HTGR-POLA: Project Overview and Approach to Spent Fuel Management

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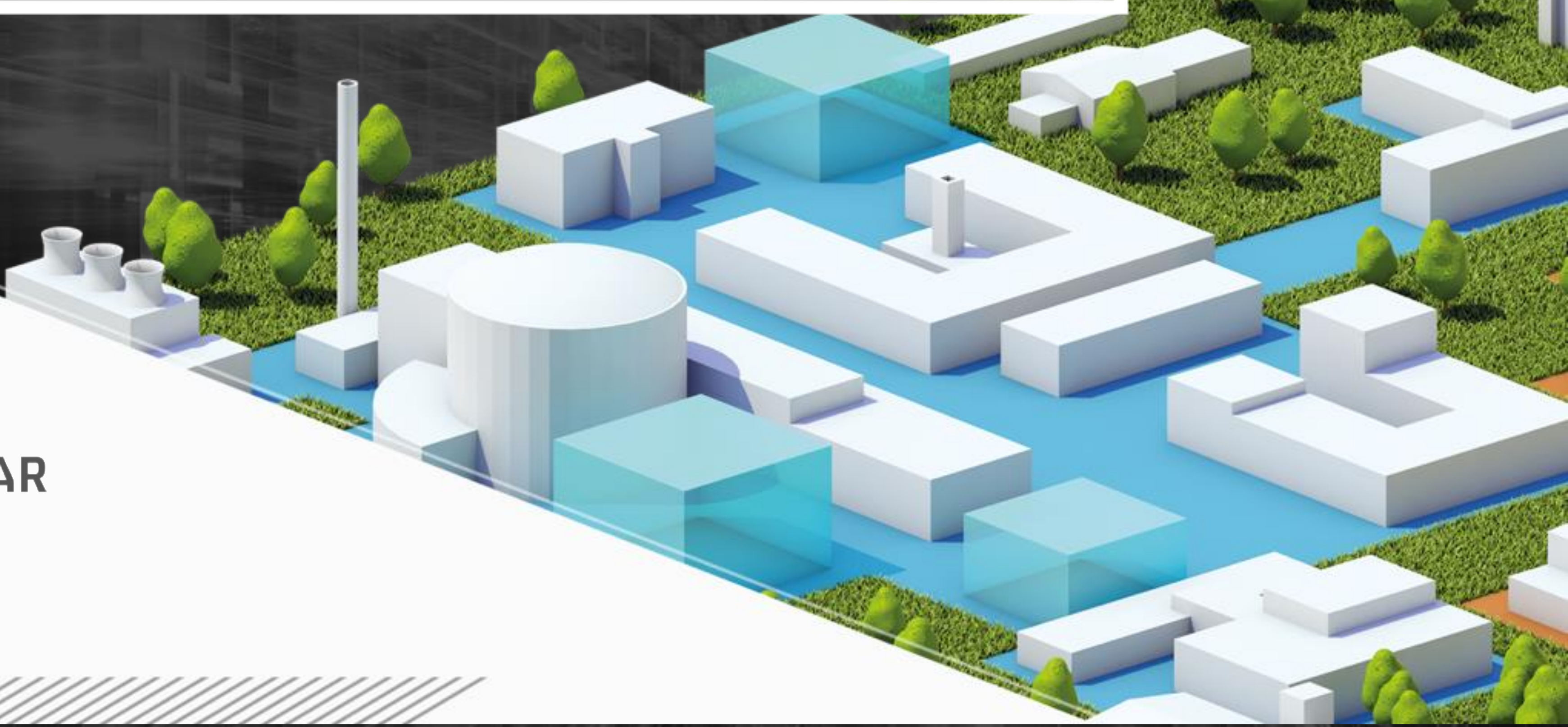
Technical Meeting on the Management of Spent Fuel (Pebbles and Compacts) from High Temperature Reactors, Vienna 7-11 July 2025



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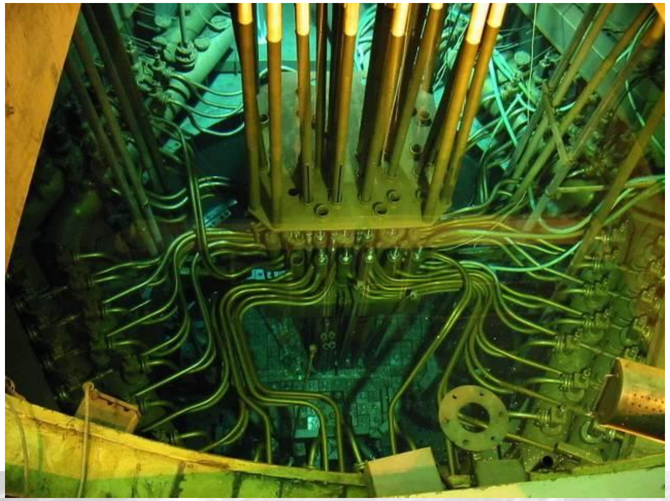
- **NCBJ is one of the largest research institutes in Poland.**
- **1170 employees, inc. 80 prof. & 185 PhD; students: ~44 students**
- **The only nuclear research reactor in Poland, MARIA.**
- **MARIA is the sole research nuclear reactor operated in Poland; 30 MWt with first criticality in 1974.**

NCBJ Highlights

- Nuclear Facilities Operations Department
- Material Physics Department
- Department of Fundamental Research
- Department of Nuclear Tech. and Equipment
- Department of Complex Systems, CIS
- Radioisotope Centre, POLATOM
- Division of Nuclear Equipment
- Science and Technology Park
- NOMATEN Centre of Excellence
- Scientific-and-Industry Centres



The HTGR-POLA project was developed in cooperation with the Japan Atomic Energy Agency (JAEA) and is being carried out on behalf of the Ministry of Science and Higher Education (formerly: Ministry of Education and Science) under the contract titled: "High-temperature research project. Technical description of a research high-temperature gas-cooled nuclear reactor" (Contract No. 1/HTGR/2021/14).

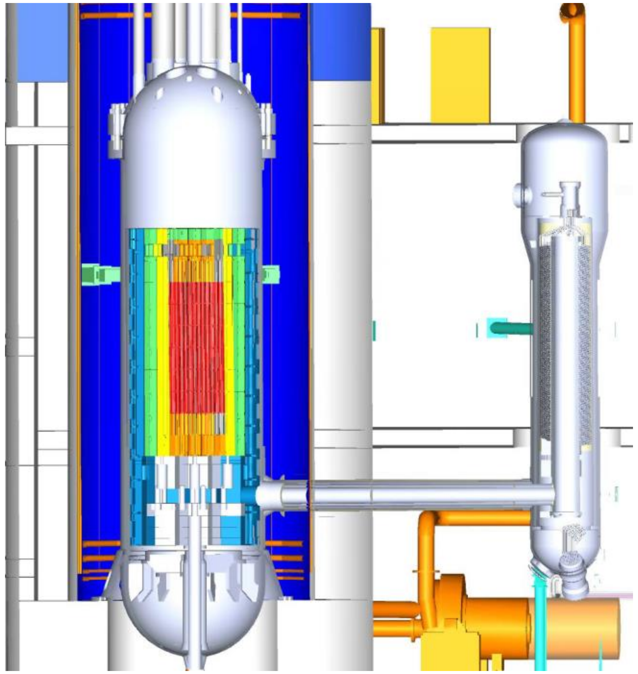
Outline

- **HTGR-POLA: background, mission objectives, status**
- **HTGR-POLA: fuel and core design**
- **SNF management options**
- **HTGR-POLA: direct interim storage**
- **HTGR-POLA: reports and recent papers**

HTGR-POLA: background, mission objectives, status

Overview

- HTGR-POLA is a **research reactor** concept developed by **NCBJ** in collaboration with the **Japan Atomic Energy Agency** (JAEA), leveraging their experience with the HTTR reactor.
- Intellectual property NCBJ:JAEA is 50:50
- HTGR-POLA is a **small-scale, prismatic-type**, helium-cooled, graphite-moderated reactor with a **thermal power output of 30 MW**.
- It is **designed for cogeneration**, capable of producing up to 10 MW of electricity and high-temperature steam at 540°C, **suitable for industrial processes** and municipal heating.
- **Engineering support**: Energoprojekt Katowice, Mitsubishi Heavy Industries (MHI), Fuji Electric, Toshiba Energy Systems and Solutions (Toshiba ESS), AGH University of Science and Technology.

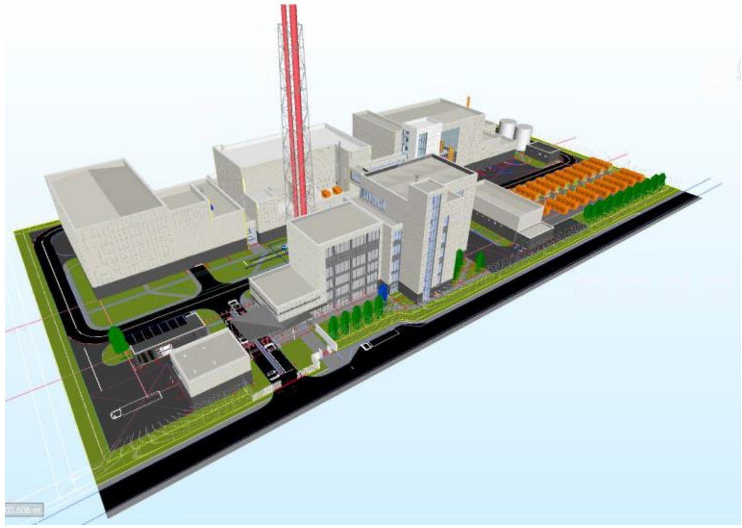


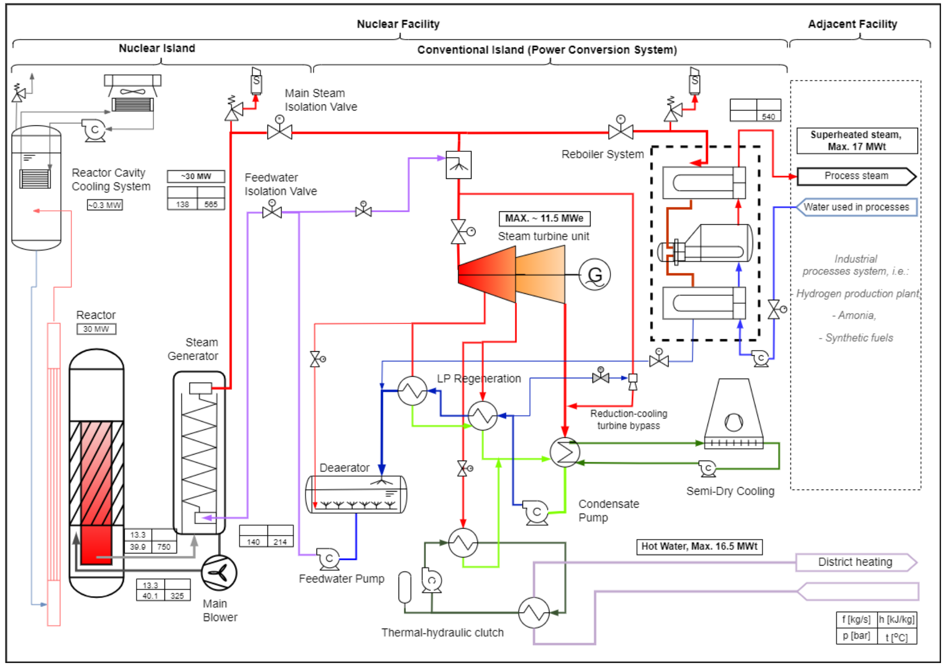
Mission objectives

HTGR-POLA

The primary **mission objectives** of HTGR-POLA are to:

- **Support the licensing and demonstration** process for industrial-scale commercial reactors.
- Demonstrate and assess HTGR technology and its practical applications in an industrial setting.
- Advance **research on structural materials and TRISO fuel**.
- **Build expertise** in design, construction, operation, and training.
- Improve **safety assessment methods and tools**.





Project status

HTGR-POLA

2012-2019: Preliminary studies and technological innovation

2019-2021: Preconceptual design phase and technology assessment

2021-2022: Conceptual Design Phase

2022-2024: Basic Design Phase

- basic design of a plant (LOD minimum 200) and selected chapters of Preliminary Safety Report
- separate designs for a nuclear island and a conventional island (a superheated steam supply energy conversion plant), followed by the integration of two islands into a single project.
- May 2025, the Ministry of Science and Higher Education formally approved the final report and basic design documentation of the HTGR-POLA project.

Next phases (planned): Licensing Phase and Detailed Design Phase, Construction, Commissioning

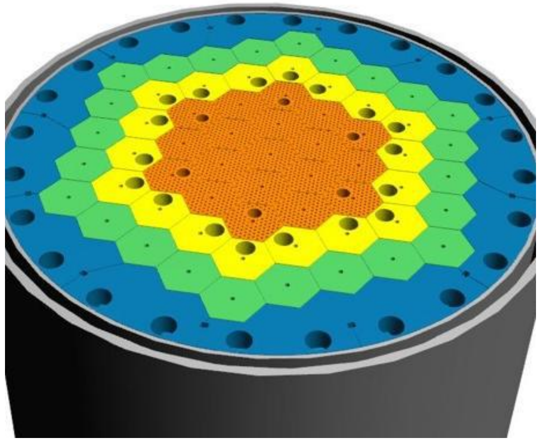
To date, a governmental decision to proceed to the next phase of the HTGR-POLA development has not yet been issued. However, in May 2025, **NCBJ initiated an official technical dialogue with the National Atomic Energy Agency** to obtain a general opinion on the HTGR-POLA facility.

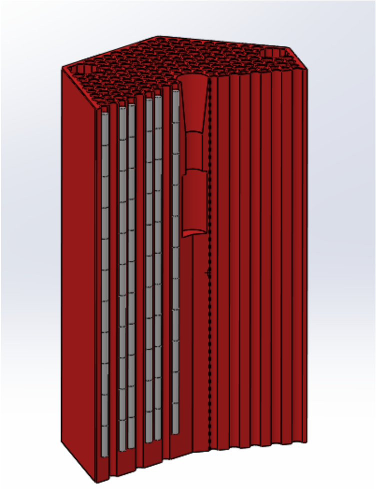
HTGR-POLA: fuel and core design

Design 1/2

HTGR-POLA

- Prismatic-type, helium-cooled, graphite-moderated reactor.
- Active core: **19 fuel columns, each of 6 fuel blocks**, assembled into two rings around a central column.
- Two types of fuel blocks: standard fuel blocks and control fuel blocks
- Fuel block: a triangular array of **blind-drilled fuel holes** and **through-drilled coolant channels**.
- High-Assay Low-Enriched Uranium (**HALEU**) in the form of **UO_2**.
- **Enrichment level and packing fraction** of TRISO particles in compacts **vary** according to location.





Design 2/2

- **Multiple core design options were evaluated**, including variations in fuel type, enrichment levels, packing fractions, as well as fuel reloading schemes and spent fuel management strategies.
- Reference approach, an **open fuel cycle with direct interim storage** of entire fuel assemblies.
- A **single-batch fuel management scheme** is adopted, in which the entire reactor core is replaced with fresh fuel.
- Reference core design specifies the use of TRISO fuel particles, with a core-averaged enrichment of approximately 9%.
- Packing fraction of TRISO fuel within the compacts over the core is non-uniform.
- HTGR-POLA plans to use the same **TRISO fuel** that has been previously **qualified and demonstrated** by JAEA **in the High-Temperature Test Reactor** (HTTR) operated in Oarai, Japan.
- Consequently, for the current design phase, the **fuel burnup is limited to 40 GWd/tHM**.

SNF management options

SNF management options

Worldwide: several strategies are being considered for the storage, processing, and disposal of spent nuclear fuel (SNF) from HTGRs. These are based on experience gained from legacy HTGRs and national nuclear programmes, as well as extensive past and ongoing research and development efforts.

Several feasible pathways exist for prismatic HTGRs [*ref*]:

1. Direct interim storage and disposal of fuel blocks without separation.
2. Separation of fuel compacts from fuel blocks, followed by separate management of fuel compacts and graphite blocks.
3. Separation of TRISO particles from fuel compacts; separate conditioning, interim storage, and disposal of TRISO particles, graphite matrix from fuel compacts, and graphite blocks.
4. Extraction of fuel kernels from TRISO particles to enable reprocessing; separate management of coating scraps, graphite matrix from the compact, and graphite blocks.

[*ref*] HTR2024 conference, paper ID: 096: Fuel and graphite waste management strategies for the HTGR reactor GEMINI+
D. Hittner , M. Fütterer , J. Havette , D. Muszyński , M. Olin, A. Tzelepi , K. Kiegiel , W. VonLensa , O. Tougait

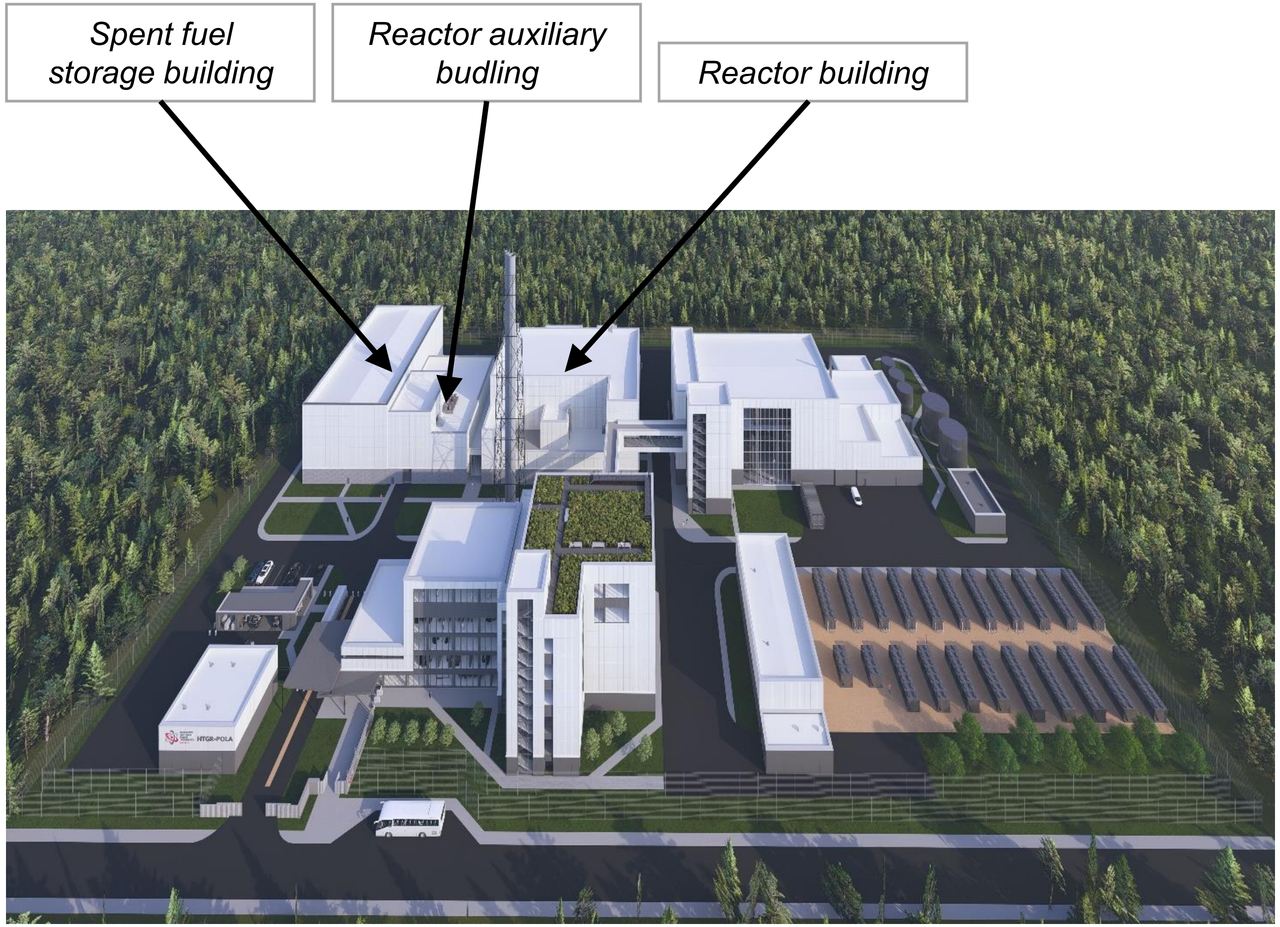
HTGR-POLA: direct interim storage

HTGR-POLA: Direct interim storage

- The primary strategy for spent nuclear fuel management at the HTGR-POLA facility involves storing the fuel blocks directly in **interim storage without any separation**.
- This approach **simplifies handling procedures** and minimizes operational complexity.
- The **on-site interim storage** is designed with a storage capacity sufficient to accommodate waste for a period of **60 years**.
- Poland does not have a deep geological repository for the disposal of high-level radioactive waste and spent nuclear fuel. The construction of such a repository is expected to begin no earlier than 2065 (draft update Polish Nuclear Power Program, June 2025).
- The management plan for spent fuel and irradiated graphite in HTGR-POLA will be updated in line with any future policy decisions made by the Polish government.

HTGR-POLA: direct interim storage

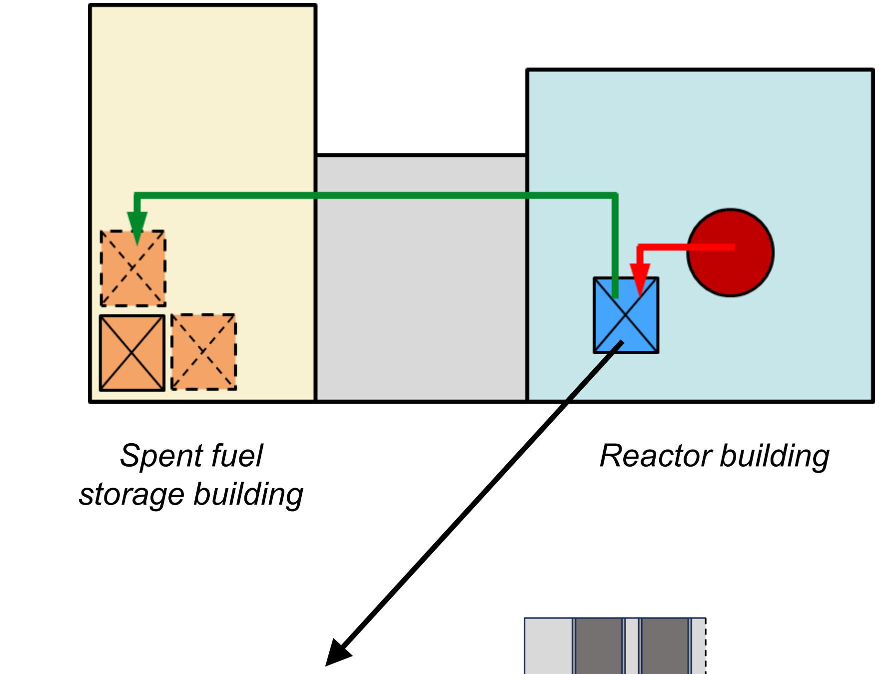
- The spent fuel elements (fuel blocks) unloaded from the reactor core are first placed in **temporary spent fuel storage cell located in the reactor building**.
- Following approximately two years of cooling, fuel blocks are transferred to one of the **interim storage cell in the spent fuel storage building**.



HTGR-POLA: direct interim storage

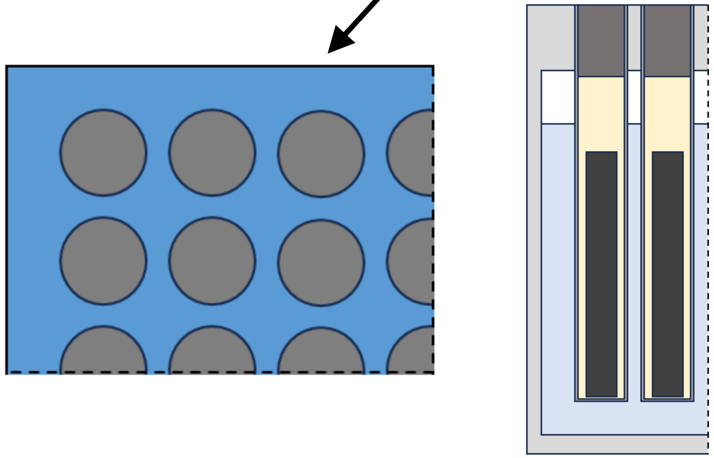
Spent fuel storage cell located in the reactor building

- Unloaded fuel elements from the core are first placed in temporary storage cell in the reactor building.
- Function: to decrease the activity and heat generation before transport to the interim storage.
- Storage racks in a water pool.
- Spent fuel blocks are stacked vertically in the rack.
- A shielding plug is used to close the rack.



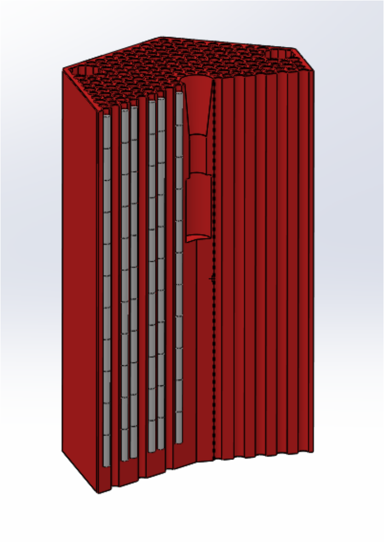
Interim storage cell in the spent fuel storage building.

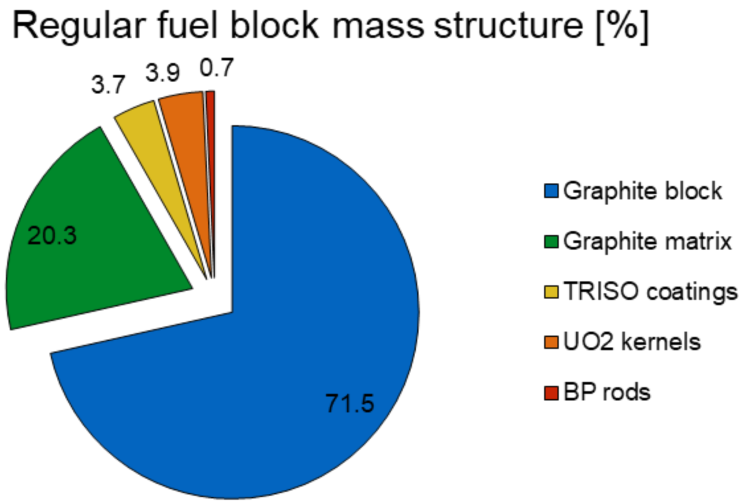
- Designed with a sufficient storage capacity to accommodate fuel elements for a period of 60 years.
- Multiple storage cell design
- Cell design similar to the spent fuel storage cell in the reactor building.
- Cooled by natural air circulation



HTGR-POLA: direct interim storage

- Number of fuel blocks in a core: 114
- FSV fuel block type: separate cooling channels and fuel holes.
- Max burnup 40 MWd/tHM, average burnup above 30 MWd/tHM.
- Fuel cycle: 620 days.
- Single-batch fuel management scheme.





HTGR-POLA: reports and recent papers

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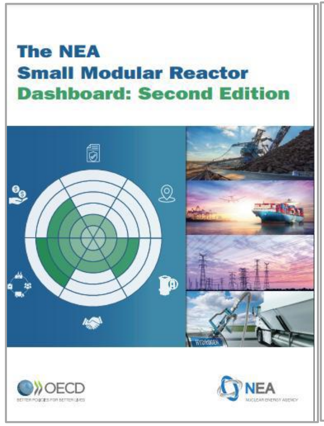

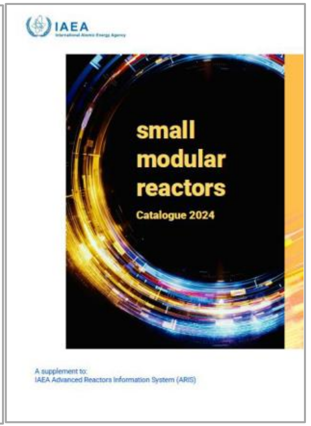

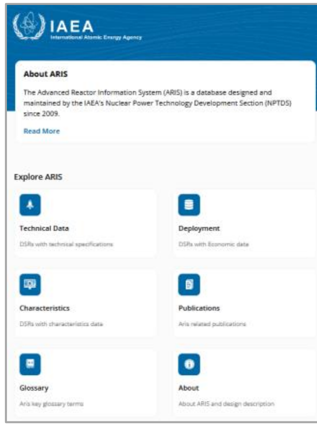

Reports/database

- The NEA Small Modular Reactor Dashboard: Second Edition, OECD
- Small Modular Reactors, Catalogue 2024, IAEA
- Advanced Reactor Information System (ARIS) database , IAEA

Concept of the Polish high temperature gas cooled reactor HTGR-POLA
M.P. Dąbrowski et al., Nuclear Engineering and Design Vol. 424 (2024)
DOI https://doi.org/10.1016/j.nucengdes.2024.113197

11th International Topical Meeting on HTR Technology (HTR2024)

- M. Skrzypek, E. Skrzypek, D. Muszynski, Thermal hydraulic and neutronic deterministic safety analysis for the HTGR SMR research demonstrator for Poland (paper ID: 057)
- M.P. Dąbrowski, H. Ohashi, Polish-Japanese Collaborative Design of the Research-Demo High Temperature Gas-cooled Reactor “POLA” (paper ID: 089)

Thank you for your attention

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