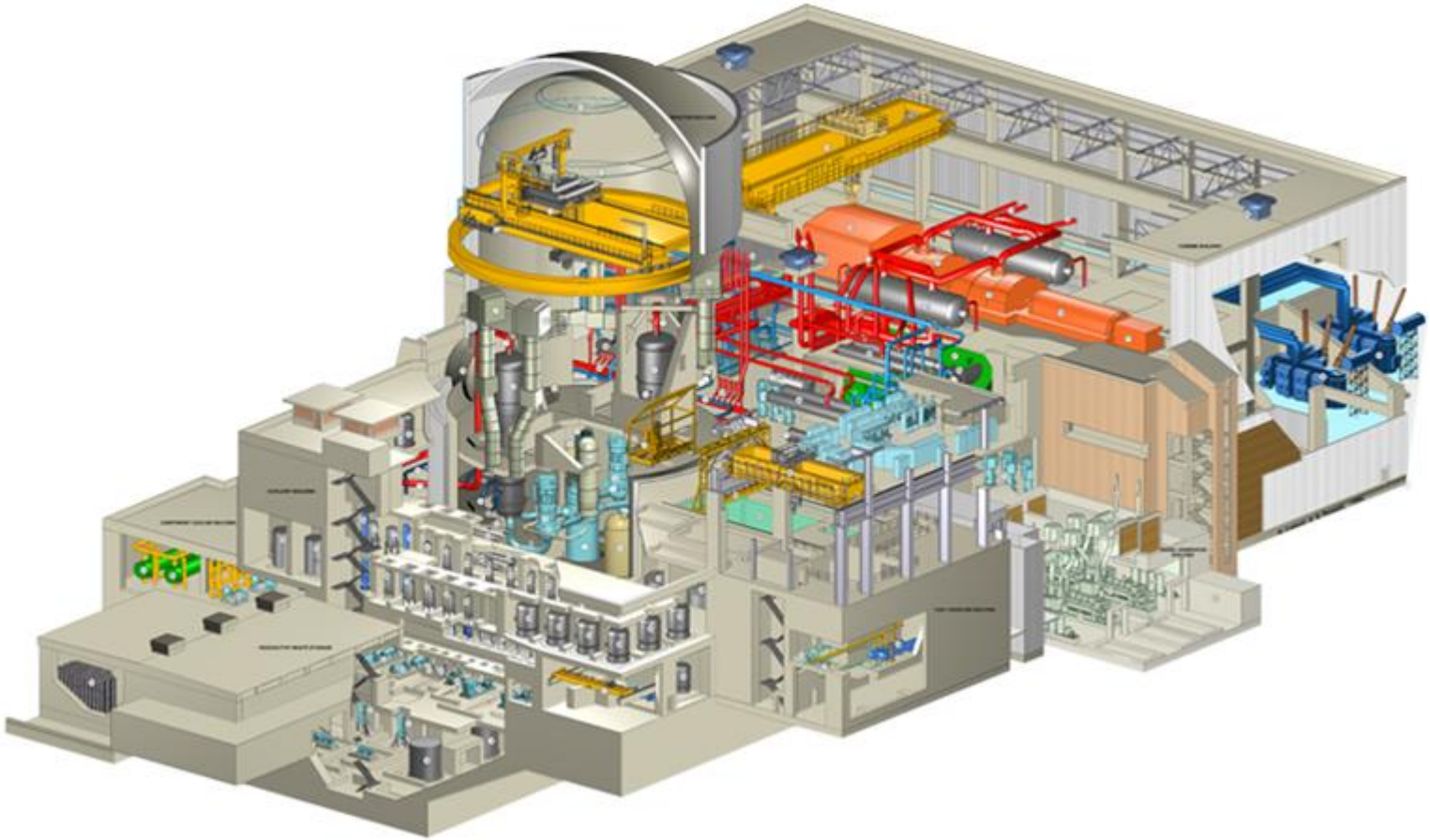


Unit price in 2020: 32.61 €/MWh

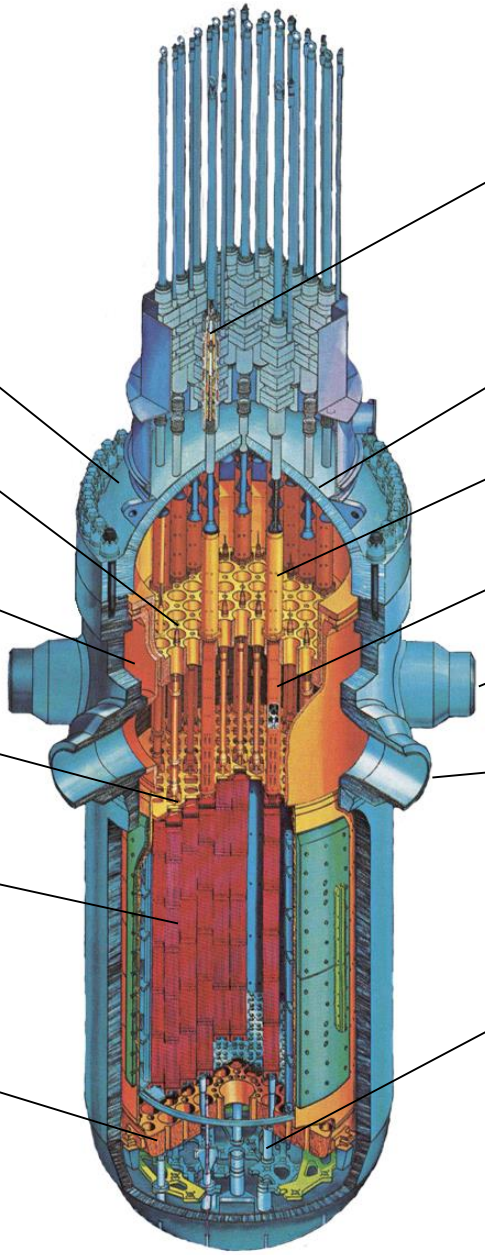
Plant Design – three cooling loops



Schematic Section of the Plant



Reactor Vessel



Control Rod Drive Mechanism

Reactor Vessel Head

Upper Support Plate

Thermal Sleeves

Core Barrel

Control Rod Assembly Conduit

Control Rod Assembly Drive Shaft

Upper Core Plate

Outlet Nozzle

Inlet Nozzle

Fuel Assemblies

In-core Nuclear Instrumentation Guide Thimbles

Support Plate Forging

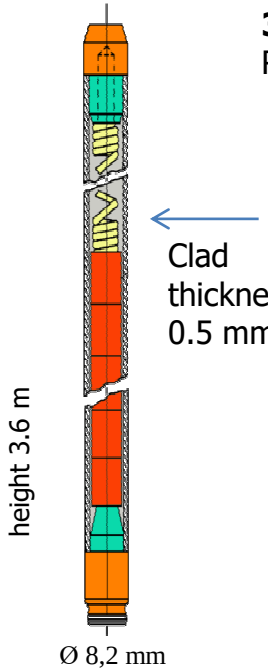
Nuclear Fuel

10.236.600 tablets → **28.435** fuel rods → **121** fuel assemblies → **1** reactor core

2 tablets =

On-year home heating costs

Uranium tablet

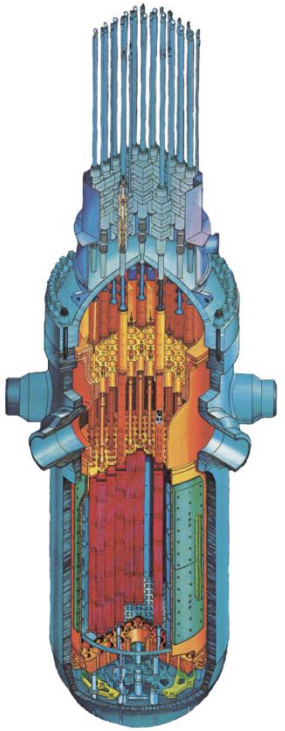


Clad thickness 0.5 mm

Fuel Rod
360 tablets in one rod

Control Rods
33 Control Rod Assemblies in Reactor

Fuel Assembly
235 rods in one assembly



Reactor
121 fuel assemblies in reactor

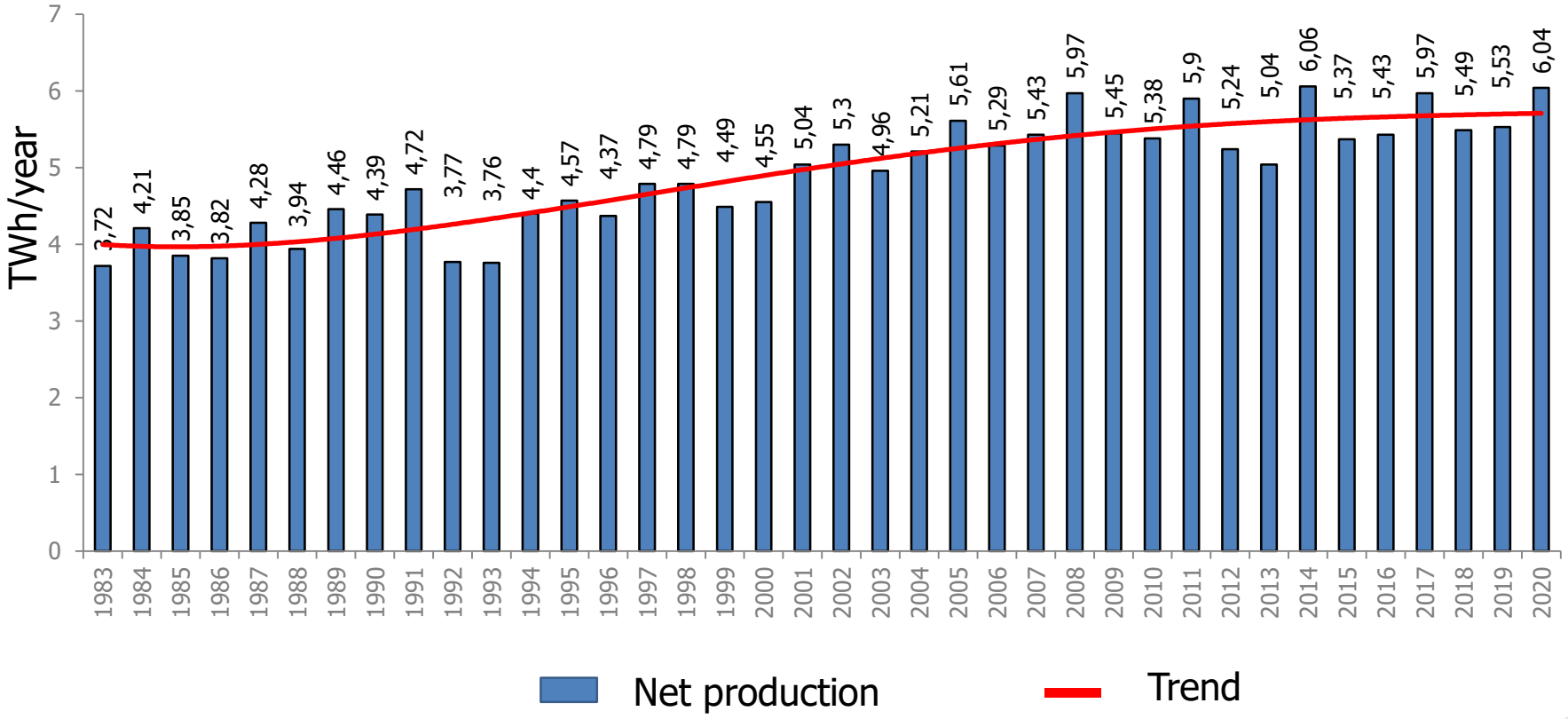
- Reactor power depends on nuclear fission rate.
- The fission is controlled by:
  - control rods (silver, indium, cadmium - 80/15/5%),
  - changing the boron concentration in the primary coolant.

- 16 x 16 fuel assembly
- Equivalent core height 366 cm
- UO_2 tablet, clad material ZIRLO™ (Modified VANTAGE+)
- Enrichment up to 4.95% for fuel cycle 32
- Up to appr. 56 fresh fuel assemblies

Positive Production Trend

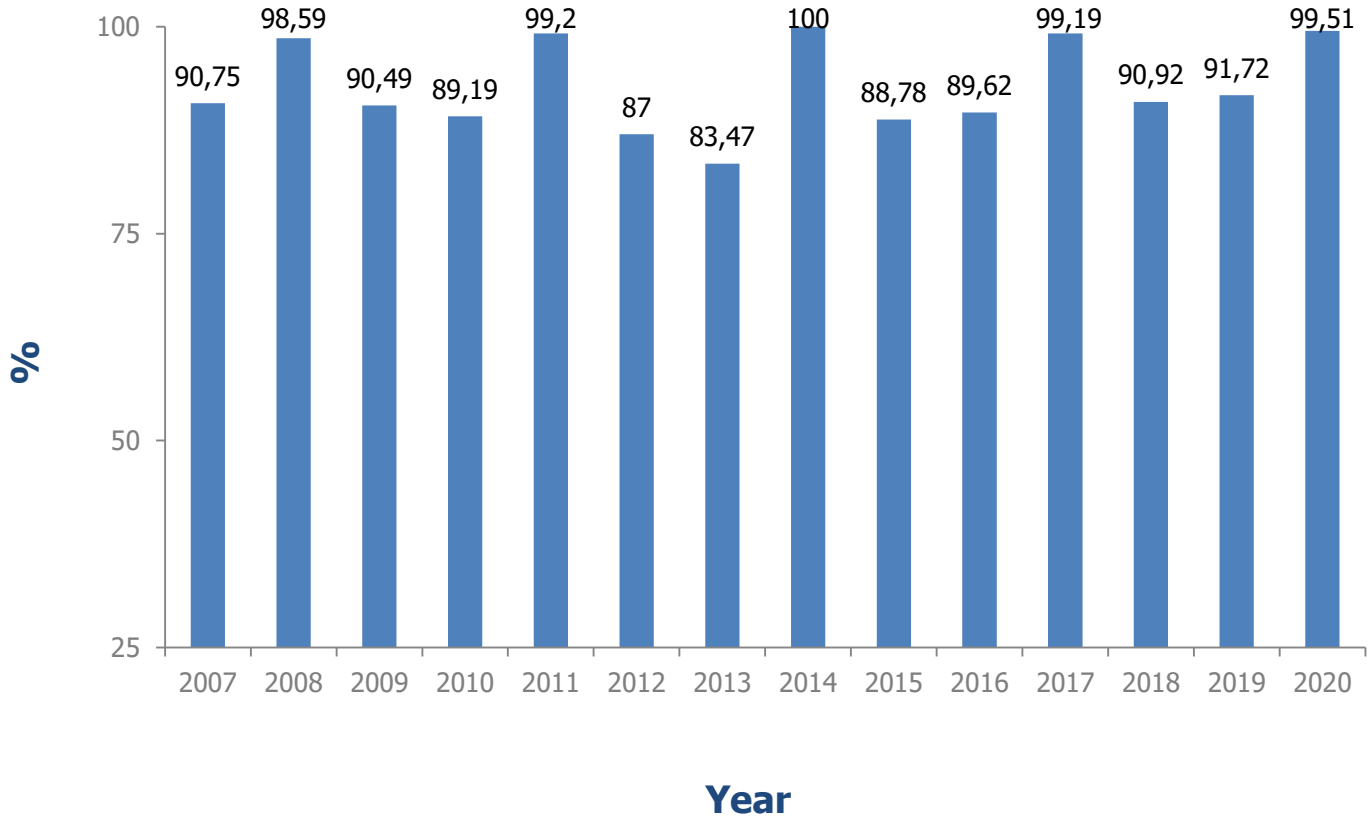
A result of work process optimization, 18 month fuel cycle, good material condition, and employee commitment

- Cumulative: 186.6 TWh
- 3-year average:5.69 TWh/year



Performance Indicators

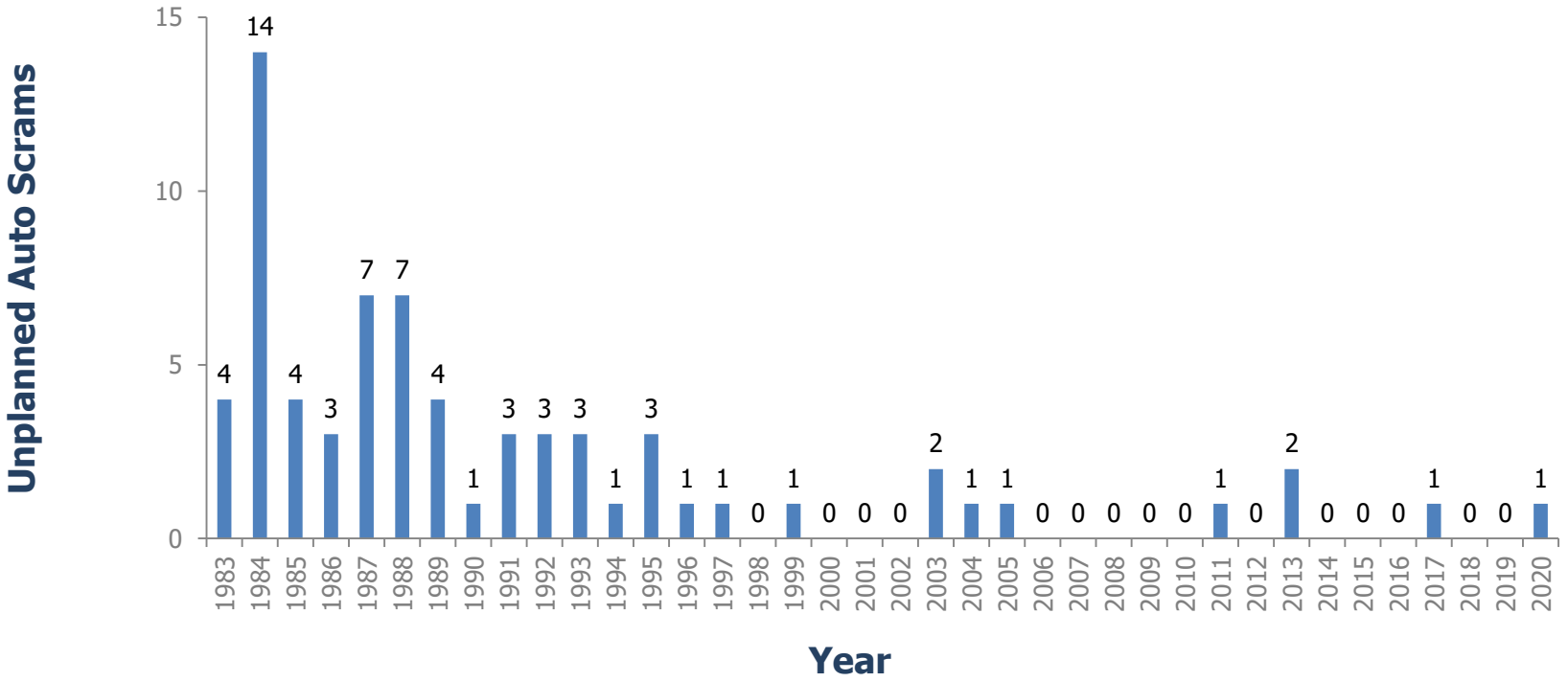
Unit Capability Factor



Unit capability factor is defined as the ratio of the available energy generation to the reference energy generation over the period of 12 months.

Performance Indicators

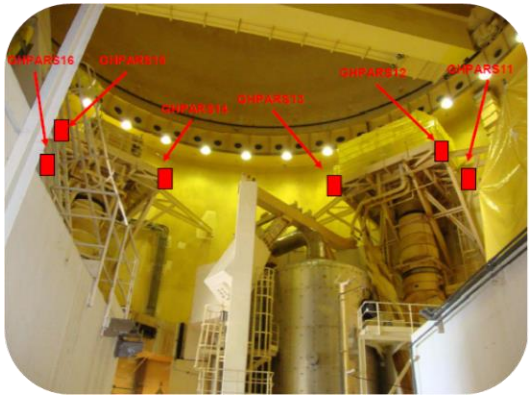
Unplanned Auto Scrams



Major Investment Projects Performed

To improve Nuclear Safety

- Full-scope Simulator
- 125 V DC Supply (batteries)
- PRZR PORVs Bypass
- Radiation Monitoring System
- Emergency AC Power System (DG 3)
- Flood Safety
- Passive Autocatalytic Recombiners (PAR)
- Passive Containment Filtering Ventilation System
- TD Auxiliary Feedwater Pump
- Emergency Control Room
- RCP high temperature seals
- BB2– Alternative SI PMP and Alternative AF PMP with bunkered water sources

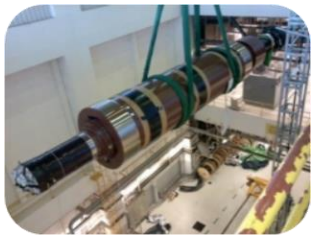


Major Investment Projects Performed

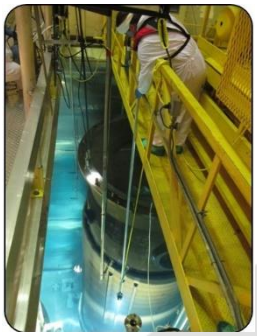
To increase Availability

- Condenser
- Process Computer
- Steam Generators
- Low-pressure Turbine Rotors
- Spent Fuel Pit Re-racking
- Cooling Tower Extension
- Reactor Coolant Pump Motors
- Secondary Heaters
- In-core Instrumentation

- Digital Turbine Control
- Moisture Separator Reheaters
- Generator Stator & Rotor & Exciter
- Reactor Head
- Main Transformers
- Switchyard
- Main transformer 500 MVA
- Renewal of 400 kV switchyard





Assuring Health and Safety at Work

At Krško NPP, we provide exemplary working conditions for safe work and work without damage and without negative health effects to everyone working at the power plant.

- We comply with the programme of health & safety management systems at work and fire protection in accordance with the requirements of ISO 45001.

- "WE WORK SAFELY" is the slogan of our internal campaign by which we:
  - Draw attention to the various aspects of safety;
  - Encourage consistent adherence to rules and processes; and
  - Strengthen the personal responsibility of our employees and subcontractors and their motivation for safe work.

Production Effect of some Mayor Investments

Power Upgrade

- **2000:** Steam Generator Replacement & Power Upgrade ...

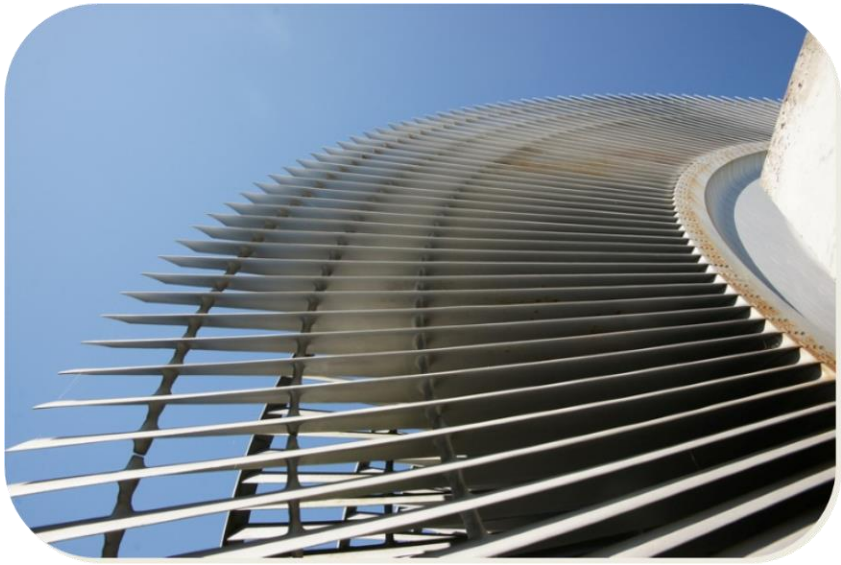
  664 MW → 707 MW

- **2006-2007:** Low-pressure Turbine & Heat Exchangers' Replacement ...

  707 MW → 727 MW

- **2022:** High-pressure Turbine Replacement - planned for 2022

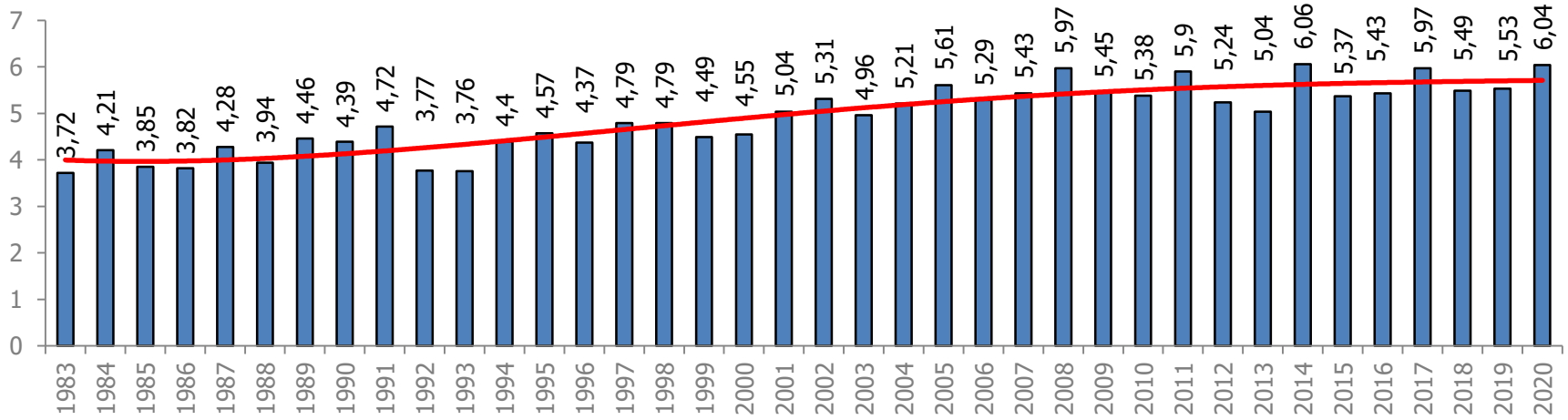
  727 MW → 737 MW



Availability Improved Over Time

- Cooling Tower Extension;
- Fuel Cycle Prolongation to 18 months;
- Shorter Regular Outages;
- Preventive Maintenance;
- Upgraded Work Processes.

Plant power output increased from **4.5 TWh/year** to **5.59 TWh/year.**



The difference of 1.1 TWh/year in the plant power output is equal to the production of appr. 8 Hydro Power Stations on the Lower Sava River.

Extensive Radiological Monitoring in the Vicinity of Krško NPP

Krško NPP & Authorised Institutions continuously monitor eventual impacts of plant operations on the surroundings:

- 57 OSL (Optically Stimulated Luminescence) dosimeters around the plant within a distance of 10 kilometres,
- 9 TL dosimeters on the plant fence,
- 10 TL dosimeters in Croatia,
- 14 permanent dose rate monitors.
- The samples of air, soil, water, food, and fodder are taken in several tenths of locations.

Extensive Radiological Monitoring in the Vicinity of Krško NPP

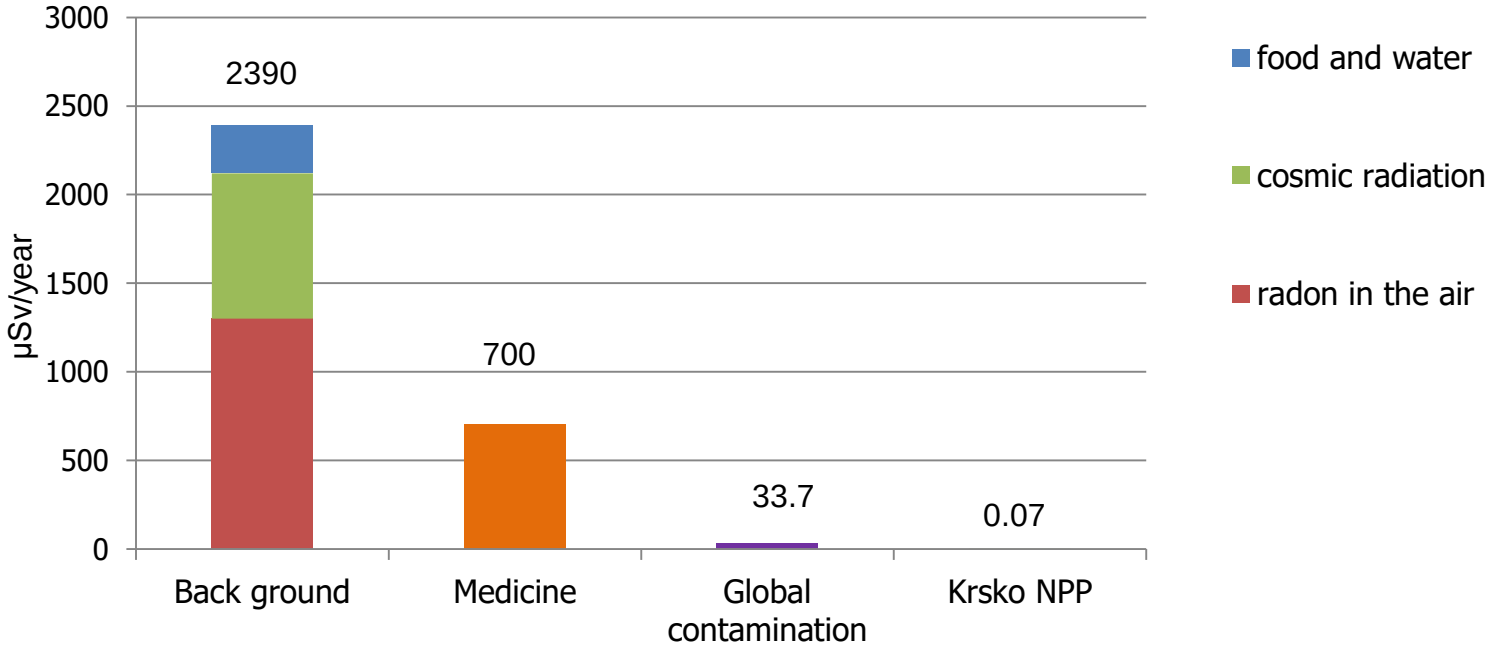
Conservatively estimated effective dose equivalent* of an individual as the result of the Krško NPP emissions amounts to:

0.06 µSv/year due to radioactive releases into the atmosphere,
0.02 µSv/year due to liquid discharges into the Sava River.

Radioactive releases from the Krško Nuclear Power Plant account for 0.14% of the regulatory limit which is 50 µSv per year in compliance with international standards.

* Dose is a general term used to express (quantify) how much radiation exposure a person or other material has received. Effective dose, then, is the dose to the whole body, whether from external or internal sources.

The effects of radioactive releases to the public from the Krško NPP are low



The estimated value of radiation contributions (annual effective dose) from the Krško NPP to the general public in the vicinity of the plant amounted to **0.07 µSv** in 2020 which is **0.003%** of the dose on average received by an individual due to natural sources of radiation.

Radioactivity is a natural part of our environment

Annual dose from natural sources: 2390 μSv

Annual dose from artificial sources (medicine, industry): 700 μSv

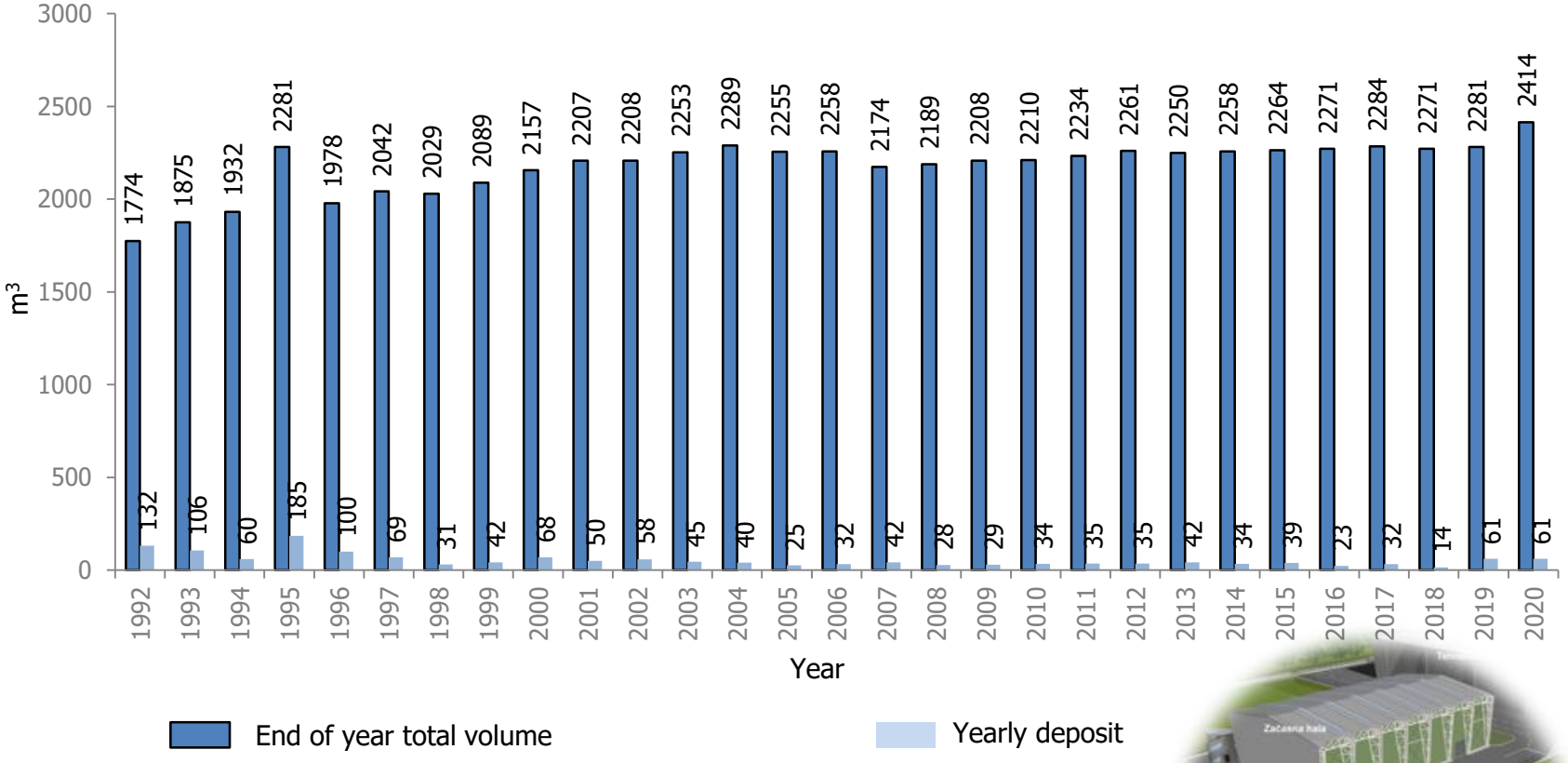
A flight from Europe to the USA: 40 μSv

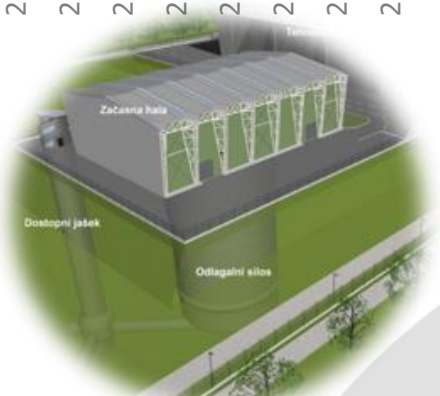
Nuclear-weapons tests, Chernobyl accident: 33.7 μSv

Annual dose from Krško NPP: 0.07 μSv

Minimising the Volume of Low and Intermediate Level Radioactive Waste - LILRW

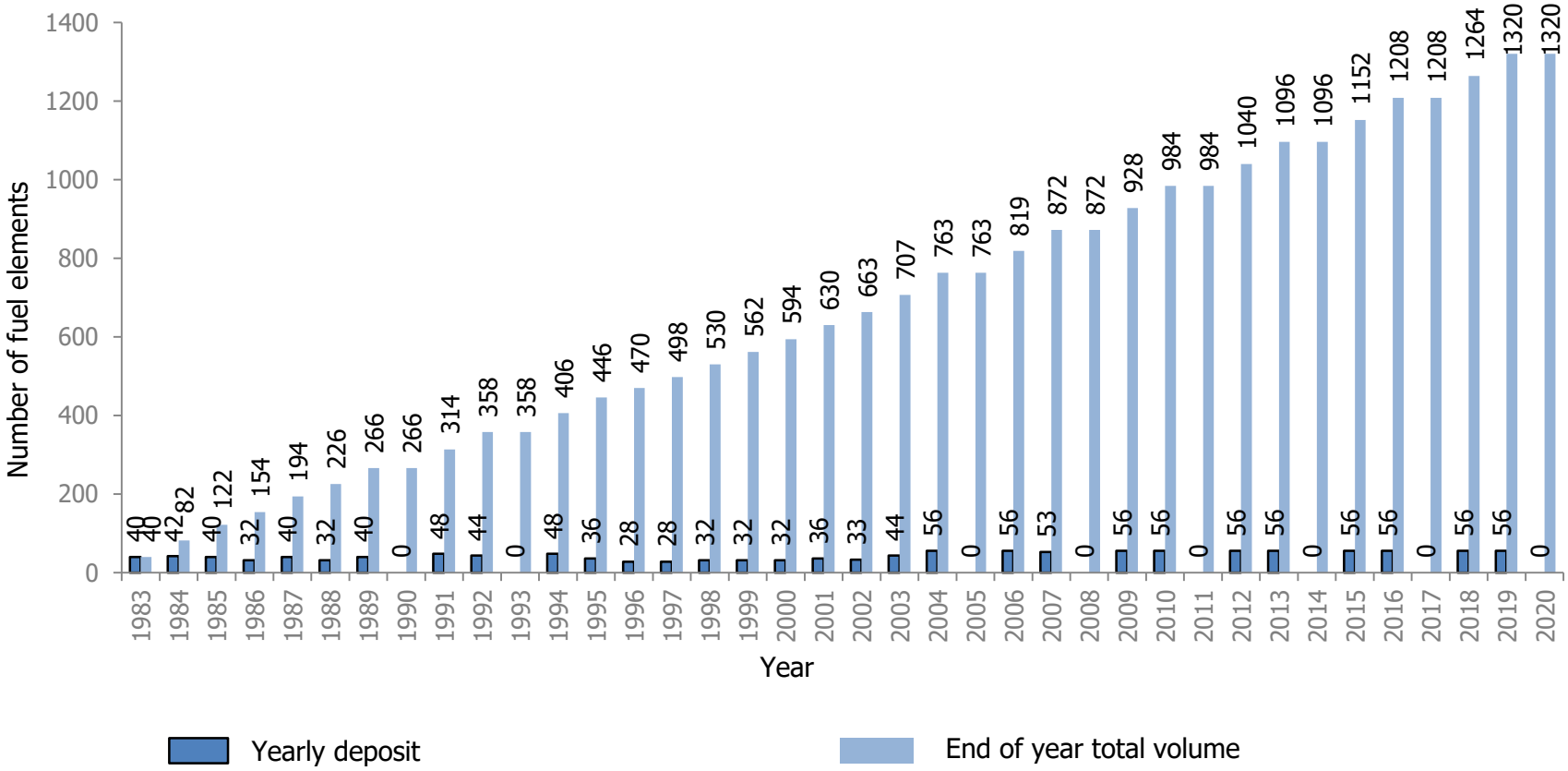
Volume of low and intermediate level solid radioactive waste





Spent Fuel Management

Total No. of Spent Fuel Elements in the SFP per year



Up to **2020**, there were **1320** spent fuel elements stored in the SFP, i.e. 512.9 tonnes.

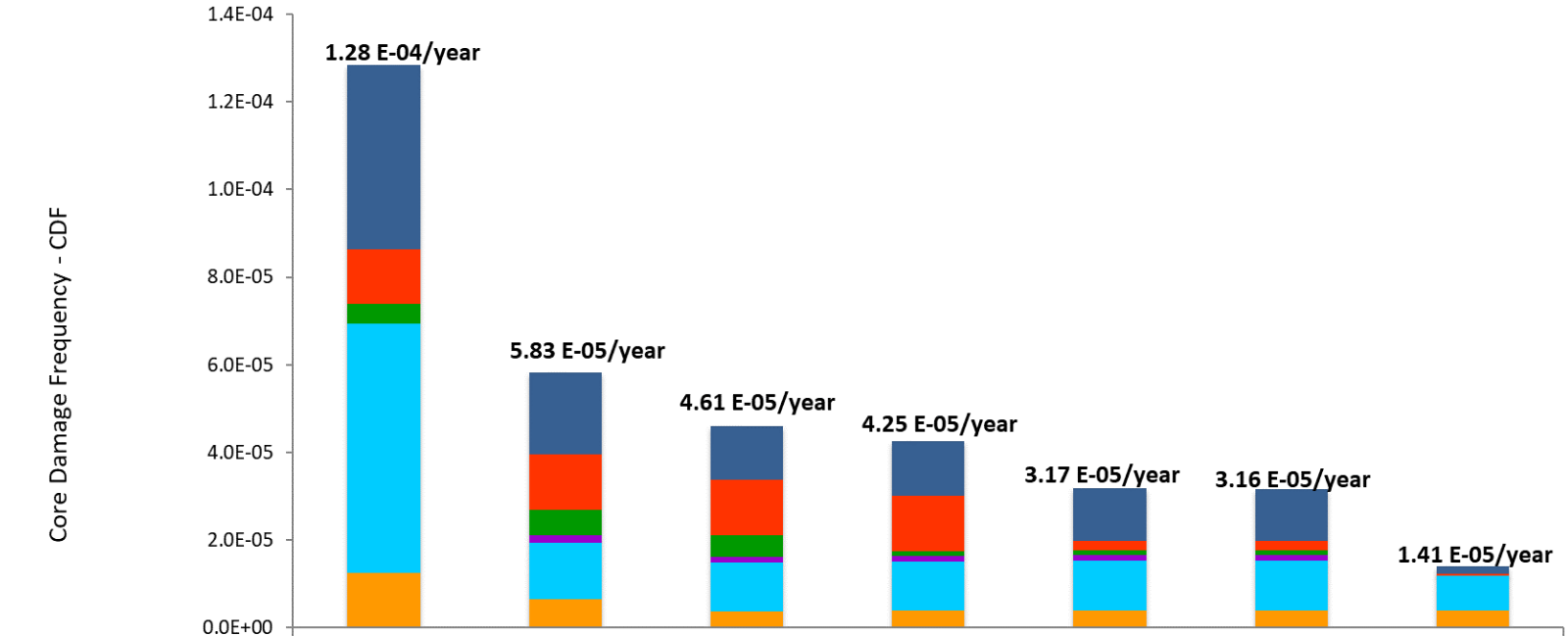
Nuclear Safety Goals

- **Stable Plant Operation –** prevent design basis accidents & maintain/ensure minimal radiological risks & extremely low probability of beyond-design basis accidents.

- **Exposures to Ionising Radiation ALARA –** low radioactive releases during routine plant operations and accident conditions in compliance with prescribed limits.

- **Environmental Protection –** safe work places, public safety & environmental safety, effective radiation protection.

Reducing the Risk of Core Damage Frequency (CDF)



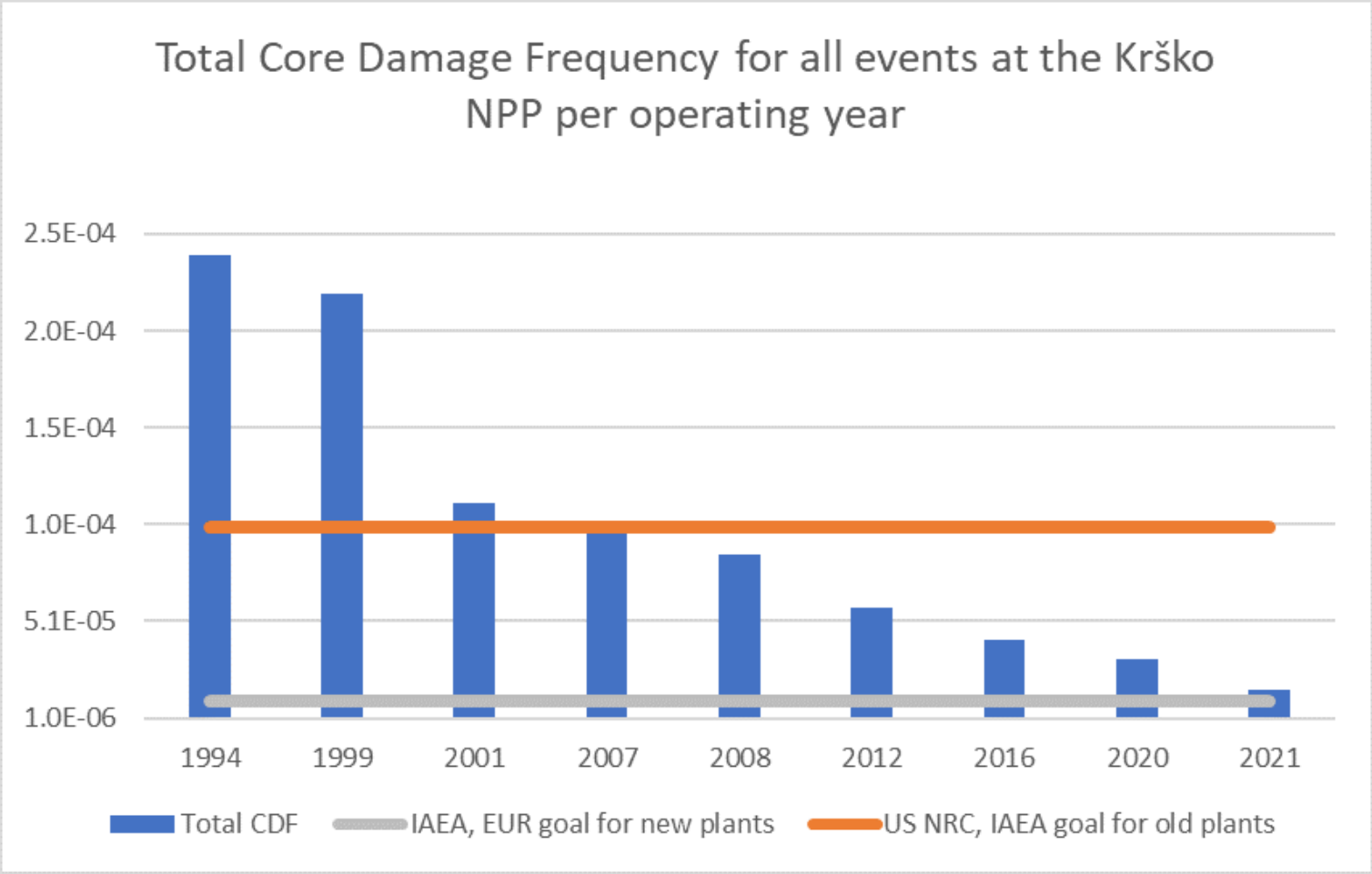
	2000	2012	2015	2016	2018	2019	2021
Internal Initiating Events	4.20E-05	1.87E-05	1.24E-05	1.24E-05	1.20E-05	1.18E-05	1.81E-06
Internal Fire	1.25E-05	1.28E-05	1.26E-05	1.26E-05	2.14E-06	2.14E-06	3.53E-07
Internal Flooding	4.53E-06	5.61E-06	4.87E-06	1.14E-06	1.13E-06	1.14E-06	9.03E-09
High Energy Line Breaks		1.79E-06	1.39E-06	1.36E-06	1.24E-06	1.28E-06	2.82E-08
Seismic Events	5.67E-05	1.29E-05	1.11E-05	1.12E-05	1.14E-05	1.14E-05	8.04E-06
Other External Events	1.26E-05	6.50E-06	3.73E-06	3.83E-06	3.83E-06	3.83E-06	3.83E-06

HELB = High Energy Line Break

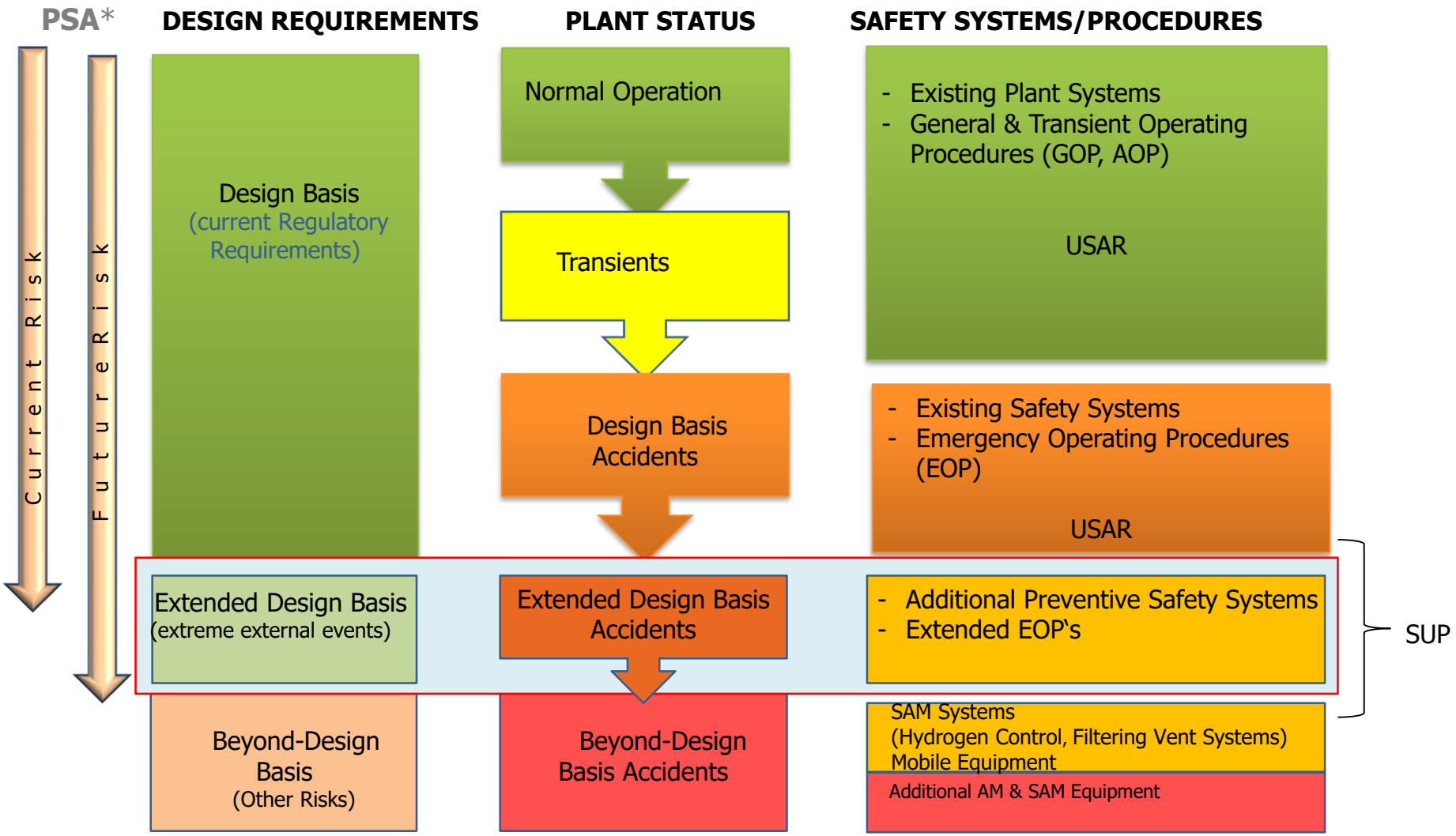
CDF = Core Damage Frequency

IE = Initiating Event

Reducing the Risk of Core Damage Frequency (CDF)



Safety Upgrade Program Concept



***PSA** – Probabilistic Safety Assessment

Safety Upgrade Program (SUP) 2011-2021- objectives

Assuring nuclear safety in case of extreme natural disasters and other law probable extreme events

- **Safety Upgrade Program (SUP) 2011-2021 - 10-year investment cycle (~350 mil EUR)**
  - Introduces new **robust engineering solutions** to assure additional resistance of the plant against extreme natural disasters and other extreme events.
  - The scope of the SUP is: **new Emergency Control Room and Technical Support Centre, new independent system for RCS depressurization, new RCS/CNT alternative long-term cooling, upgrade of NSSS flooding protection, SFP alternative cooling, upgrade of Operational Support Centre, bunkered additional water sources, and Spent fuel dry storage.**

- The SUP is based on the **highest nuclear standards of nuclear industry** developed after Fukushima accident, based on Slovenian regulatory requirements and European practice.

- The SUP is supporting **Krško NPP long-term plant operation** (up to 2043). It is approved by Slovenian Nuclear Safety Administration, and financially supported by the owners.

- The SUP is **divided into three phases**: the first phase is already implemented, the implementation of the remaining two is being finalized, and the completion of the **spent fuel dry storage** is scheduled for 2022. The first 592 fuel elements will be moved from the spent fuel pit to the dry storage in 2023.

- The implementation of the Safety Upgrade Program will enable long-term operation. When completed, the residual risk of the plant will be **comparable to the risk of the newly built units.**

Safety Upgrade program to meet new regulatory requirements

Design Extension Conditions - DEC

- Design Extension Conditions (DEC) is derived on the basis of **engineering judgment, deterministic assessments and probabilistic assessments** based on reference IAEA SSR-2/1 document[1], NEK IPE evaluation and Krško NPP Analyses of Potential Safety Improvements. There are some combinations of events that are more severe than design basis accidents and are considered as design extension requirements. These combinations addressed in the area of prevention (**DEC A**) of severe accidents are:
  - Combination of **seismic event** (PGA up to 0.6g), consequentially caused **LOCA and Station Blackout (SBO)**, assuming that **new bunkered DEC A equipment is available** and existing **DB** equipment (DG, AF, SI, RHR ...) is not available.
  - Combination of **seismic event** (PGA up to 0.6g) and **external flooding**, assuming that **new bunkered equipment (DEC A) is available** and **DB** equipment is not available, NSSS complex is not flooded.
  - Combination of **seismic event** (PGA up to 0.6g), **loss of Ultimate Heat Sink (UHS) and SBO**, assuming that **new bunkered equipment (DEC A) is available** and **DB** equipment is not available.
  - Combination of **large commercial aircraft crash and fire**, assuming that **new bunkered equipment (DEC A)** is available and **DB** equipment is not available.
- **All other combinations** of events /accidents are considered as Beyond Design Bases and will be addressed **by mobile equipment (FLEX approach)**.

1- IAEA Specific Safety Requirements, SSR-2/1, January 2012.

Safety Upgrade program to meet new regulatory requirements

Design Extension Conditions – DEC (continued)

- The assumed **time duration** of the before mentioned conditions for **DEC A** equipment/systems are the following:
  - Loss of off-site power (**LOOP**) for **7 days**,
  - Station blackout (**SBO**) for **72 hours**, **valid for DB equipment** emergency power supply with assumed DEC equipment available and DB equipment not available,
  - Loss of ultimate heat sink **(UHS) for 30 days**,
  - **Loss of the UHS combined with SBO**, assuming that DEC equipment is available,
  - **flooding water will retain for 7 days**.

- For the purpose of **severe accident mitigation (DEC B)** it is assumed that none of the equipment (**DB and DEC A** – bunkered equipment) **will be available for first 24 hours** and that core will be **melted and corium relocated** into containment.
  This is the basic assumption for Design Extension Conditions for Containment Filtering Vent System and Passive Autocatalytic Recombiners

DEC B Basic Design requirements: prevent CNT failure and any long-term land contamination

Safety Upgrade program to meet new regulatory requirements

Projects of SUP – implementation in 3 phases

- **CFVS and PAR -** ensuring containment integrity – passive pressure & hydrogen control → **Phase 1 2013**

- **BB1 –** Upgrade/relocation of Emergency Control Room and Technical Support Center
- **New Independent system for RCS depressurization**
- **SFP alternative cooling** (installation of permanent spray and pipes to allow quick connection of mobile Hx)
- **RCS/CNT alternative long-term cooling** (additional alternative RHR pump being able to recirculate primary coolant form RCS/CNT via Hx cooled by mobile means
- **Upgrade of NSSS flood protection** - ensuring flood safety even in the case that the plant site would be flooded
- **Upgrade of** the existing **Operational Support Center** to assure safety atmosphere and food for all the required personnel during a severe accident

Phase 2 2018-2021

- **BB2 – Bunkered additional water source, additional safety systems - injection into RCS & CNT, and SG.**
- **Installation of high temperature resistant RCP seals**
- **Spent Fuel Dry Storage**

Phase 3 2021/23

Safety Upgrade Program

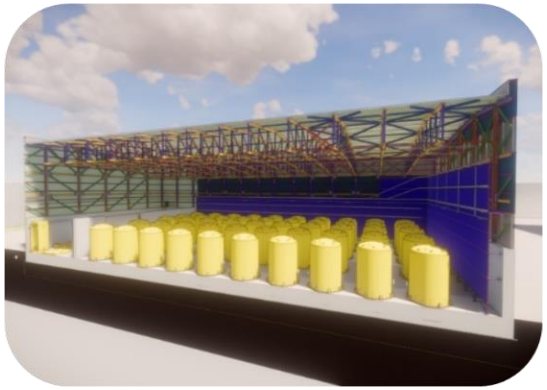
Spent Fuel Transition to Dry Storage

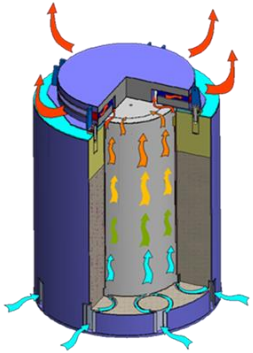
Existing wet storage

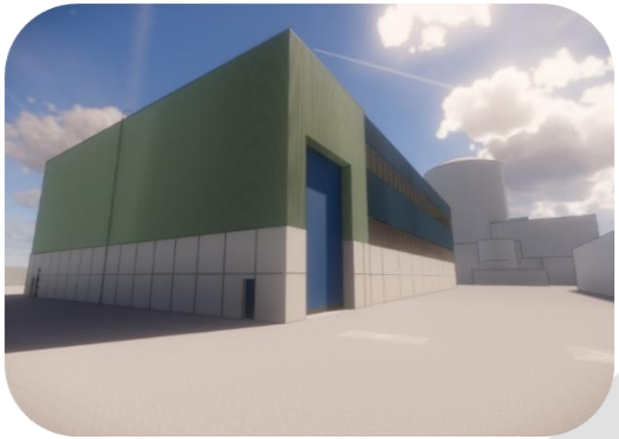
Dry storage technology

- ✓ Krško NPP decided to use HOLTEC multipurpose cask storage system with concrete over packs.
- ✓ A Dry Storage building is constructed for the amount of app. 2600 fuel assemblies. (Storage building for 70 canisters)
- ✓ Design is allowing Krško NPP to transport fuel assemblies off site in the future.
- ✓ First loading (16 containers, 592 fuel assemblies) will take place in 2023.
- ✓ Second loading (16 containers, 592 fuel assemblies) will take place in 2028.

Dry storage under construction

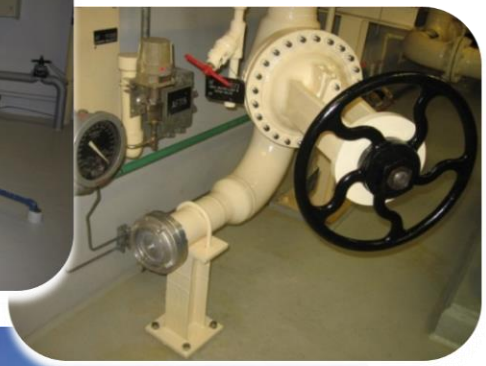






Coping with Beyond Design Basis Condition

- Mobile equipment
- SAM systems







Operating Licence

There is no time limit for plant operation. The following conditions apply:

- Carry out **PSR** every 10 years:
  (The first two completed in 2003 and 2013; the next ones will take place in 2023 and 2033.)
  - Systematic and comprehensive review of nuclear safety;
  - Use of the highest safety standards as the benchmark in nuclear safety;
  - Confirmation that the plant is able to operate safely during the next decade;
  - Highly-motivated and competent staff;
  - Proactive and competent organisation;
  - Continuous improvements in all areas.

- Operating limits are stated in the Krško NPP's TS and Radiological Effluent Technical Specifications.

- Periodic Review of emergency preparedness is required after each risk assessment, after each change in emergency resources or every three years.

Long-Term Operation (LTO) - 2043

- Krško NPP has successfully established the Ageing Management Program.
- Krško NPP installed the EQ-equipment* in Outage 2012, thus satisfying the last requirement for the LTO from 40 to 60 years.
- In July 2012, the Slovenian Nuclear Safety Administration approved the Ageing Management Programs and USAR changes allowing the Owners to extend the plant life on the basis of economic viability.
- LTO program and Krško NPP internal organization are established.
- LTO environmental assessment is in progress.

* Environmental Qualification is a process for ensuring that equipment will be capable of withstanding the ambient conditions that could exist when the specific function to be performed by the equipment is actually called upon to be performed under accident conditions (i.e. higher pressure, temperature, neutron radiation)

Radioactive Waste and Spent Fuel Decommissioning and Disposal Programs

- **Revision 3 of the Decommissioning Program of the Krško NPP and the Low and Intermediate Level Radioactive Waste and Spent Fuel Disposal Program** were finalised in 2019 and confirmed at the 14th Interstate Meeting - ISM* on July 2020.

  - At its 13th session in September 2019, the ISM concluded that no agreement was reached between the Republic of Slovenia and the Republic of Croatia on the joint disposal of low and medium radioactive waste from the Krško NPP. Each county will take half of the wastes in the years 2023 to 2025.

  - The LILRW study, which was created by the end of 2017, was confirmed in the context of the third revision of the LILRW and Spent Nuclear Fuel from Krško NPP Disposal Program.

*ISC - Interstate Commission for the monitoring of the implementation of the Treaty between the Government of the Republic of Slovenia and the Government of the Republic of Croatia on the regulation of the status and other legal relationships connected with investments in the Krško nuclear power plant, its exploitation and decommissioning.

Future Challenges

- Maintain high level of safety and availability.
- Complete the Safety Upgrade Program (SUP) and implement Ageing Management Programs.
- Successfully complete 10-year PSRs (2023, 2033, 2043).
- Ensure disposal/storage capacity for low and intermediate level radioactive waste.
- Complete Environmental Assessment as required for long-term operation.
- Complete international safety missions (SALTO, WANO).

Conclusions

- The use of nuclear energy is supported by the **INTEGRATED NATIONAL ENERGY AND CLIMATE PLAN OF SLOVENIA**

- In Slovenia, we are meeting the necesary preconditions for long-term nuclear future:

  - **safe and reliable nuclear operating history;**
  - **well established nuclear infrastructure in Slovenia;**
  - **highly motivated and competent professionals;**
  - **proactive and learning organization;**
  - **continuous improvements in all areas.**

- Nuclear energy in Slovenia:

  - **plays an important role** in reducing CO_2 emissions and in providing security of supply of electricity in a competitive way.

Thank you for visiting us.

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