JAEA R&D Overview

GIF Industry Forum
Non-Electric Applications of Nuclear Heat Workshop
October 3, Toronto, Canada

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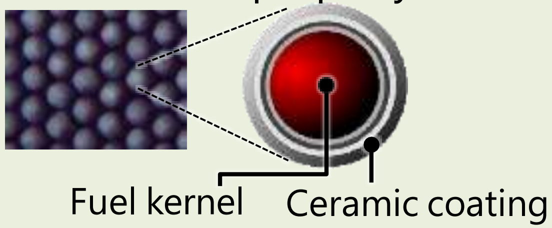
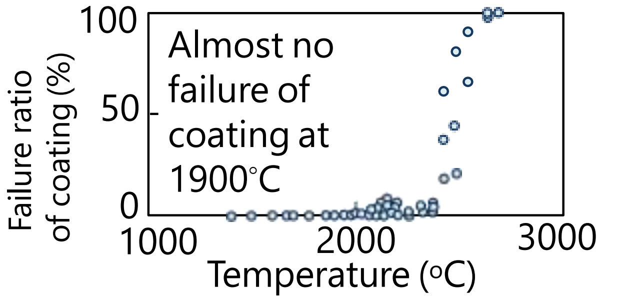
Japan Atomic Energy Agency

HTGR Features - Safety

Ceramic coated fuel particle

Inability to melt due to heat-resistant property

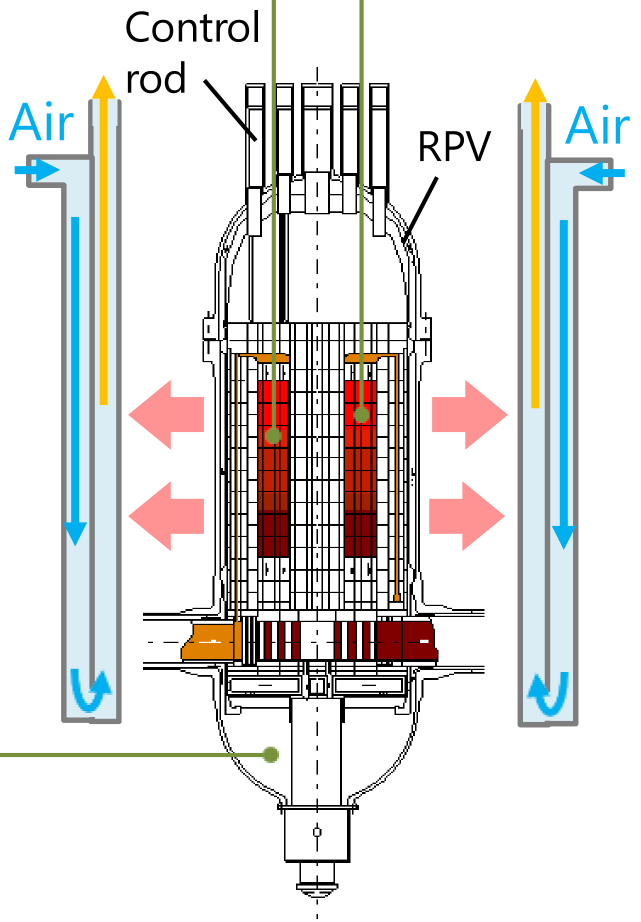




Experimental result for heated fuel particle

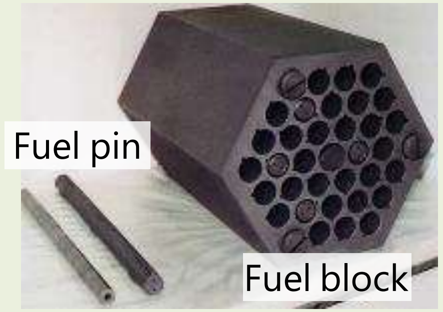
Helium coolant

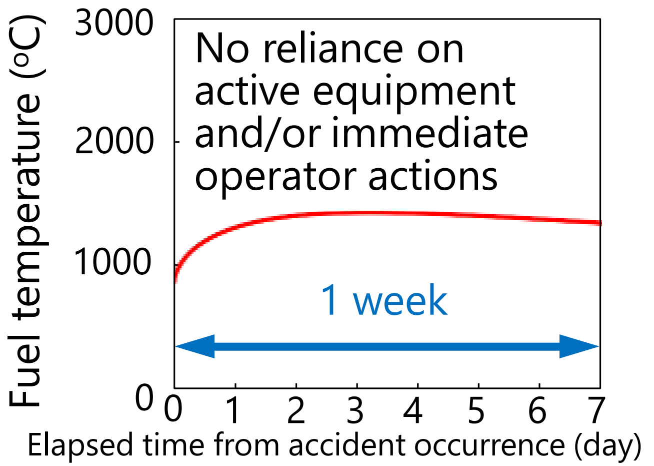
No explosions of H_2 and vapor due to chemical inertness and phase change inability



Graphite moderator

Capable to remove heat passively from RPV outside due to high heat capacity and large thermal conductivity

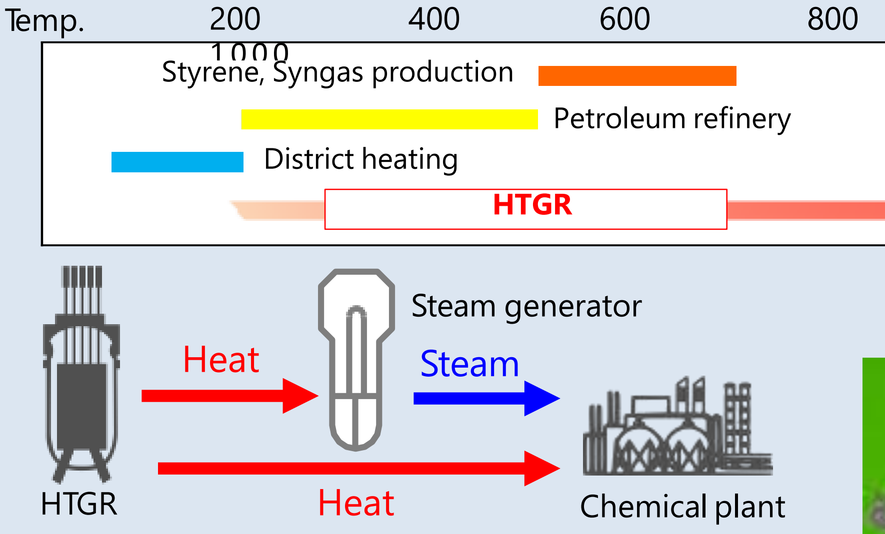




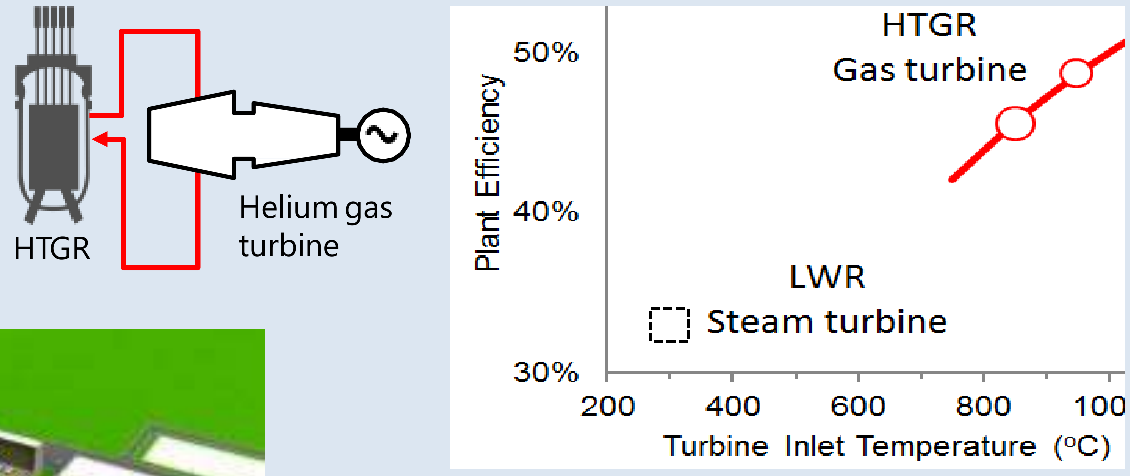
Fuel temperature during loss-of-core cooling accident (Simulation)

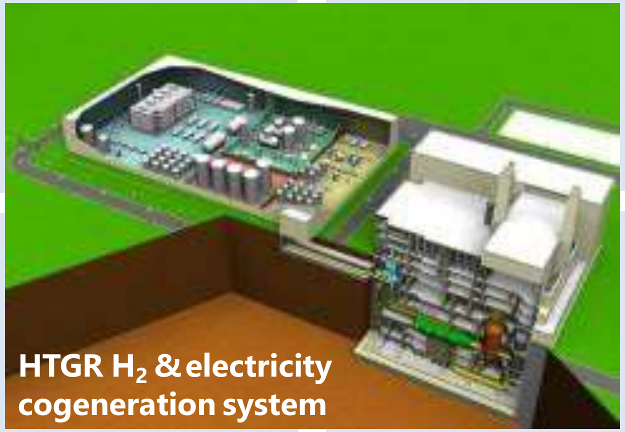
HTGR Features - Multiple Applications

Industrial use of nuclear heat

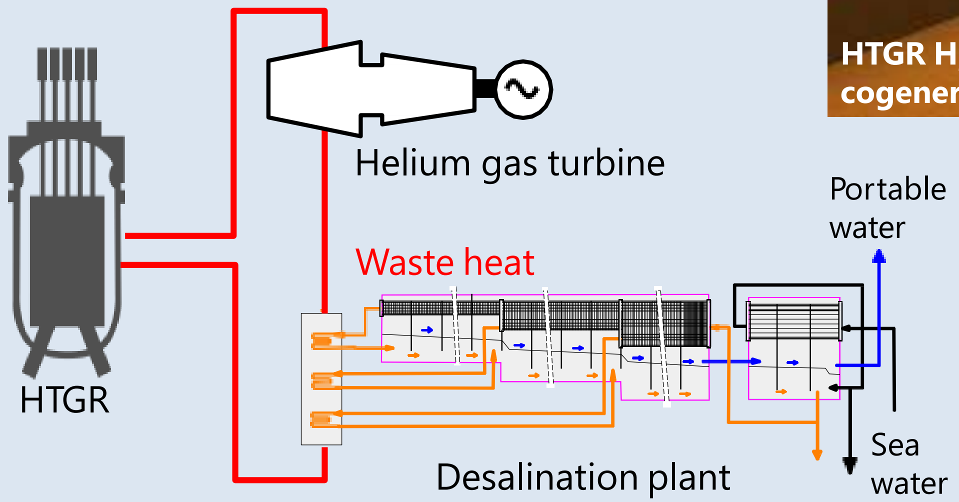


High Efficient Gas Turbine Power Generation

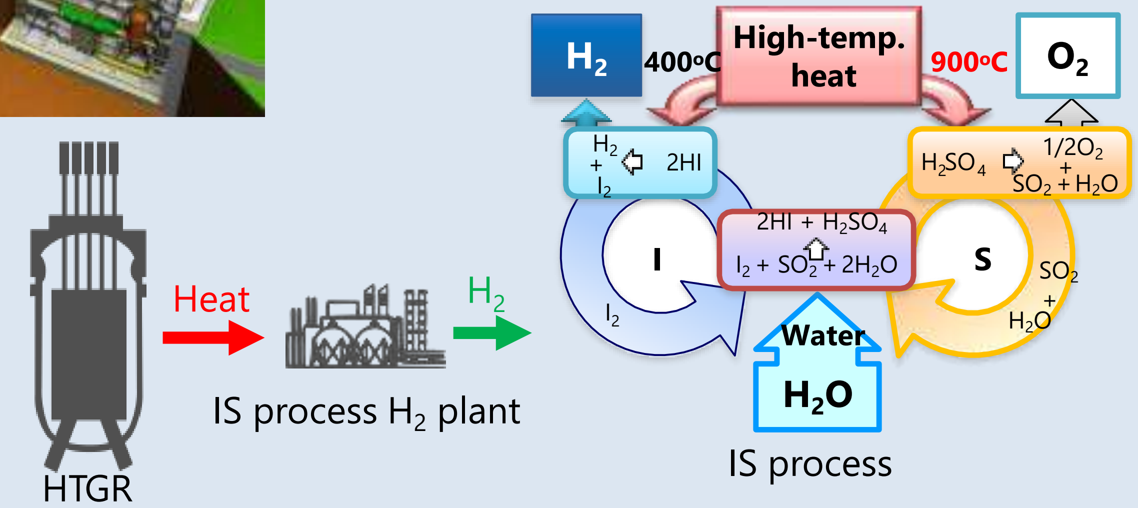




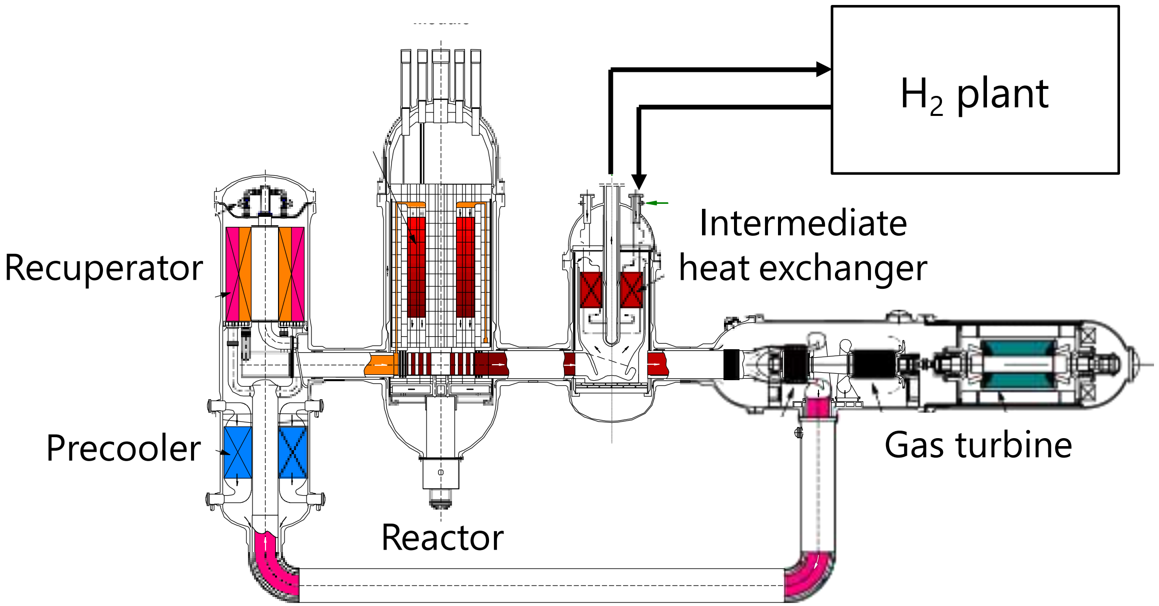
Desalination using waste heat



Carbon-free H_2 production



GTHTR300C: JAEA's HTGR Cogeneration Plant Design



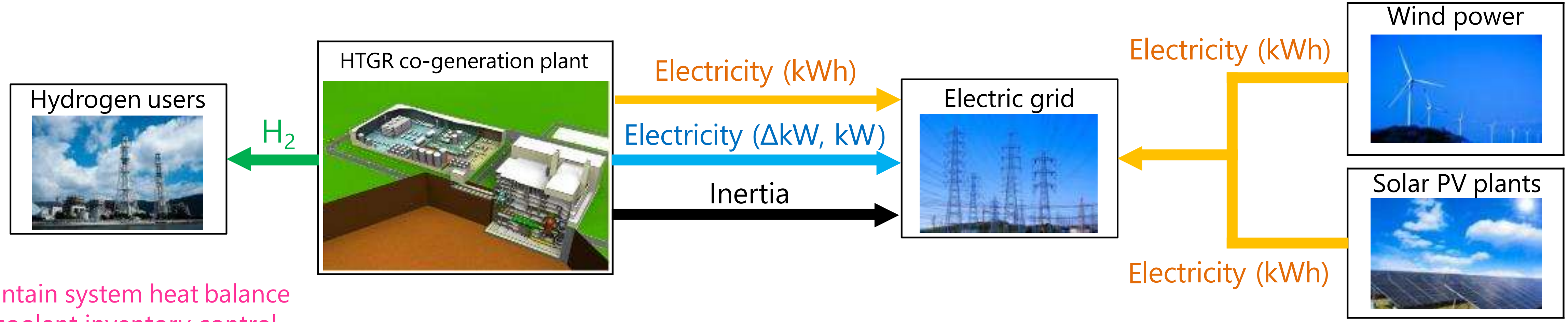
Features

- A Generation IV system
- Cooperative design of JAEA and domestic industries
- Plant is designed to minimize R&D and to obtain compelling economics
- Original design features of conventional steel pressure vessel, non-intercooled direct cycle, horizontal gas turbine
- Water or air coolable

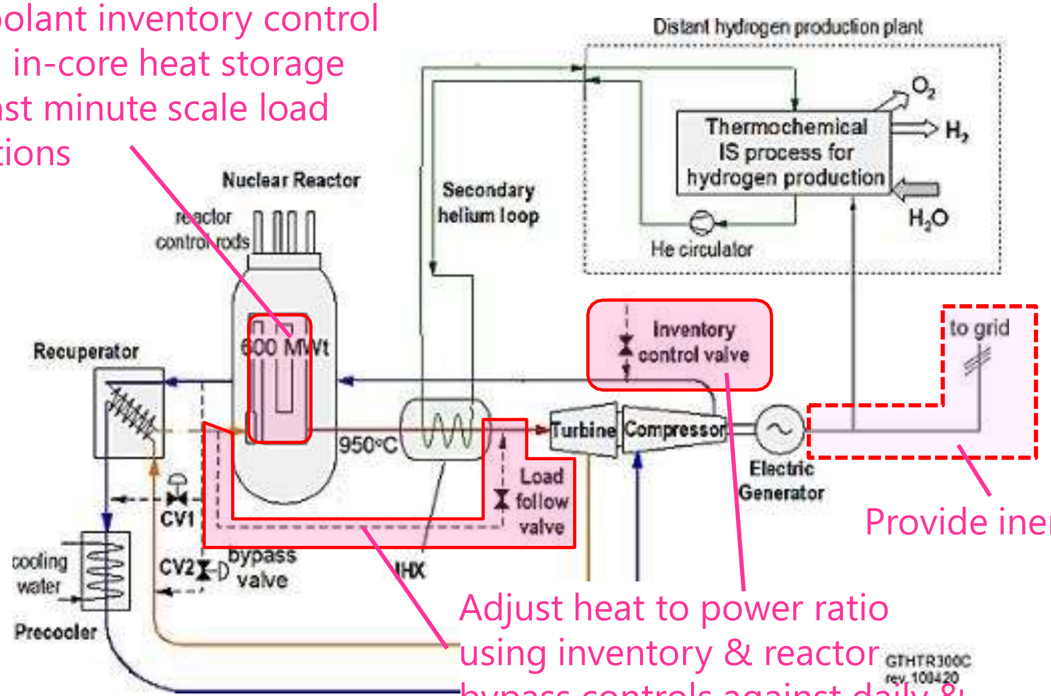
	Power & H_2 cogeneration	**Higher H_2 production capacity**
Reactor power	600MWt	600MWt
Reactor temperature (Out/In)	950°C/594°C	950°C/594°C
Power output (Efficiency)	202MWe (47%)	87MWe (37%)
H_2 production rate	1.9 – 2.4 t/h	4.1 – 5.2 t/h
Average fuel burnup	120 GWd/t	120 GWd/t
Refueling interval (month)	18	18

Ref: K. Kunitomi, et al., Nuclear Engineering and Technology 39(1) (2007) 9–20.

HTGR Renewable Hybrid Energy System

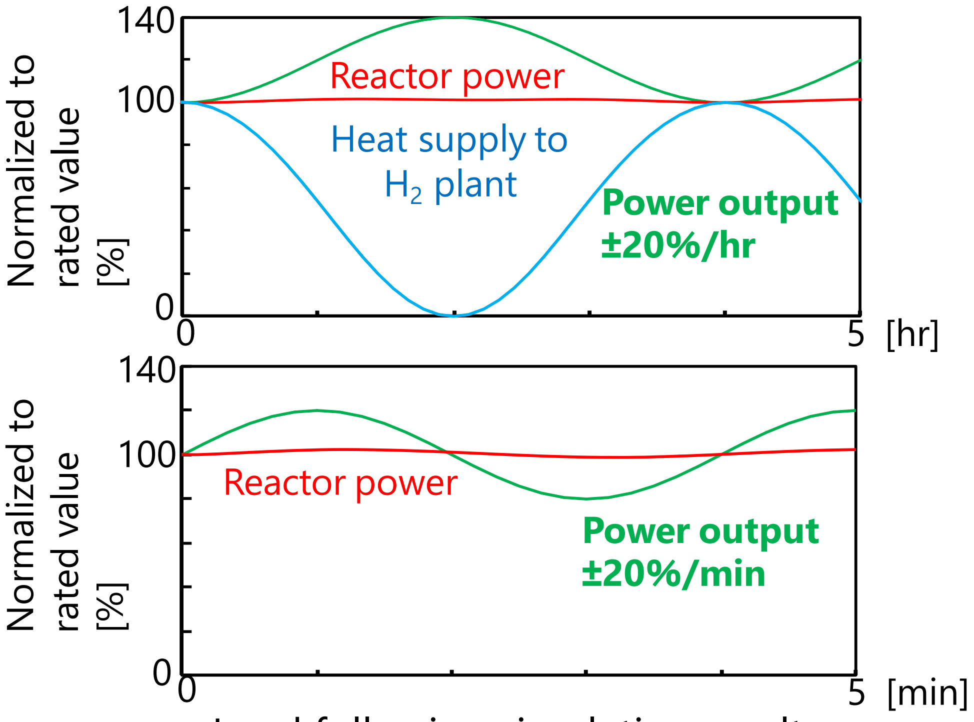


Maintain system heat balance by coolant inventory control using in-core heat storage against minute scale load variations



Provide inertia to grid

Adjust heat to power ratio using inventory & reactor bypass controls against daily & hourly load variations

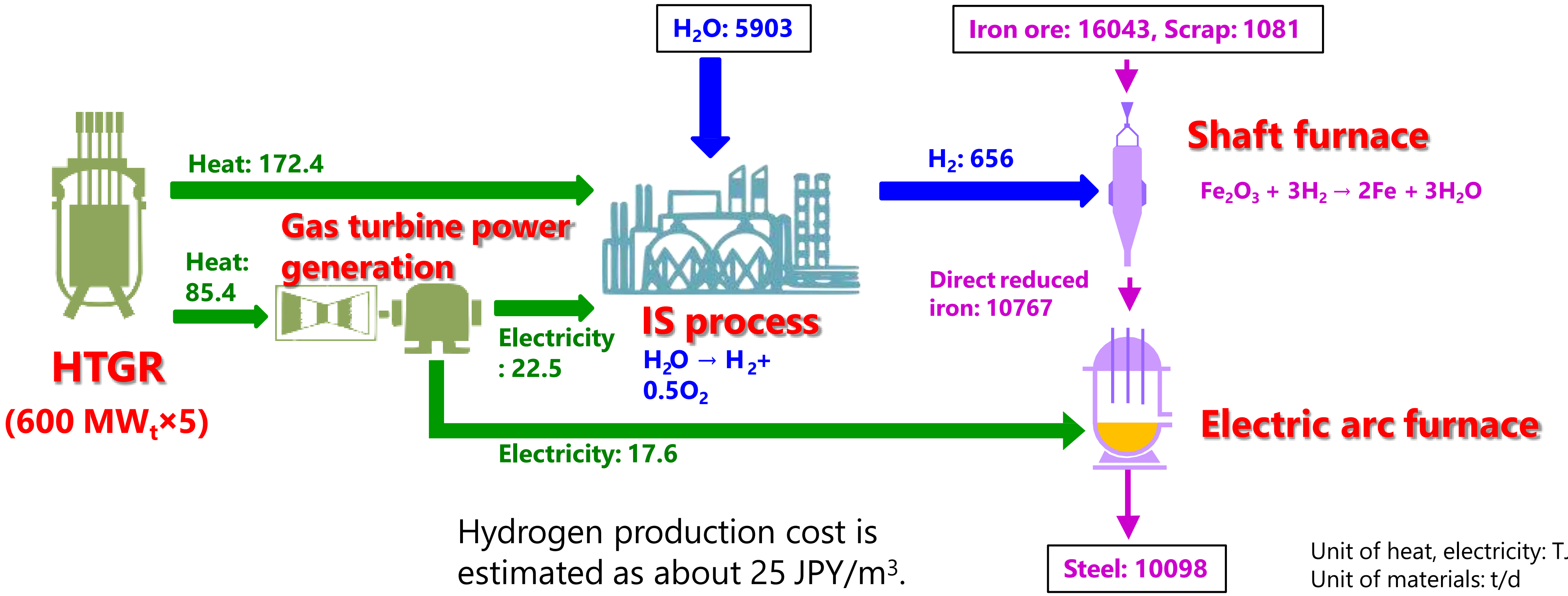


Load following simulation results

Ref：H. Sato, et al., Nuclear Engineering and Design 343 (2019) 178–186.

HTGR Energy Supplied Steelmaking System

- Steelmaking by hydrogen and electricity produced by the HTGR-IS cogeneration system
- CO_2 emission from steel plants can be cut by 100% (140 million ton/year in Japan*1).



Hydrogen production cost is estimated as about 25 JPY/m^3.

Unit of heat, electricity: TJ/d
Unit of materials: t/d

Energy and material balance of a plant to produce steel of 10,000 ton/d *2
(Scale of a standard steel plant) *3

*1 : Data of 2016. Ref.: Greenhouse gas emission data in Japan (1990-2016 definite report), Greenhouse Gas Inventory Office of Japan (May 29th, 2018 update).
*2 : Domestic steel production: c.a. 290,000 t/d (2016).
*3 : Kasahara and Ogawa, Production of Green Energy and Its Utilization in Ironmaking and Steelmaking Processes, Iron and Steel Institute of Japan, 123-143, 2012.

Overview of the HTTR Project

(1) Reactor technology

- 30 MWt and 950^{o}C prismatic core advanced test reactor (Operation start in 1998)
- Restart operation of the HTTR
- HTTR tests for HTGR safety demonstration

(2) Heat application technology


He compressor


Hydrogen facility

- R&D of gas turbine technologies such as high-efficiency helium compressor, shaft seal, and maintenance technology
- Demonstration of component integrity and stable operation for H_2 production

(3) HTGR design

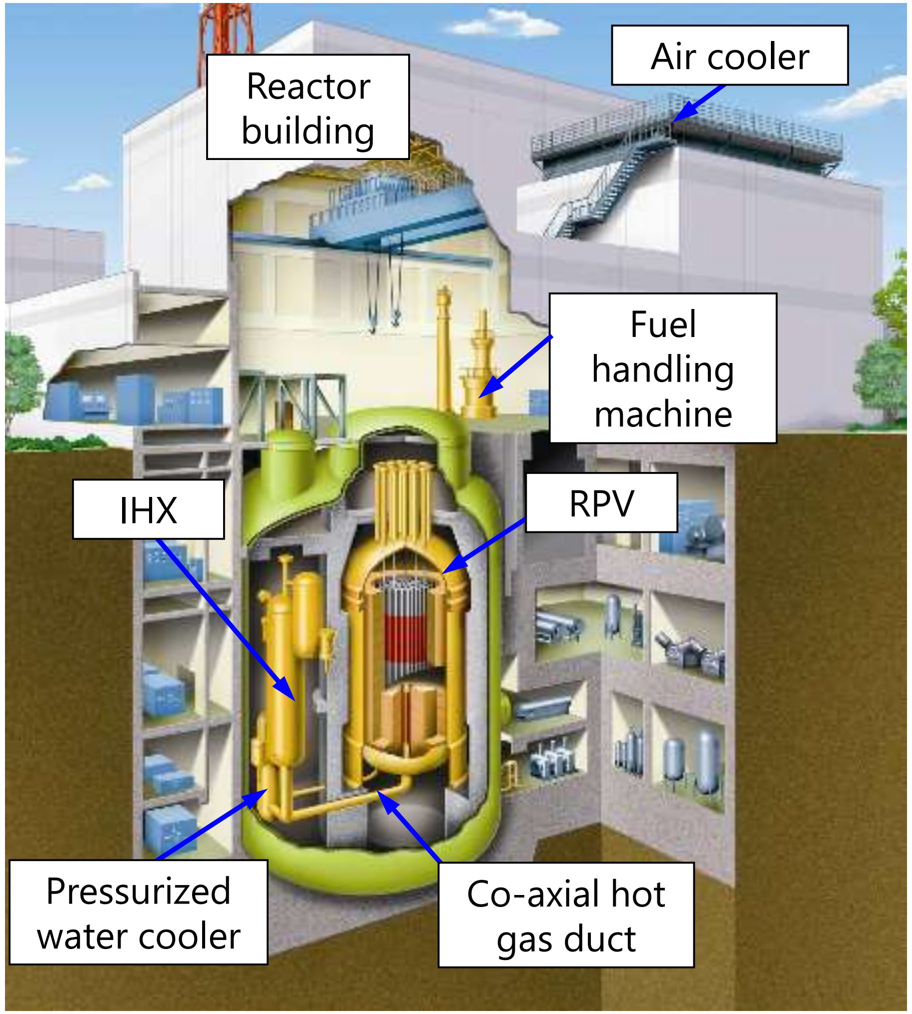
- Design study of commercial HTGR for electricity generation and H_2 production
- Establishment of commercial HGTR safety standards
- Design study of HTGR for steam supply

(4) HTTR heat application test

- Licensing acquisition of world's first nuclear hydrogen production
- Demonstration test for safe & reliable HTGR heat application technologies

Overview of the HTTR Project

The only prismatic-type High Temperature Gas-cooled Reactor (HTGR) in operation in the world



Major Specifications

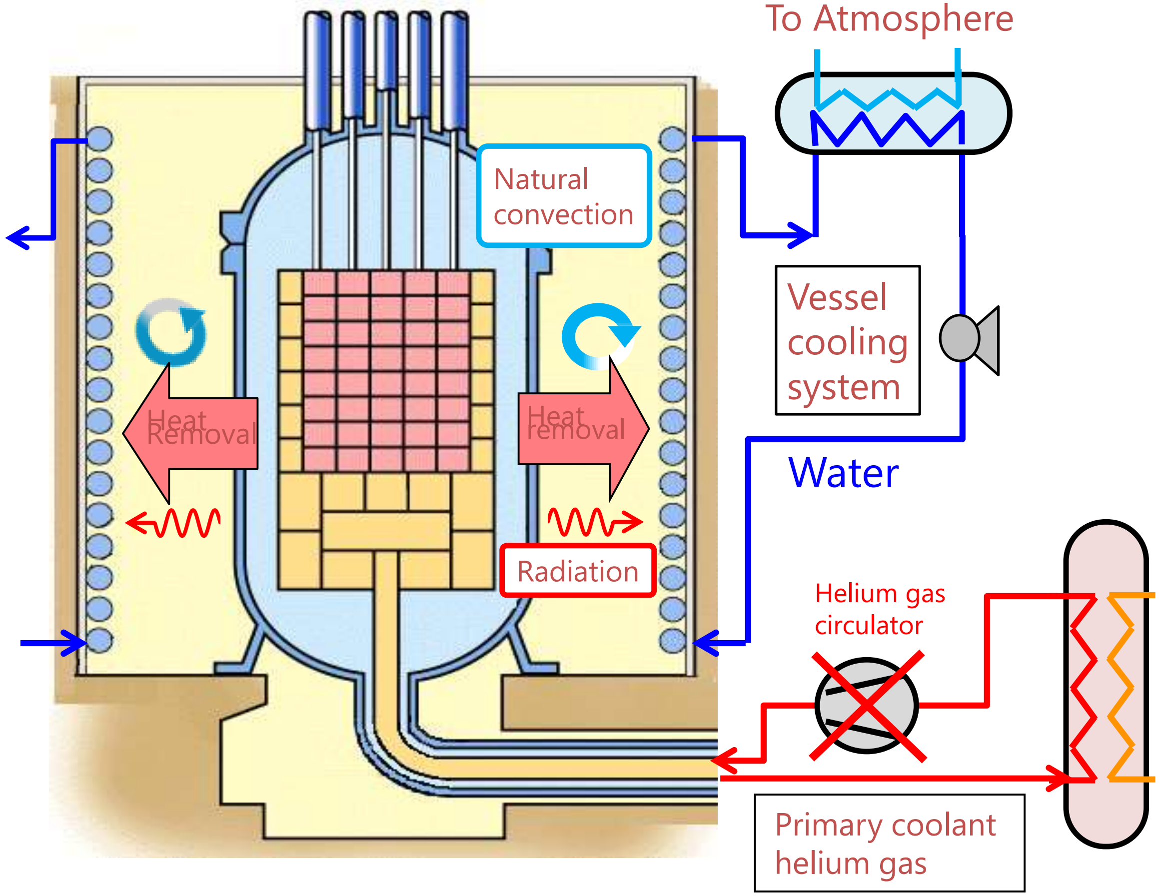
Thermal power	30 MW
Fuel	Coated fuel particle / Prismatic type
Core material	Graphite
Coolant	Helium
Inlet temperature	395°C
Outlet temperature	950°C
Pressure	4 MPa

Major Achievements

First criticality	: November, 1998
Full power operation	: December, 2001
50 days continuous 950ºC operation	: March, 2010
Obtain permission of changes to reactor installation in conformity to New Regulatory Requirements	: June, 2020
Restart operation	: July, 2021

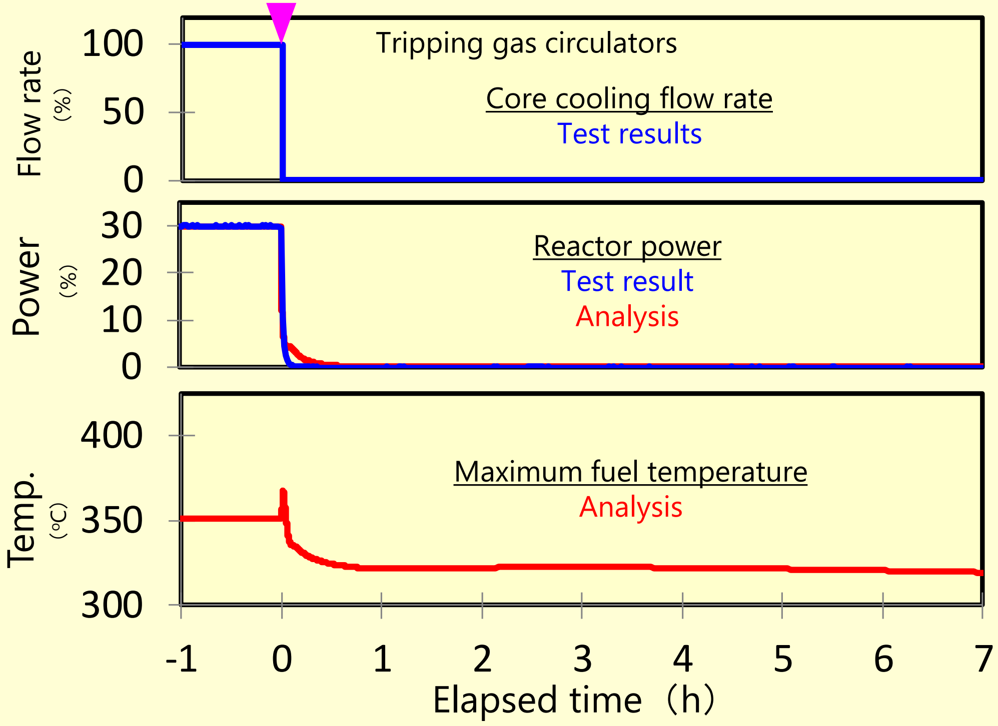
Safety Demonstration Test

- ✓ 30% power (9MW) Loss of forced cooling test (All HGC tripped)) -----Completed in 2010
- ☐ 100% power Loss of forced cooling test (All HGC tripped) ------Planned
- ✓ 30% power Loss of core cooling test (All HGC + VCS tripped) ---- Completed



Test condition

- Initial power 30% (9MW)
- Reducing core flow rate to zero
- Keeping VCS operation
- No scram operation (No CR insertion)



Reactor intrinsically shuts down as soon as the core cooling flow rate to zero. Reactor is kept stable long after the loss of core cooling

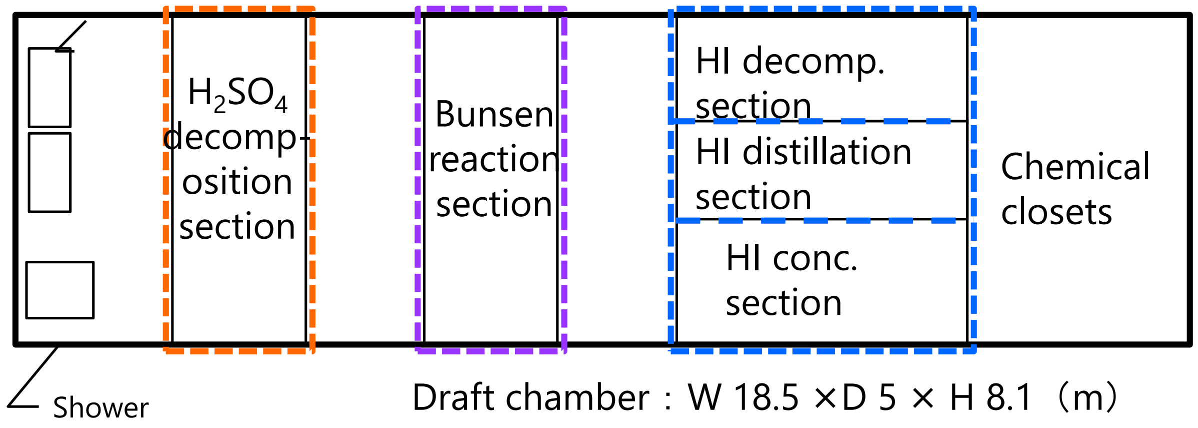
H_2 Production Technology Development

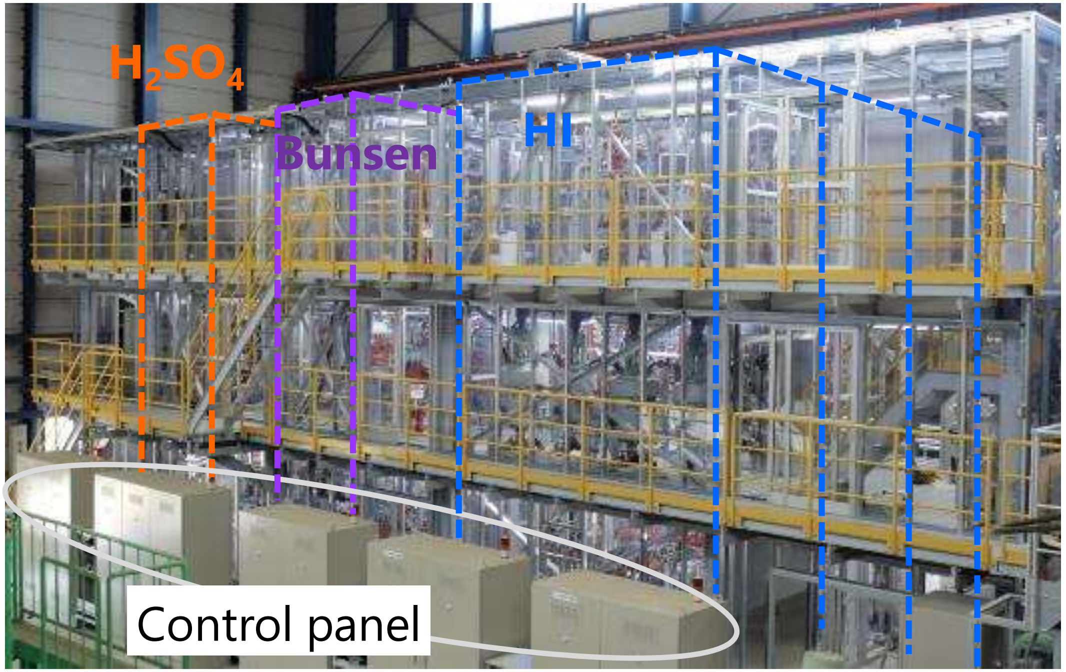
Objective

- Demonstration component integrity stable hydrogen production

Tests

- Construct an integrity test facility incorporating components technology obtained in the previous study
- Demonstration of reliability for the whole plant, investigation of hydrogen production stability
- Investigation of controllability (startup, shutdown, etc.) simulating the coupling with HTGRs

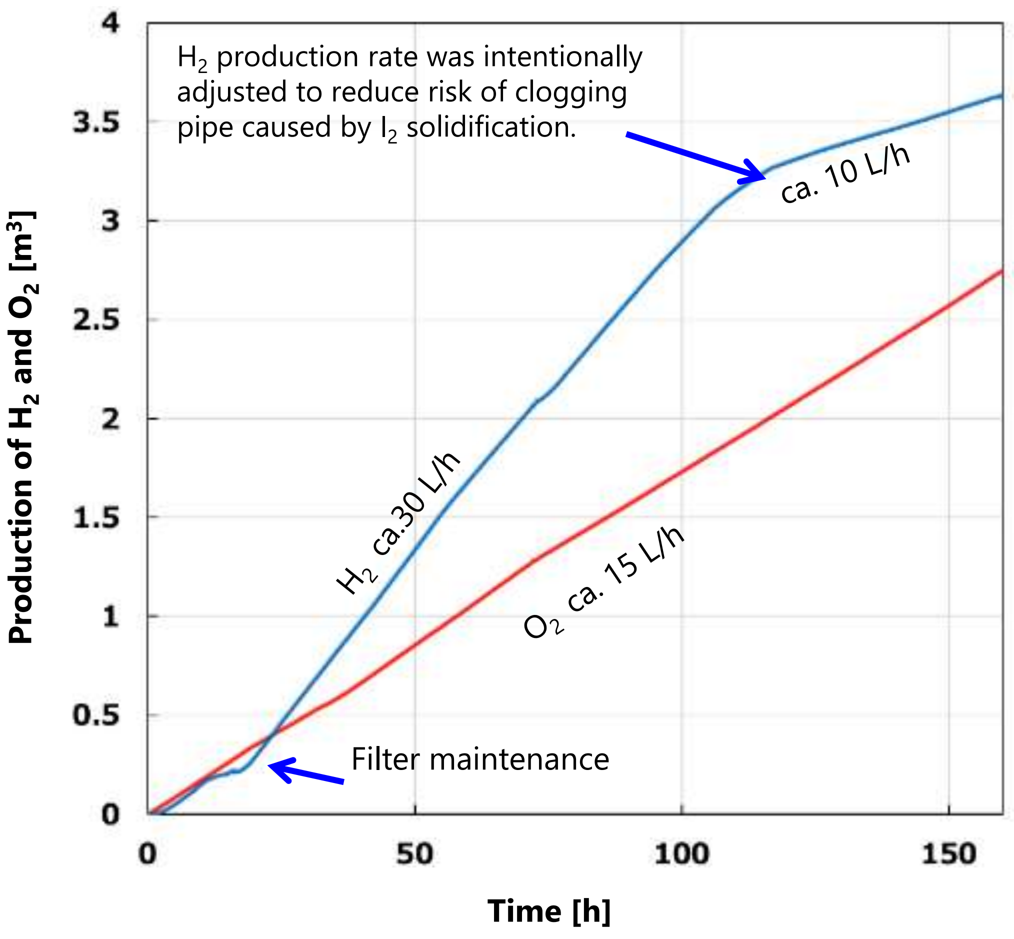




H_2 Production Technology Development -cont.

Achievements

- The 8-hour and 10 L/h continuous H_2 production was conducted with integration of 3 sections (H_2SO_4 decomposition section, Bunsen reaction section, and HI decomposition section) in February 2016.
- The 31-hour and 20 L/h continuous H_2 production was performed with integration of 3 sections in October 2016.
  - The developed HIx solution transport technology was confirmed.
  - The technology to prevent I_2 precipitation in HI decomposition section was confirmed.
- The 150-hour and 30 L/h continuous H_2 production was performed with integration of 3 sections in January 2019.
- The 92 L/h continuous H_2 production was performed with integration of 3 sections in October 2020.

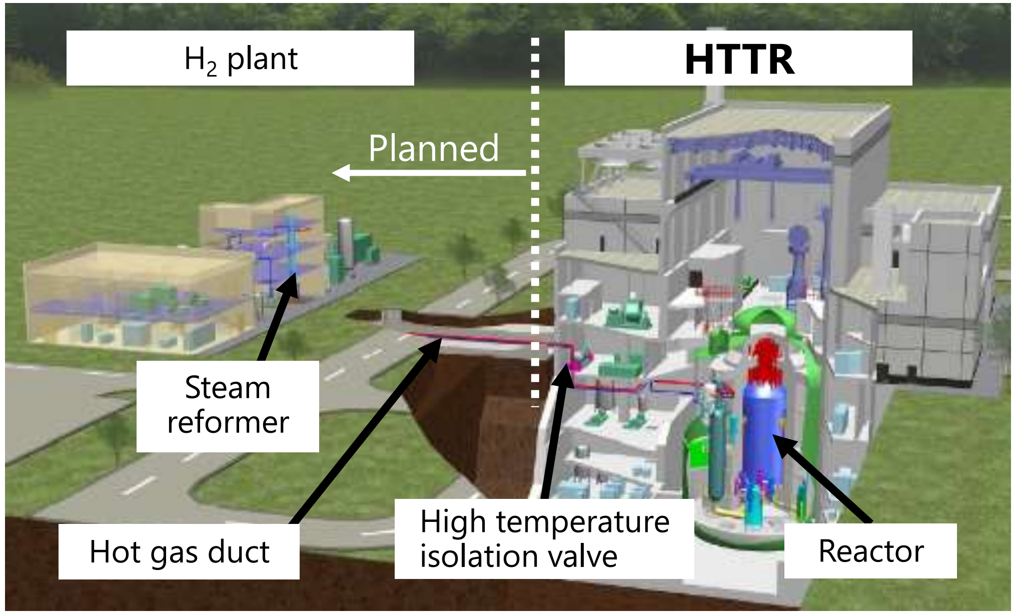


Result of operation for 3 sections integration

HTTR Heat Application Test

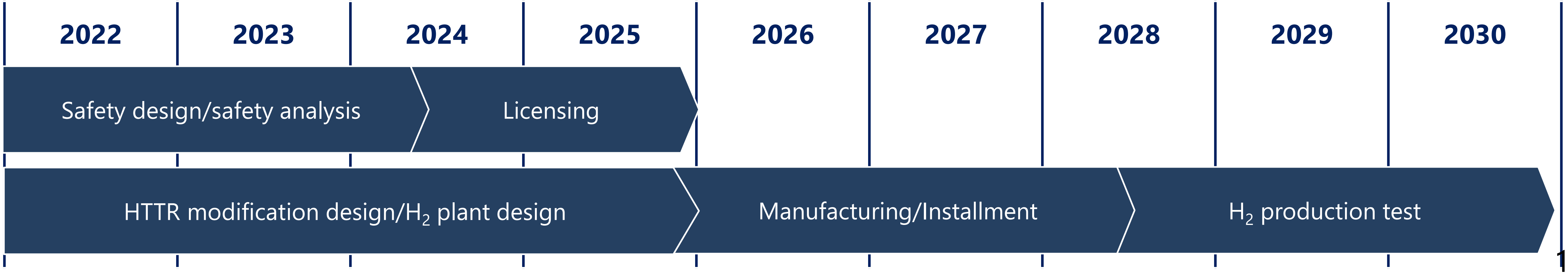
Objective
- Establish a safety design for coupling HTGR and H_2 plant through the licensing by Nuclear Regulatory Authority.
- Demonstrate performance of components required for coupling between HTGR and H_2 plant e.g. high temperature isolation valves, hot gas duct, etc. using the High Temperature engineering Test Reactor (HTTR), a HTGR test reactor in JAEA.

Tasks
- Construct a steam methane reforming H_2 plant and connect to the HTTR.
- Conduct a continuous H_2 production test and plant dynamic tests.



HTTR heat application test

Tentative Schedule



Summary

- HTGR cogeneration plant can contribute to balance and stabilize the power grid without sacrificing economics and produce carbon–free hydrogen massively at reasonable costs.
- JAEA has been conducting R&Ds aiming to demonstrate HTGR technologies for cogeneration of power and hydrogen with a central focus on the utilization of HTTR.
- The HTTR has restarted its operation on July 30, 2021. A loss of forced cooling test was carried on January 28, 2022. The test demonstrated inherent safe characteristics of HTGR.
- The HTTR heat application test project was officially started in 2022 aiming to establish safety design for coupling H2 plant to HTGR and demonstrate performance of components required for coupling between HTGR and H2 plant by 2030.