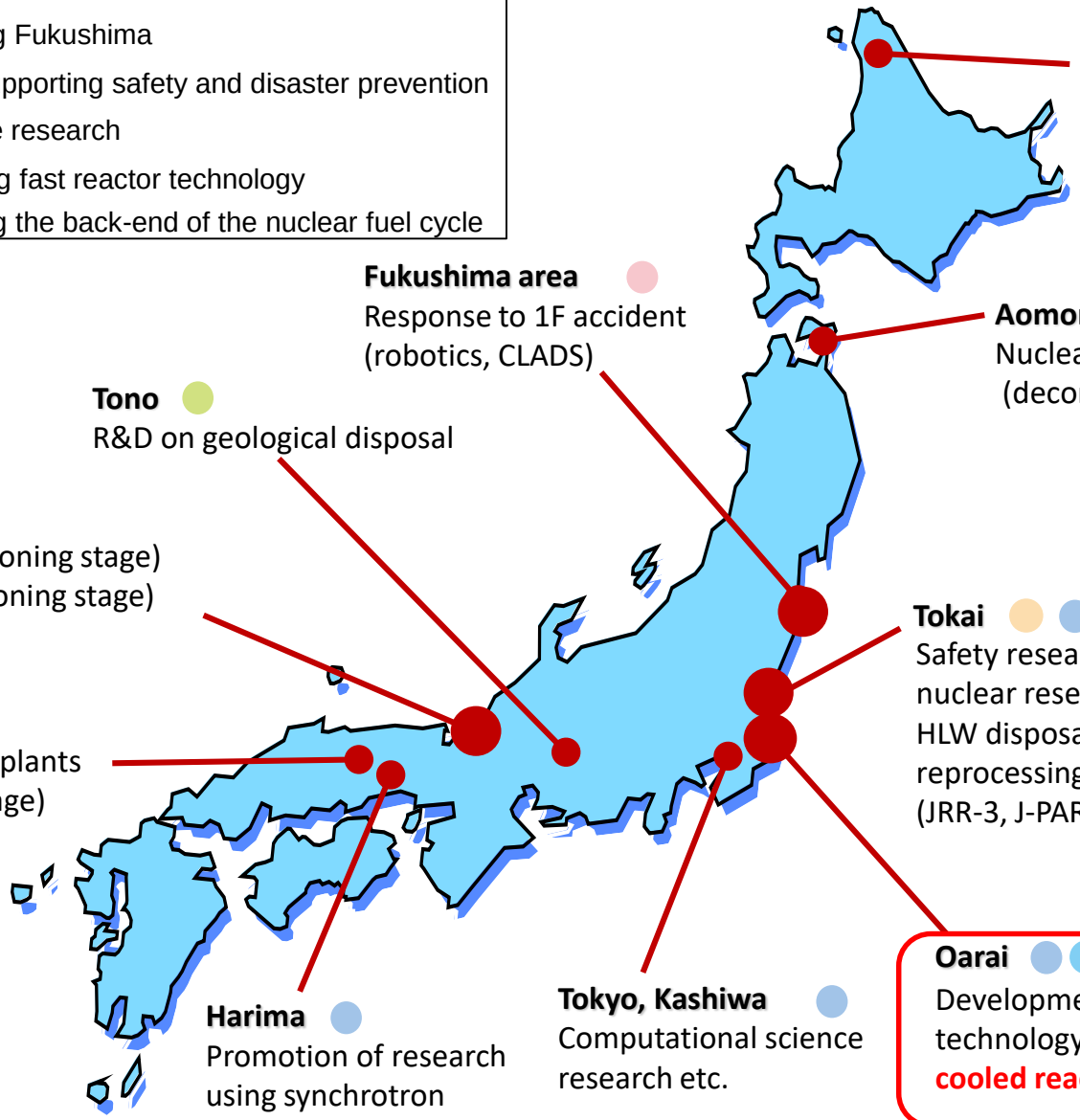
Japanese HTGR development program

Taiju SHIBATA
shibata.taiju@jaea.go.jp

Leader, International Cooperation Group
Sector of Fast Reactor and Advanced Reactor
Research and Development
Japan Atomic Energy Agency (JAEA)

R&D Centers of JAEA

- R&D concerning Fukushima
- Research for supporting safety and disaster prevention
- Nuclear science research
- R&D concerning fast reactor technology
- R&D concerning the back-end of the nuclear fuel cycle



Horonobe
R&D on geological disposal

Aomori
Nuclear ship "Mutsu"
(decommissioning stage)

Fukushima area
Response to 1F accident
(robotics, CLADS)

Tono
R&D on geological disposal

Tsuruga
Monju (decommissioning stage)
Fugen (decommissioning stage)

Ningyo-toge
Uranium enrichment plants
(decommissioning stage)

Tokai
Safety research, Basic and fundamental nuclear research, R&D on technology for HLW disposal, Development of LWR reprocessing technology
(JRR-3, J-PARC, etc.)

Harima
Promotion of research using synchrotron radiation

Tokyo, Kashiwa
Computational science research etc.

Oarai
Development of fast reactor cycle technology, **high-temperature gas-cooled reactor**, etc. (Joyo, **HTTR**)

Organization of JAEA

Re-organized in April 2018

President
Executive Vice President
Executive Directors (6)

Auditors (2)

(Management Sector)

- Decommissioning ang Radioactive Waste Management Head Office
- Office of Strategy and International Affairs
- Safety and Nuclear Security Administration Department
- R&D Program Management Department
- Legal and Audit Department
- General Affairs Department
- Personnel Department
- Financial Affairs Department
- Contract Department
- Public Relations Department
- Smart Operation Promotion Office

(Common Mission Sector)

- Intellectual Resources Management and R&D Collaboration Department
- Construction Department
- Center for Computational Science & e-Systems
- Nuclear Human Resource Development Center
- Integrated Support Center for Nuclear Nonproliferation and Nuclear Security
- Tsuruga Head Office

(Research and Development Sector)

- Sector of Fukushima Research and Development 【Fukushima, Tokai and Oarai】
- Sector of Nuclear Safety Research and Emergency Preparedness 【Tokai 】
- Sector of Nuclear Science Research 【Tokai】
- Sector of Tsuruga Decommissioning Demonstration 【Tsuruga】
- Sector of Fast Reactor and Advanced Reactor Research and Development 【Tsuruga, Tokai and Oarai 】
- Sector of Nuclear Fuel, Decommissioning and Waste Management Technology Development 【Tokai, Ningyo-toge, Tono, Horonobe and Aomori 】

R&D sector concerning HTGR

Sector of Fast Reactor and Advanced Reactor Research and Development

Director General: K. Aoto

Deputy Director General (concerning HTGR): K. Kunitomi

- **Strategy and Planning Office**
- **International Cooperation and Social Environment Office**
  - **International Cooperation Group** — *Senior Principal Researcher Group Leader: T. Shibata*
  - Social Environment Group
- **Reactor Systems Design Department** — *Deputy Director: X. Yan*
  - Fast Reactors Design Group
  - **HTGR Design Group**
  - FR Safety Design Group
- Fuel Cycle Design Department
- Fast Reactor Cycle System Research and Development Center
- **HTGR Research and Development Center**
- Waste Management and Decommissioning Technology Development Center

Strategic Energy Plan in Japan

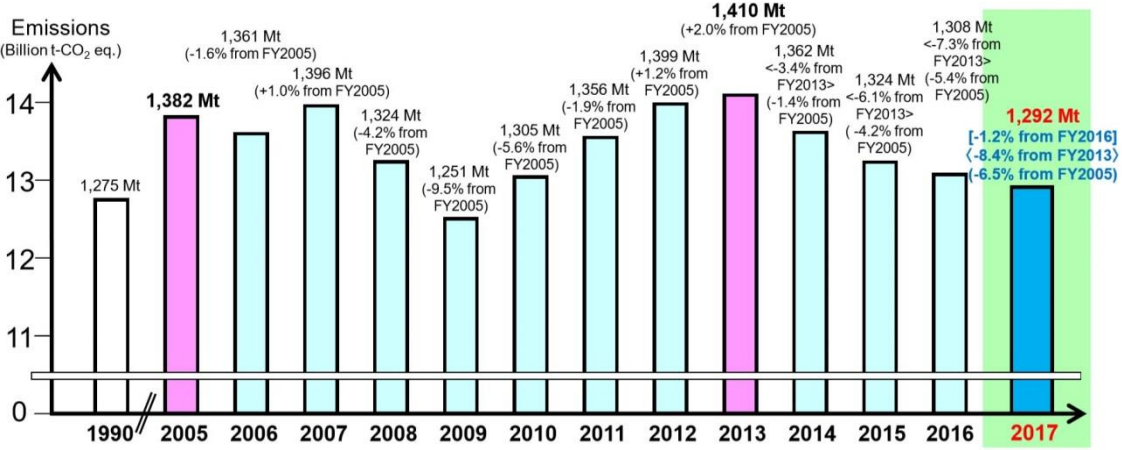
Approved by the Cabinet in July, 2018

	2030	2050
Target: Reduction of greenhouse gases emission	by 26%	by 80%
Ratio of electricity gen. (FY2010→FY2016):		
Renewables (10%→16%)	22-24%	Non-fossil fuel energy should be increased
Nuclear (26%→2%)	22-20%	
Fossil (64%→82%)	56%	
Energy Saving	35% more	
	Promotion of Hydrogen, Battery and Distributed Energy System	

Increase of renewable energy and utilization of H_2 toward 2050 are stated in cabinet decision; Long-term Strategy as a Growth Strategy Based on the Paris Agreement (tentative name) (June 2019 Cabinet Decision) JAEA Translation

Role of HTGR
-Greenhouse gas emissions & reduction goals-

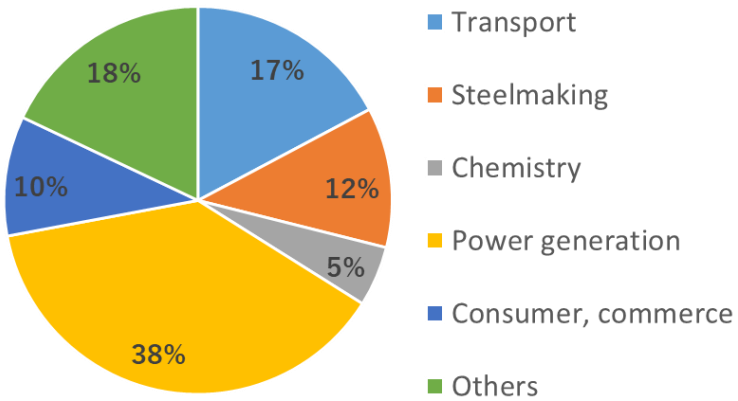
GHG emission in Japan (report of FY2017)



Ref. : Website of Ministry of Environment, Japan

- Emission reduction in FY2017 : 8.4% compared to FY2013
- To achieve the goal,
  - ✓Reduction by additional 18% by 2030
  - ✓Reduction by additional 72% by 2050

Breakdown of GHG emission in Japan



- Reduction of GHG emission about transport, steelmaking and power generation is important.

⇩

- HTGR producing hydrogen for fuel cell vehicle and steel making
- HTGR can supply steam to industries

Use of HTGR beyond power generation is important.

HTGR Systems

Hydrogen production system

hydrogen →

Fuel cell vehicles

Iron making

- Thermo-chemical water splitting process (IS process) or steam methane reforming process for hydrogen production

High temperature steam for industry

Process heat
Electricity →

Chemical plant

- Process heat can be supplied to chemical plant, petroleum refining plant, etc. and power can be produced by steam turbine

Hybrid system with renewable energy

+

→ Constant power to grid

→ Hydrogen production

- Renewable power variation may be absorbed by simple and efficient load following of HTGR power and additional hydrogen cogeneration

Multipurpose cogeneration

Hydrogen, desalination, electricity, etc →

hydrogen town

- Cogeneration (power generation, hydrogen production, desalination, etc.) can achieve 80% of heat utilization rate

✓ **HTGR can attain high efficiency (up to 50% in power generation, to 80% for heat utilization rate).**
✓ **HTGR may be sited near demand areas due to its excellent safety features.**

Policies of HTGR Development in Japan

Strategic Energy Plan (July 2018 Cabinet Decision) Provisional Translation

Under international cooperation, GOJ also facilitates R&D of technologies that serves the safety improvement of nuclear use such as high-temperature gas-cooled reactors, which are expected to be utilized in various industries including hydrogen production and which have an inherent safety.

Growth Strategy 2018 (June 2018 Cabinet Decision) JAEA Translation

The government also will advance research and development for the future by utilizing test reactors that include an experimental fast reactor and a high temperature gas-cooled reactor.

Strategic Roadmap for Hydrogen and Fuel Cells JAEA Translation
(March 12, 2019 Agency for Natural Resources and Energy)

We will consider all possibilities: not only energy resources such as fossil energy and sunlight that are already used for hydrogen production, but also utilization of innovative technologies that can be used for hydrogen production such as high temperature geothermal energy, ocean energy, space sunlight, high temperature gas-cooled reactor, etc.

Long-term Strategy as a Growth Strategy Based on the Paris Agreement (tentative name) (June 2019 Cabinet Decision) JAEA Translation

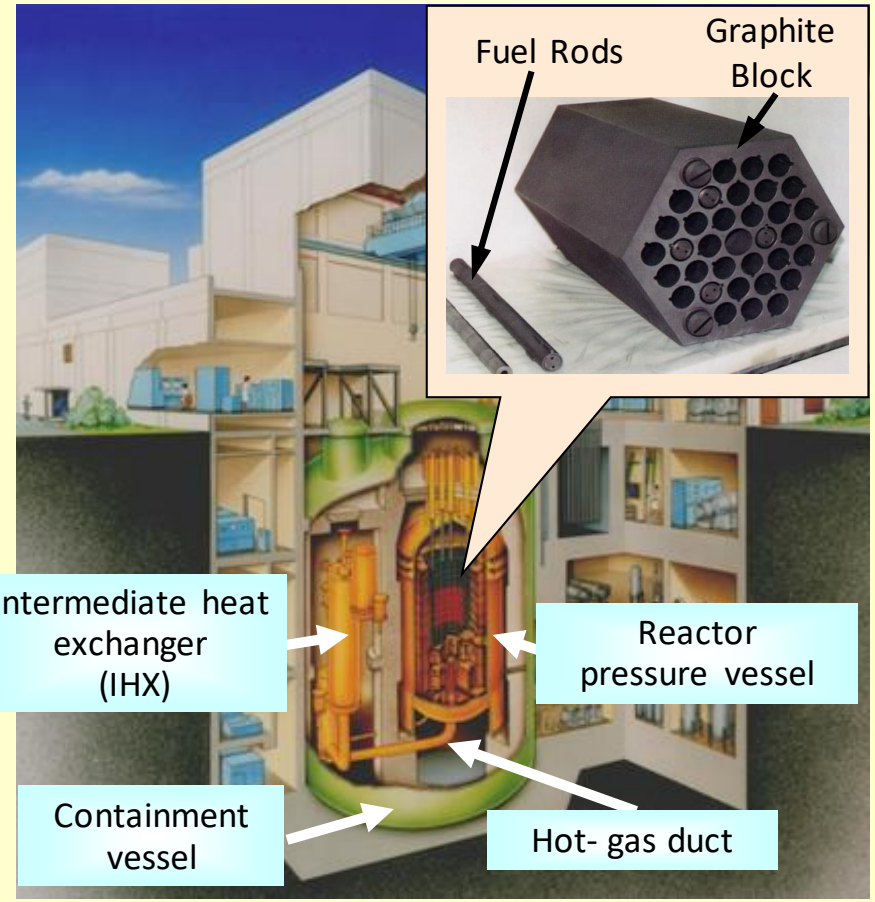
Target: Reducing hydrogen production cost to less than 1/10

Examples of hydrogen production technology: high efficiency water electrolysis, ..., thermochemical hydrogen production using solar heat, industrial waste heat, etc. (IS Process)

Major specification of HTTR, Japan's first HTGR

HTTR(High Temperature Engineering Test Reactor)

Graphite-moderated and helium-cooled HTGR



Major specification

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

First criticality : 1998
Full power operation : 2001
50 days continuous 950°C operation : 2010
Loss of forced cooling test at 9MW : 2010

History and status of HTTR

Proposal for prototype commercial system

Establishment of fundamental technologies

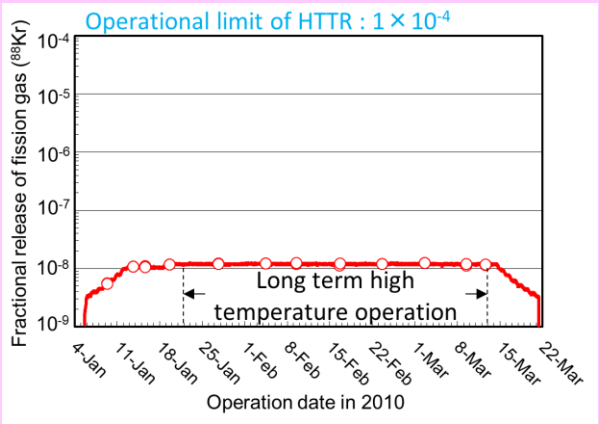
Construction

R&D, design

2014	Conformity review on the new regulatory requirements start toward resumption of operation
2010	Start of loss of forced cooling test
	950ºC/50 days operation
2007	850ºC/30 days operation
2004	Reactor outlet coolant temperature 950ºC
2002	Safety demonstration test (control rod drawing test)
2001	Reactor outlet coolant temperature 850ºC (30MWt)
1998	First criticality
1997 ~ 1991	Construction
1990 ~ 1989	Application and permission of construction
1988 ~ 1985	Detail design
	H T T R
1984 ~ 1981	Basic design
1980 ~ 1974	System integrity design
1973 ~ 1969	Conceptual design

Long term high temperature operation

<Integrity of fuel coating> 950°C, 50days



- R/B of ^{88}Kr : 4 orders of magnitude less than the operational limit

Research and development

Fuels・Materials

In-pile helium loop (OGL-1)

Reactor physics

Very High Temperature Reactor Critical assembly (VHTRC)

Thermal hydraulics

Helium Engineering Demonstration Loop (HENDEL)

HTGR and Heat Application Technologies in JAEA

(1) Reactor technology

- 30 MWt and 950°C prismatic core advanced test reactor (Operation started in 1998)
- Technology of fuel, graphite, superalloy and experience of operation and maintenance.
- Safety evaluation by NRA has almost been completed.

(2) Gas turbine and H_2 technology

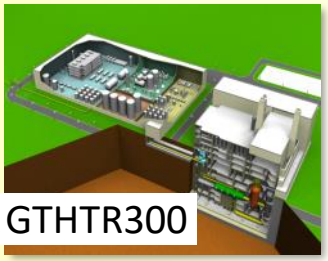
He compressor

- R&D of gas turbine technologies such as high-efficiency helium compressor, shaft seal, and maintenance technology

Hydrogen facility

- 150 hours of H_2 production with rate of 0.03m^3/h in January 2019

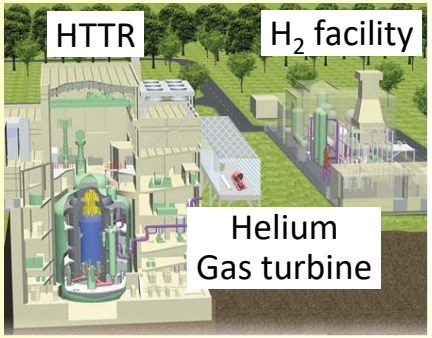
(3) Innovative HTGR design



GTHTR300

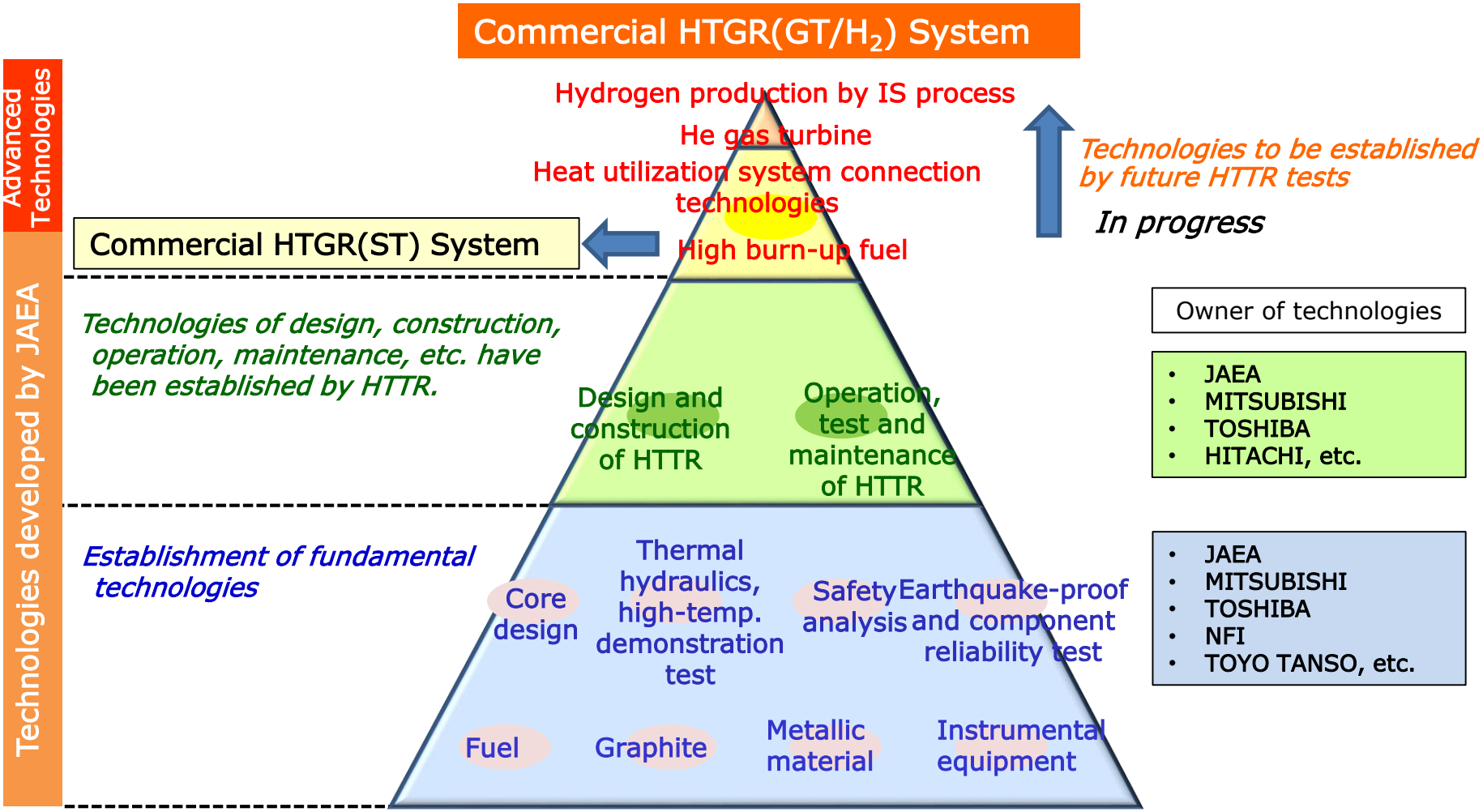
- GTHTR300 for electricity generation, cogeneration and nuclear/renewable energy hybrid system
- HTGR with thorium fuel
- Clean Burn HTGR for plutonium burning
- Establishment of safety design philosophy

(4) HTTR-GT/H2 test



- Connection of a helium gas turbine and hydrogen production system with the HTTR.
- Basic design for the HTTR-GT/H_2 test

Remaining R&D for Japan's HTGR(GT/hydrogen)



R&D towards commercialization of GT and hydrogen HTGR

2020 | 2030 | 2040 | 2050

Private Company

- Design of demonstration reactor（GT, SR）
- Demonstration tests for component（GT, SR ）

- Construction of demonstration reactor（GT, SR）
- Design of demonstration reactor（GT, IS）
- Demonstration tests for component（IS）

- Construction of commercial reactor（GT, SR)
- Construction of demonstration reactor（GT, IS）

International collaboration

- Research reactor
- Demonstration reactor

- Technology of Steam generator, Steam system connecting technology
- High burnup fuel, High performance core
- System with inherent safety
- Establishment of safety standard for steam connecting technology

JAEA

HTTR-GT test

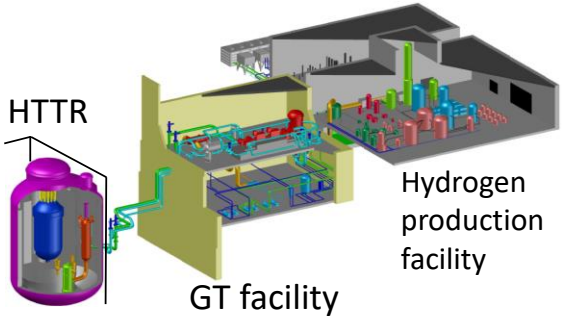
- Confirmation of fuel/material performance under commercial reactor condition
- Support of establishing design/ material standard
- Development of basic technologies for IS process

HTTR-IS test

- Confirmation of fuel/material performance under commercial reactor condition

HTTR-GT/H_2 test

- Design of GT, fuel, and IS facility, core, heat flow and seismic design, support of safety evaluation
- Provision of HTTR-GT/H2 test data and technical knowledge
- Training of operator



※GT : Gas Turbine, SR : Steam reformer, IS : IS process

Summary

- Reduction of CO_2 emission is a crucial subject. Increase of renewable energy and utilization of H_2 toward 2050 are stated in cabinet decision.
- HTGR is an attractive to reduce CO_2 emission by using beyond power generation such as H_2 production, heat supply, etc.
- JAEA has established various advanced HTGR technologies necessary for commercial HTGR systems through construction and operation of HTTR.
- JAEA's HTGR technologies are applicable to deploy HTGR through international collaboration.