

Slovenian dual track policy for HLW and SF disposal

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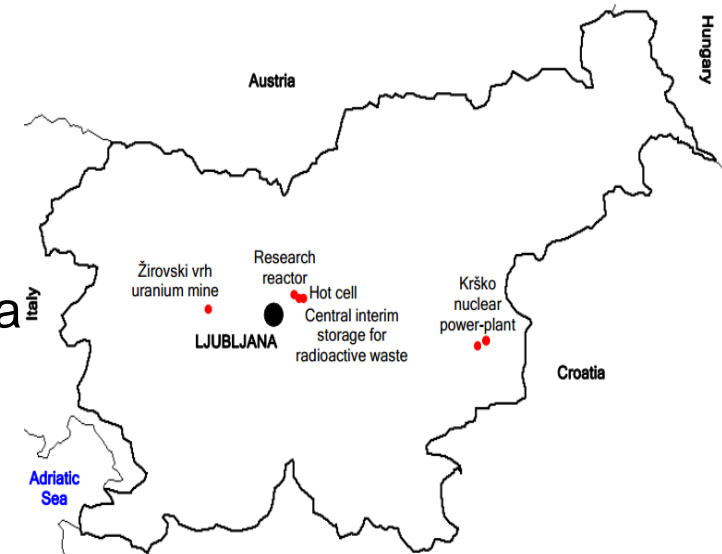
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Slovene Nuclear Program

Small nuclear program

- 1 NPP, 727 MW_e – electric power; 5 to 6 TWh/y operated by NEK, owned by Slovenia (GEN) and Croatia (HEP)
- 1 research reactor; 250 kW_{th} operated by JSI, owned by RS
- 1 closed, remediated uranium mine (operation period 1984 - 1990)
2 disposal sites operated by ARAO and RŽV, owned by RS
- 1 central interim storage facility for institutional waste operated by ARAO, owned by RS
- 1 approved site for LILW repository (2009-) finalisation of the construction permit approval and start of construction



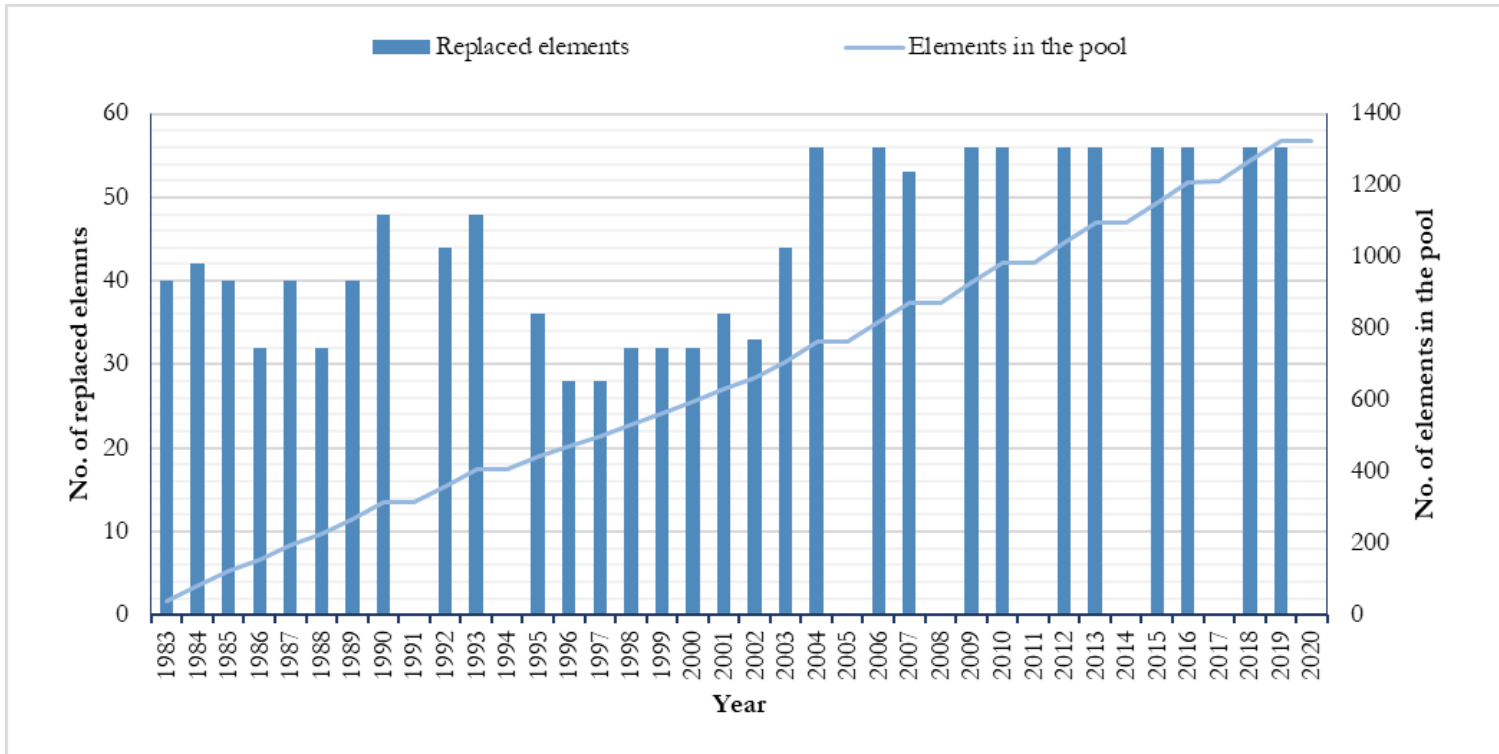
Nuclear Power Plant Krško



- Ownership: 50 % GEN energija, 50 % HEP
- Westinghouse PWR, 2 loop, 1994 MWt, 727 MWe, in operation since 1983
- It is planned that the operation of the NPP will be extended from 2023 to 2043, pending the successful conclusion of EIA and periodic safety reviews in 2023 and 2033
- 2004 NPP started operating with eighteen-month fuel cycles ($\frac{1}{2}$ of core removed - average 56 FA)
- Spent fuel stored in wet spent fuel pool (31/12/2020 SFP – 1323 FA)
- NPP LILW waste managed and stored on site (2303 m³)

SF Inventory in Slovenia 31/12/2020

SF in WSFP in Krško NPP



There are currently no spent or damaged RR Triga fuel elements. In 1999, all total 219 spent fuel elements were shipped for return to the USA.

RW and SF Management Framework

- Ionising Radiation Protection and Nuclear Safety Act from 2002 (last amended in 2017 and 2019) requires national RW and SF management programme
- Revision in National Programme for Managing Radioactive Waste and Spent Nuclear Fuel for period 2016-2025 (ReNPRRO16-25)
- Letter of formal notice from EC \Rightarrow ReNPRRO16-25 will be amended. ARAO prepared the expert basis for ReNPRRO23-32 - in September 2021 submitted to the Ministry of the Environment and Spatial Planning for further approval procedures, adoption planned by the end of 2022.
- Treaty between the Government of the RS and the government of the RC on the regulation of the status and other legal relations regarding investment, exploitation and decommissioning of the Krško NPP
- Program of Krško NPP Decommissioning and Program of Krško NPP SF & RW Disposal according to bilateral treaty with RC

National Policy

- Included in the ReNPRRO16-25
- Safe, secure and efficient management of RW
- To ensure uninterrupted operation and sufficient storage capacity in the SFP, dry cask storage facility is under construction with operational license for 60 years after Krško NPP shutdown.
- Operation of the research reactor TRIGA is approved until 2024 with possibility of extension until 2043.
- For final SF&HLW disposal, a dual-track policy has been adopted as the appropriate solution in the present situation. The dual-track approach in the Slovenian strategy includes both the option of multinational or regional disposal and a basic reference scenario for national geological disposal.

Current plans for HLW and SF management

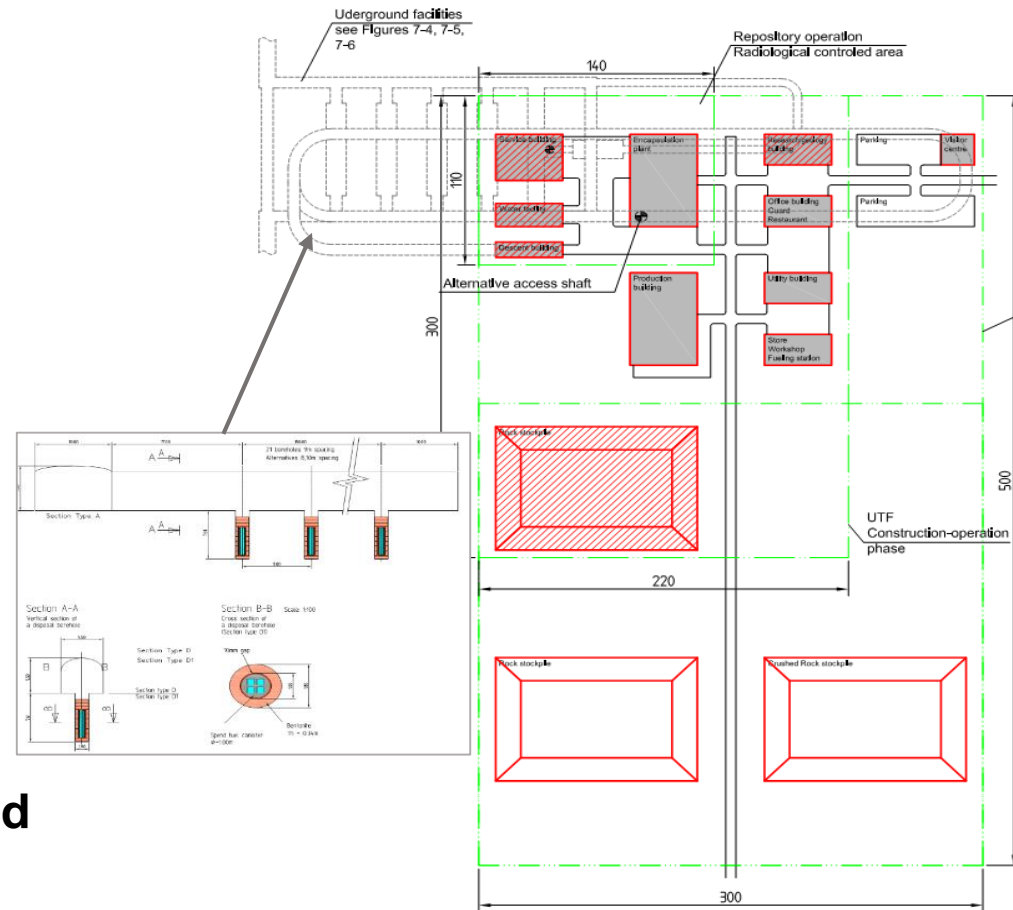
- Owner is responsible for management before disposal.
- NPP SF is stored on site (wet storage in pools, dry storage facility construction started in March 2021).
- SFDS can only be operated at NPP Krško site under domain of NEK until the end of NPP operation (2043). Further operation of SFDS at NPP Krško site is subject of additional negotiation and potential further agreement between Slovenian and Croatian government.
- Until 2025, SF owners have to analyze reprocessing and recycling options for the SF taking into account safety and economy aspects.

Possible disposal solutions for HLW&SF

- **Possible alternative options for final solution for SF&HLW management (dual track approach):**
 - Different options of fuel reprocessing,
 - Disposal of reprocessing remains
 - Disposal of SF or/and HLW (reprocessing residues):
 - National repository,
 - Disposal in regional, multinational repository for smaller EU nuclear power programs
- **SLO-CRO discussions for the disposal of HLW and SNF will be ongoing with the current plan being to develop a joint solution that involves either**
 - a deep geological repository in one of the countries, or
 - joint participation in a multinational repository.
- **ARAO monitors international development in the field of SF&HLW managing and disposal**

Deep Geological Disposal facility

- Reference scenario 2004
- Revised in 2009
- Hard rock environment 500m (KBS-3V)
- Crystalline – igneous and metamorphic
- Basic repository description
- Small underground “footprint”
- Shared responsibility
 - Between Slo and Cro
 - Several areas
- 2019 revision of the reference scenario with cost estimation under the umbrella of revised Krško NPP Radioactive Waste and Spent Fuel Disposal Program
- A new revision planned in 2022



Reference scenario 2018 for geological disposal

- Two basic scenarios, both with NEK operation until 2043 are examined as follows:
 - Base case scenario (Scenario No. 1) – start of regular operation of the SF repository in 2093; 10 years of operation; dry storage facility needed until 2103;
 - Sensitivity case scenario (Scenario No. 2) – start of regular operation of the SF repository in 2065; 10 years of operation; dry storage facility needed until 2075
- In addition, several options are assumed and evaluated for RS 2018 as alternative solutions
 - Option 1: Post closure monitoring for 50 years (not part of basic scenarios);
 - Option 2: Encapsulation in regional encapsulation plant; and
 - Option 3: Disposal in multinational repository (dual-track approach)

Dual track approach-international solutions

- **Plans for national deep geological disposal were prepared, they are regularly updated, and new knowledge is added**
- **In parallel to a national disposal programme (last updated in 2019), multinational disposal is a possible option. Both options work in parallel until the beginning of construction of a national repository in 2086**
- **Slovenia participates and contributes to shared knowledge and participates in EU & IAEA projects to receive the benefit of shared RD&D**
- **Active participation in multinational initiatives (ERDO, IFNEC, IAEA) provides prospect of a shared solution**
 - ARAO as a founding member participated in ERDO WG - European Repository Development Organisation WG, and is now a member of new ERDO Association
 - Slovenia is member and supports IFNEC RNFSWG work

Why is the Dual Track Strategy Suitable for Slovenia?

- **Is it really feasible to have in each and every country a deep geological repository (DGR) ?**
 - In the country A that generates 20 tHM per year and
 - in the country B that generates 2 m³ of HLW per year?
- **That is neither the most optimal, nor economical, nor safest approach!**
- **Slovenia is a small and densely populated country with a heterogeneous and relatively geological active environment.**
- **It would be difficult to identify a suitable location to site a DGR according to all required established international conditions and standards.**
- **In Slovenia, the export of the SNF and HLW is an acceptable societal solution.**
- **RD&D competence and capacity needed for deep geological disposal is currently limited in Slovenia as in many small program countries.**
- **Slovenia is responsible for disposal of only small amount of HLW and SNF (1/2 Slovenian share from Krško NPP approx. 460 tHM SNF and 41 t of HLW).**

Why is the Dual Track Strategy Suitable for Slovenia cont.?

- 2019: Costs of construction and operation of a national DGR were estimated at 1.14 billion € (1.26 billion \$). Specific per unit cost is approx. 1.23 million € (1.36 million \$) per tHM - significantly higher compared to advanced national DGR programs (Finland, Sweden, France, ...).
- Cost of back-end fuel cycle is higher for small programs (The Economics of the Back End of the Nuclear Fuel Cycle; 2013, OECD NEA 7061, Paris)
- Is this the opportunity for shared HLW & SNF disposal solutions?

Why is the Dual Track Strategy Suitable for Slovenia cont.?

- If 5 partners (nations) decided to construct one joint DGR, equally sharing investment and contingency costs with variable inventory-dependent operational costs, then total costs for the disposal of 926 tHM from Krško NPP would amount to 0.50 billion EUR (0.55 billion USD) with unit disposal costs of 0.55 million EUR (0.61 million USD) / tHM.
- SNF and HLW quantities are small and provide almost no disposal economy of scale. The burden on electricity price production due to assuring adequate financing for national disposal is relatively large.

What has Slovenia done so far to implement and promote the dual track policy?

- Confirmed that its policy, principles of RW and SF management and national legislation does allow this approach.
- Documented its policy: e.g., in the Joint Convention reports and reports for the European Commission in line with Council Directive 2011/70/Euratom.
- Has gained a lot of experience from joint nuclear program with Croatia including discussions, planning and implementation for LILW repository and SF and HLW storage facility.

What has Slovenia done so far to implement and promote the dual track policy? cont.

- Signed up at government level to partner with other like-minded countries (e.g. in Arius, ERDO-WG and ERDO Association).
- Allocated long-term funding for such activities.
- Allocated responsible organizations and personnel with duties for following and promoting this.
- Officially compared the costs of both tracks.
- Participates actively in relevant activities of international organizations (IAEA, EC, IFNEC, WNA, regional meetings and others).
- Participates in European projects considering sharing pre-disposal activities and facilities as a first step towards shared disposal.

Activities planned to support/enhance the dual track policy

- Annual funding for planning, RD&D and other activities for disposal of HLW&SF in national, regional or multinational repository will be increased and secured on long term basis
- Cooperation with RC on the issue of LILW, SF storage and disposal will continue
- 4th revision of the joint Disposal program for RW&SF from Krško NPP: planned that disposal in sedimentary geo structures and DBD option will be additionally analysed, regional/multinational option will be explored in more detail

Activities planned to support/enhance the dual track policy cont.

- **KPI's: ARAO should perform at least 3 major activities every 5 years (planned):**
 - Revision of disposal concept, design, ...
 - PA/SA and preliminary WAC
 - Siting criteria development
 - RD&D plan, pre-operational monitoring development
 - Analysing reprocessing option and its influence on disposal program
 - Alternative disposal concepts (DBD, ...)
 - Cooperation in international organisations, associations, projects, ... to analyse, develop and implement regional/multinational pre-disposal and disposal activities and facilities
- **ARAO should at least every 5 years prepare an analysis of available options and feasibility, timetable, concept of disposal and cost estimates for the disposal of HLW&SF in a national, regional or multinational repository.**

Opportunities and Challenges

- Preparation of the 4th revision of the Krško NPP Decommissioning Program and Disposal Program for the RW&SF from Krško NPP with other partners (Fund NEK and NPP Krško)
- Further improvements of SF&HLW plans with more details on technical solutions and reliable cost estimates (parallel development of geological disposal concept in other geological environments including the data acquisition for such formations)
- In parallel analysis and development of regional/multinational disposal options (first focusing on pre-disposal activities, costing and financing, benefits and challenges, identifying preliminary WAC, regulations and RW inventory harmonisation, ...)
- Research and development activities for RW&SF management planning – participation in EU projects and IAEA Technical Cooperation Program
- ERDO Association- active membership, continuation of work in 2 ongoing projects (DBD and LWC), potential to start new (costing and financing, sharing predisposal activities, ...)

Conclusions

- SFDS at Krško NPP site will enable safe and cost-effective storage of all planned SF and HLW inventory for at least 60 years after Krško NPP shutdown.
- Every country should, regardless of the implemented national dual track policy develop, maintain and regularly update its plans for HLW&SF disposal in a national repository.
- The essence of the dual track policy is that you should constantly promote, monitor, develop and compare possible multinational disposal options with the national DGR project. This means that nothing is lost, and you can change track when needed and give acceleration to national DGR project when necessary.
- The reference scenario for repository in suitable hard rock on the generic location somewhere on the territories of RS and RC has been prepared and options of SF disposal in a regional repository and/or use of regional encapsulation plant were considered.

Conclusions cont.

- Slovenia, with a small nuclear programme and limited options for potential repository locations with unfavourable geological disposal conditions finds it difficult to implement a complex and capital-intensive national repository project.
- From the perspective of a small country and programme, we see development of any geologic repository as a very challenging and complicated task that can benefit significantly through regional or multinational cooperation.
- Only modest resources are required in Slovenia to maintain the dual track approach and promote regional or multinational disposal.

Thank you for your attention!

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ISO 9001 Q-1599
ISO 14001 E-216

