Japanese HTGR development program

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

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

Tokai
- Nuclear ship “Mutsu” (decommissioning stage)

Horonobe
- R&D on geological disposal

Aomori
- Nuclear ship “Mutsu” (decommissioning stage)

Tono
- R&D on geological disposal

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

Ningyo-toge
- Uranium enrichment plants (decommissioning stage)

Tsuruga
- Monju (decommissioning stage)
- Fugen (decommissioning stage)

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 and 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

(Research and Development Sector)
Sector of Nuclear Science Research
[Tokai]
Sector of Higher Education and Research
[Tokai]
Sector of Nuclear Fuel, Decommissioning and Waste Management Technology Development
[Tokai, Ningyo-TOGE, Tono, Horonobe and Aomori]

(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

Sector of Fukushima Research and Development
[Fukushima, Tokai and Oarai]
Sector of Nuclear Safety Research and Emergency Preparedness
[Tokai]
Sector of Tsuruga Decommissioning Demonstration
[Tsuruga]
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
  □ Social Environment Group
  Senior Principal Researcher
  Group Leader: T. Shibata
  Deputy Director: X. Yan

◆ Reactor Systems Design Department
  □ 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

<table>
<thead>
<tr>
<th></th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target:</strong> Reduction of greenhouse gases emission</td>
<td>by 26%</td>
<td>by 80%</td>
</tr>
<tr>
<td><strong>Ratio of electricity gen.</strong> (FY2010→FY2016)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renewables (10%→16%)</td>
<td>22-24%</td>
<td>22-20%</td>
</tr>
<tr>
<td>Nuclear (26%→2%)</td>
<td>56%</td>
<td>Non-fossil fuel energy should be increased</td>
</tr>
<tr>
<td>Fossil (64%→82%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Energy Saving</strong></td>
<td>35% more</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Promotion of Hydrogen, Battery and Distributed Energy System</td>
<td></td>
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</table>
Role of HTGR - Greenhouse gas emissions & reduction goals -

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

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.
Hybrid system with renewable energy

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

Hydrogen production system

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

High temperature steam for industry

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

Multipurpose cogeneration

- 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.
Strategic Energy Plan (July 2018 Cabinet Decision) Provisional Translation

Under international cooperation, GOJ also facilitates R&D of technologies that serve 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 (March 12, 2019 Agency for Natural Resources and Energy) JAEA Translation

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

- Fuel Rods
- Graphite Block
- Intermediate heat exchanger (IHX)
- Reactor pressure vessel
- Containment vessel
- Hot-gas duct

**Major specification**

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal power</td>
<td>30 MW</td>
</tr>
<tr>
<td>Fuel</td>
<td>Coated fuel particle / Prismatic block type</td>
</tr>
<tr>
<td>Core material</td>
<td>Graphite</td>
</tr>
<tr>
<td>Coolant</td>
<td>Helium</td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>395°C</td>
</tr>
<tr>
<td>Outlet temperature</td>
<td>950°C</td>
</tr>
<tr>
<td>Pressure</td>
<td>4 MPa</td>
</tr>
<tr>
<td>First criticality</td>
<td>1998</td>
</tr>
<tr>
<td>Full power operation</td>
<td>2001</td>
</tr>
<tr>
<td>50 days continuous 950°C operation</td>
<td>2010</td>
</tr>
<tr>
<td>Loss of forced cooling test at 9MW</td>
<td>2010</td>
</tr>
</tbody>
</table>
History and status of HTTR

- **Establishment of fundamental technologies**
  - 1998: First criticality
  - 1997–1991: Construction
  - 1990–1989: Application and permission of construction
  - 1988–1985: Detail design
  - 1984–1981: Basic design
  - 1980–1974: System integrity design
  - 1973–1969: Conceptual design

- **Construction**
  - Proposal for prototype commercial system
  - 2014: Conformity review on the new regulatory requirements start toward resumption of operation
  - 2010: Start of loss of forced cooling test
  - 2007: Reactor outlet coolant temperature 850°C/30 days operation
  - 2004: Reactor outlet coolant temperature 950°C
  - 2002: Safety demonstration test (control rod drawing test)
  - 2001: Reactor outlet coolant temperature 850°C (30MWt)
  - 1998: First criticality
  - 1997–1991: Construction

- **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)

- **Long term high temperature operation**
  - Operational limit of HTTR: $1 \times 10^{-4}$
  - Fractional release of fission gas ($\text{mBq/kg}$)
  - R/B of $^{88}$Kr: 4 orders of magnitude less than the operational limit

- **Timeline**
  - 1973–1969: Conceptual design
  - 1981–1980: System integrity design
  - 1989–1980: Application and permission of construction
  - 2001: Reactor outlet coolant temperature 850°C (30MWt)
  - 2002: Safety demonstration test (control rod drawing test)
  - 2004: Reactor outlet coolant temperature 950°C
  - 2007: Reactor outlet coolant temperature 850°C/30 days operation
  - 2010: Start of loss of forced cooling test
  - 2014: Conformity review on the new regulatory requirements start toward resumption of operation
(1) Reactor technology

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

(2) Gas turbine and H₂ technology

- R&D of gas turbine technologies such as high-efficiency helium compressor, shaft seal, and maintenance technology
- 150 hours of H₂ production with rate of 0.03 m³/h in January 2019

(3) Innovative HTGR design

- 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/H₂ test
Technologies of design, construction, operation, maintenance, etc. have been established by HTTR. Technologies to be established by future HTTR tests are in progress.

Commercial HTGR(GT/H2) System

- Hydrogen production by IS process
- He gas turbine
- Heat utilization system connection technologies
- High burn-up fuel

Design and construction of HTTR
- Thermal hydraulics, high-temp. demonstration test
- Safety/Earthquake-proof analysis and component reliability test
- Instrumental equipment
- Metallic material
- Graphite
- Fuel

Commercial HTGR(ST) System

Establishment of fundamental technologies

- Core design

Owner of technologies
- JAEA
- MITSUBISHI
- TOSHIBA
- HITACHI, etc.

Remaining R&D for Japan’s HTGR(GT/hydrogen)
### R&D towards commercialization of GT and hydrogen HTGR

**Timeline:**
- **2020:**
  - Design of demonstration reactor (GT, SR)
  - Demonstration tests for component (GT, SR)
- **2030:**
  - Construction of demonstration reactor (GT, SR)
  - Design of demonstration reactor (GT, IS)
  - Demonstration tests for component (IS)
- **2040:**
  - Construction of commercial reactor (GT, SR)
  - Construction of demonstration reactor (GT, IS)
- **2050:**
  - Construction of commercial reactor (GT, SR)

### Key Activities:
- **Private Company**
  - HTTR - IS test
  - Confirmation of fuel/material performance under commercial reactor condition
  - Support of establishing design/material standard
- **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
  - HTTR-IS test
    - Confirmation of fuel/material performance under commercial reactor condition
  - Development of basic technologies for IS process

### HTTR-GT/H₂ 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
Reduction of CO₂ emission is a crucial subject. Increase of renewable energy and utilization of H₂ toward 2050 are stated in cabinet decision.

HTGR is an attractive to reduce CO₂ emission by using beyond power generation such as H₂ 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.