Research and development in SMR technologies - HTGR, a promising technology -

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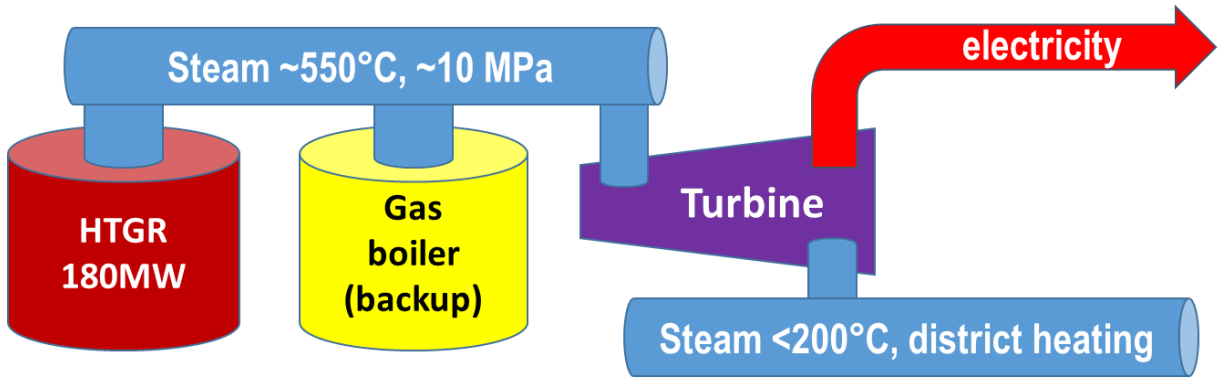
ZPP Conference, Warsaw, 12 June 2023

NATIONAL CENTRE FOR NUCLEAR RESEARCH ŚWIERK

Advanced nuclear technologies in Poland (2016)

Although priority of Poland is to implement nuclear power programme based on large scale reactors we are aware of potential future benefits of HTR. As a result we initiated the scientific project on HTGR's (especially for industrial cogeneration) with the following objectives:

- Decreasing dependence on fossil fuel import.
- Decreasing sensitivity of economy to environmental regulations.
- Synergy with multi-GW LWR programme.

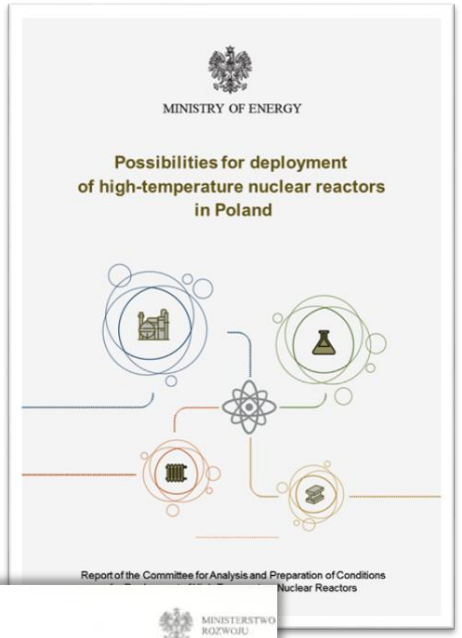


Industrial Heat Market in Poland:

13 largest chemical plants need 6500 MW of heat at T=400-550°C.

Formal basis for HTR technology in Poland

- Minister of Energy appointed Committee for deployment of high-temperature nuclear reactors in Poland in July 2016. Report with results of the Committee's works published in January 2018. Minister accepted the report, took note that deployment of HTGR reactors in Poland is desirable and requested Ministry to prepare further steps.
- Strategy for Responsible Development - the governmental program for Polish economic development - adopted in February 2017, contain e.g.: Deployment of HTR for industrial heat production. The project for this action is: Nuclear cogeneration – preparation for construction of the first HTR of 200-350 MWth supplying technological heat for industrial installation.



HTGR, a promising technology

HTGR (High Temperature Gas-cooled Reactor) technology is mature and available for early implementation.

- Coolant – Helium, Moderator – Graphite.
- Fuel based on TRISO particles.
- Outlet temperature up to 750˚C (qualified existing industrial materials), 900-1000˚C (with advanced materials).
- Several test reactors and industrial prototypes.
- In the last 2 decades in Europe:
  - Several design projects.
  - Large progress in the technology:
    - National R&D programmes.
    - Euratom funded projects (17 projects).
    - International cooperation (Generation IV International Forum).
- An industrial prototype, HTR-PM, started operation in China last year.

DRAGON, U.K. 20 MW, 1963-76

Peach Bottom, US 200 MWth, 1967-74

Fort Saint-Vrain, US 300 MWe, 1976-89

AVR, Germany 15 MWe, 1967-88

THTR, Germany 300 MWe,1986-89

HTR-10, China 10 MWth, since 2000

HTR-PM, China 2x250 MWth, since 2021

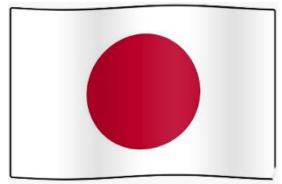
HTTR, Japan, 30 MWth, since 1998

NCBJ nuclear cogeneration activities

- GEMINI+ (2017 – 2021). The main design options for HTGR fitting the requirements for cogeneration use in Europe.
- The NOMATEN Centre of Excellence has received 7 years (2018-2025) of joint financial support (€37M) from the Foundation for Polish Science (FNP) and the European Commission. NOMATEN focus on the studies and development of novel materials, specifically those designed to work under harsh conditions – radiation, high temperatures and corrosive environments.
- GoHTR (2019-2022). In the frame of national strategy program GOSPOSTRATEG project for preparation of law, organization and technical instruments to deploy the HTR reactors in Poland.
- National Centre of Nuclear Research (NCNR) is gaining knowledge on HTGR technology by strengthening collaboration with Japan Atomic Energy Agency (JAEA). Implementing Agreement signed in 2019.

NCBJ nuclear cogeneration activities

- *Action Plan for the Implementation of the Strategic Partnership between the Government of the Republic of Poland and the Government of Japan for the years 2021-2025 seeks cooperation in the field of High Temperature Gas-cooled Reactors (HTGR) between the NCNR and JAEA, as well as other relevant entities towards possible deployment of industrial HTGR's.*
- 1.06.2021 we start 3,5 years long NCBJ - MEiN Programme – HTGR Basic Design, a first phase of program (design and construction of small experimental HTGR, being also the technology demonstrator). Financing will be based on national resources (€14M).
- GEMINI 4.0 (2022 – 2025). New Euratom project as a continuation of GEMINI+.



Ministerstwo Edukacji i Nauki

GEMINI 4.0

GEMINI+ - the modular HTGR (completed)

GEMINI+ selected for funding in the frame of the 2016 call of H2020
(3.5 years project, 4 M€. Started in September 2017, completed in February 2021)

Polish, European and international context

- The strategy proposed by the Polish government on application of an HTGR system for providing process steam to industry.
- The Nuclear Cogeneration Industrial Initiative (NC2I) is grouping at European level nuclear industry and R&D organisations supporting application of nuclear energy for industrial process heat supply.
- International cooperation between NC2I, the US NGNP Industry Alliance, JAEA and KAERI.
- The project GEMINI+, proposed by NC2I in Euratom H2020 programme, has been selected for funding.
- 26 partners from EU (industry, R&D, TSO), US, Japan & Korea.

Objectives

- GEMINI+ system has been designed to support an early demonstration of industrial nuclear cogeneration of electricity and steam in Poland using an inherently safe HTGR.
- To develop the design basis of a nuclear heat plant;
  - for process heat needed by industry in Poland and Europe,
  - that can become competitive with fossil fuel-fired plants,
  - taking into account penalties on CO2 emission.
- To propose a licensing framework for such a nuclear system and its coupling with industrial process heat applications.
- To prepare a full scale demonstration in Poland.

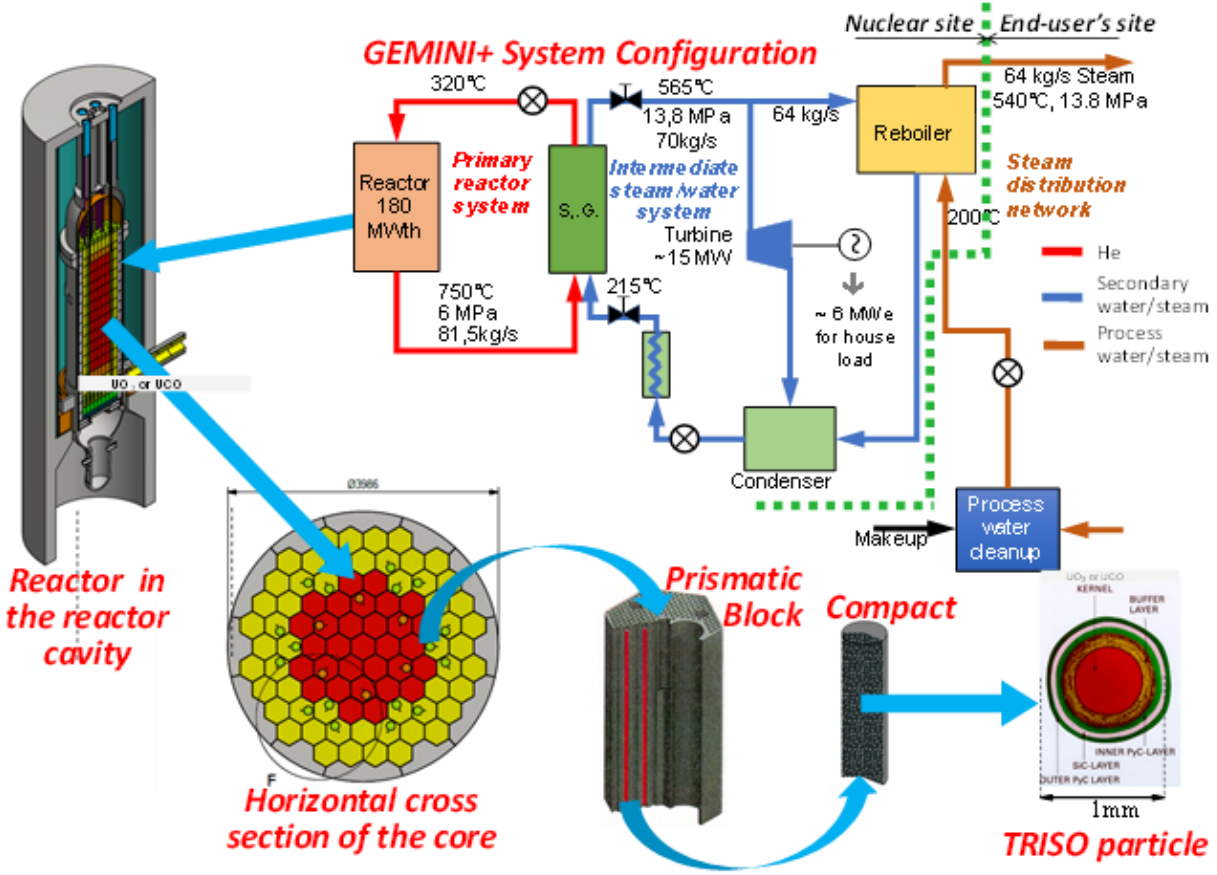
https://iopscience.iop.org/article/10.1088/1742-6596/2048/1/012043; https://iopscience.iop.org/article/10.1088/1742-6596/2048/1/012030; https://iopscience.iop.org/article/10.1088/1742-6596/2048/1/012004

Main achievements of GEMINI+

GEMINI+ was designed to support early demonstration of industrial nuclear cogeneration of electricity and steam in Poland using an inherently safe HTR.

Main results:

- Flexible standard design that can address needs for process steam in industry.
- Safety approach meeting present highest safety standards.
- Identification of residual technology gaps.
- Better understanding of industrial application needs: Importance of hydrogen for industrial applications.
- Proposals for integration of high temperature nuclear cogeneration systems in global or local energy systems.



GOSPOSTRATEG-HTR (GoHTR) completed

- GOSPOSTRATEG - strategic Polish program of scientific research and development (R&D) work "Social and economic development of Poland in the conditions of globalizing markets"
- Finance: National Centre for Research and Development (approximately €4M)
- Duration: January 2019 – March 2022
- Consortium: Ministry for Climate and Environment, National Centre for Nuclear Research and Institute for Nuclear Chemistry and Technology.

Results

Preparation to the licensing process
- Pre-conceptual design
- Facility concept
- Analysis methodology

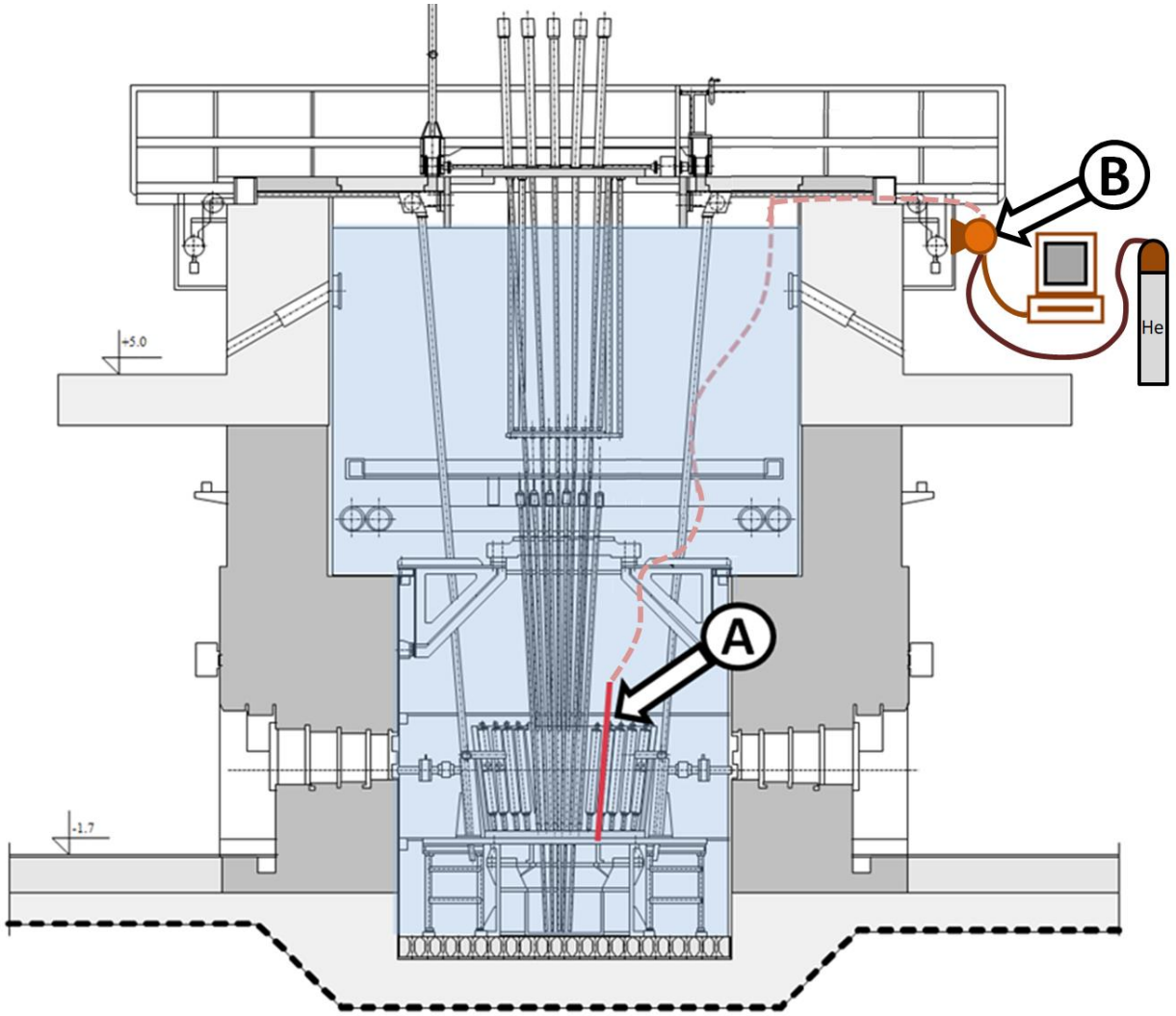
Material tests
- Implementation of testing procedures
- Identification materials for tests
- Irradiations in the MARIA reactor (ISHTAR)

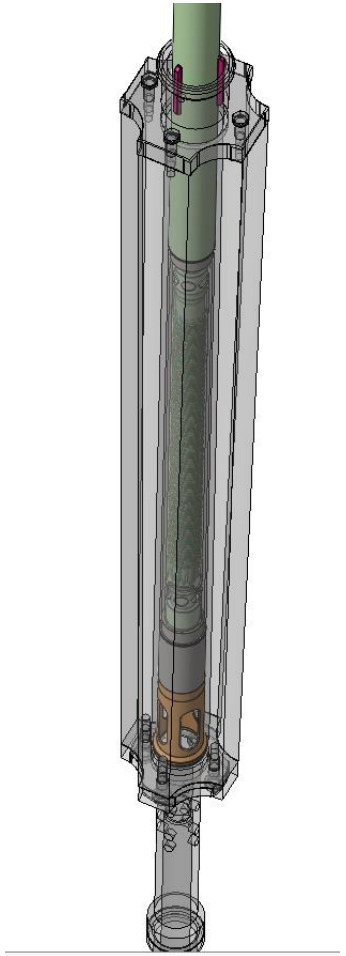
Legal, social, economic and industrial aspects of the project
- Legal regulations for the HTR investments implementation
- Public and industrial communication

https://www.mdpi.com/1996-1073/15/6/2084

ISHTAR - Irradiation System for High-Temperature Reactors

- Operating temperature - 1000°C.
- Vertical temperature homogenization.
- Insulation - helium gap.
- The use of electric and gamma heating.
- Testing of HTGR materials.
- Two pending patent applications.



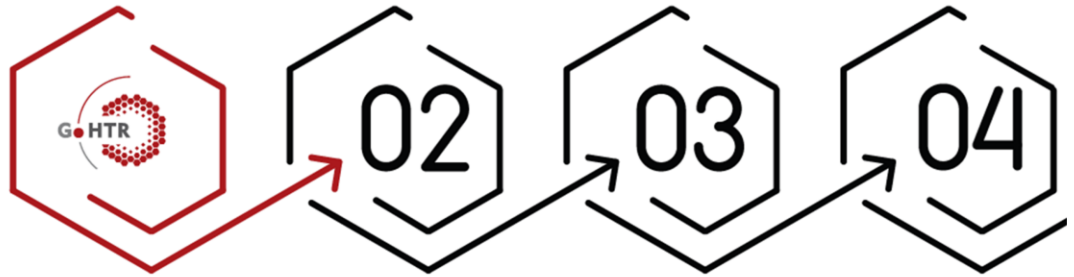


GEMINI 4.0 (For Zero Emission) project

- Objectives
  - Can clean hydrogen be produced in a competitive way by the GEMINI+ system?
  - Improving some open points of the design and safety analysis of the GEMINI+ system.
  - Defining the fuel design and the fuel cycle options, as well as the conditions for developing a European fuel supply chain for the GEMINI+ system.
  - Assessing the licensing feasibility of the GEMINI+ system and of its fuel.
  - Communication on the benefits of nuclear industrial cogeneration extended to non-nuclear stakeholders (industry, policy makers, citizens…).
- Budget for GEMINI 4.0 is €3.13 million + in kind contribution from JRC.
- Accepted, project kick-off in June 2022.

NCBJ-MEiN Programme – HTGR Basic Design

- Contract No 1/HTGR/2021/14 between the National Centre for Nuclear Research (NCBJ) and the Ministry of Education and Science (MEiN) entitled “Technical description of the HTGR gas-cooled high-temperature research nuclear reactor” signed on May 12, 2021. It is intended for the implementation of another batch of design works for the experimental HTGR, being also the technology demonstrator.
- The contract determines that the conditions for the construction of a high-temperature research reactor in Poland will be created within three years and that the conceptual design and further most of the basic design of such a device will be prepared. The reactor will be a prismatic type HTGR using TRISO fuel producing approximately 30-40 MWth at an outlet temperature of 750 ^{o}C.
- Time: 1.06.2021 – 1.06.2024.
- Value: approximately €14M



NCBJ-MEiN Programme – HTGR Basic Design

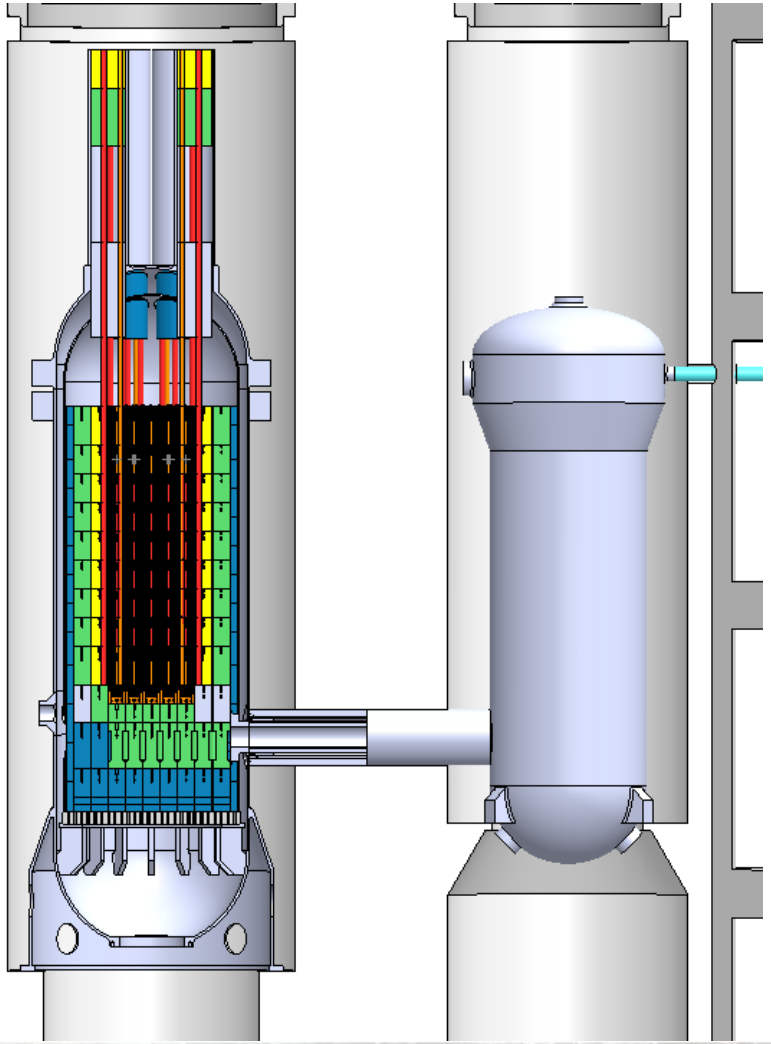
Scope of the project:

- Preparation of laboratory facilities with the necessary accreditations and a quality management system necessary to perform research in view of licensing materials for HTGR technology.
- Performing tests of materials that can be used for the construction of HTGR, in terms of compliance with the requirements of HTGR technology.
- Development of the basic design of the HTGR reactor (basic / preliminary design according to IAEA-TECDOC-881).
- Performing verification simulations for the project and preliminary HTGR safety report in accordance with the requirements of the Regulation of the Council of Ministers from 2012.
- Preparation of selected elements of the preliminary safety report (CSR) for HTGR in accordance with the Regulation of the Council of Ministers (as above).

High Temperature Gas-cooled Reactor - POLish Atom (HTGR-POLA)

Basic technical characteristics

Design development	National Centre for Nuclear Research, NCBJ
Reactor type	High-temperature gas-cooled reactor (HTGR)
Core design	Prismatic (core composed of hexagonal blocks)
Reactor thermal power	30 MW
Fuel enrichment	Low-enriched uranium dioxide UO2, HALEU
Fuel type	TRISO particles in a graphite matrix (compact)
Fuel cycle	Open, spent fuel stored on site
Moderator	Graphite
Coolant / circulation	Helium / blower-induced circulation
Coolant pressure	6 MPa
Coolant temperature at the reactor inlet	325°C
Coolant temperature at the reactor outlet	750°C
Secondary system coolant	Water / steam
Secondary system pressure	13.8 MPa
Safety systems	Passive and active
Reactivity control	Control rods, burnable poisons, reserve neutron absorbing capsules
Reactor building	Reinforced concrete construction, design over-pressure up to 0.1 MPa, ventilated building
Power output	Cogeneration operation, electrical power max. 10 MW gross, high-temperature heat in steam max. 25 t/h, low-temperature thermal power in water max. 16.5 MW
Design service life	60 years



Thank you for your attention

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EU energy consumption reality

Most of greenhouse gas emissions are not related to electricity generation but to heat generation, industrial processes (not only process heat needs, but the processes themselves), transport, etc.

With high temperature reactors, nuclear can bring a significant contribution to eliminate non-electricity emissions.