Nuclear Power Strategy Briefing

June 5, 2023

Mitsubishi Heavy Industries, Ltd.

Outline

1．MHI Nuclear Power Business Domain

2．Nuclear Power Developments in Japan and Overseas

3．Initiatives by Business Area
- Support of Restarting/Maintenance work for Existing plants
- Establishing Nuclear Fuel Cycle
- Major Activities in Overseas Market

4．Development of Advanced Reactors

5．Business Plan

MHI Nuclear Power Business Domain

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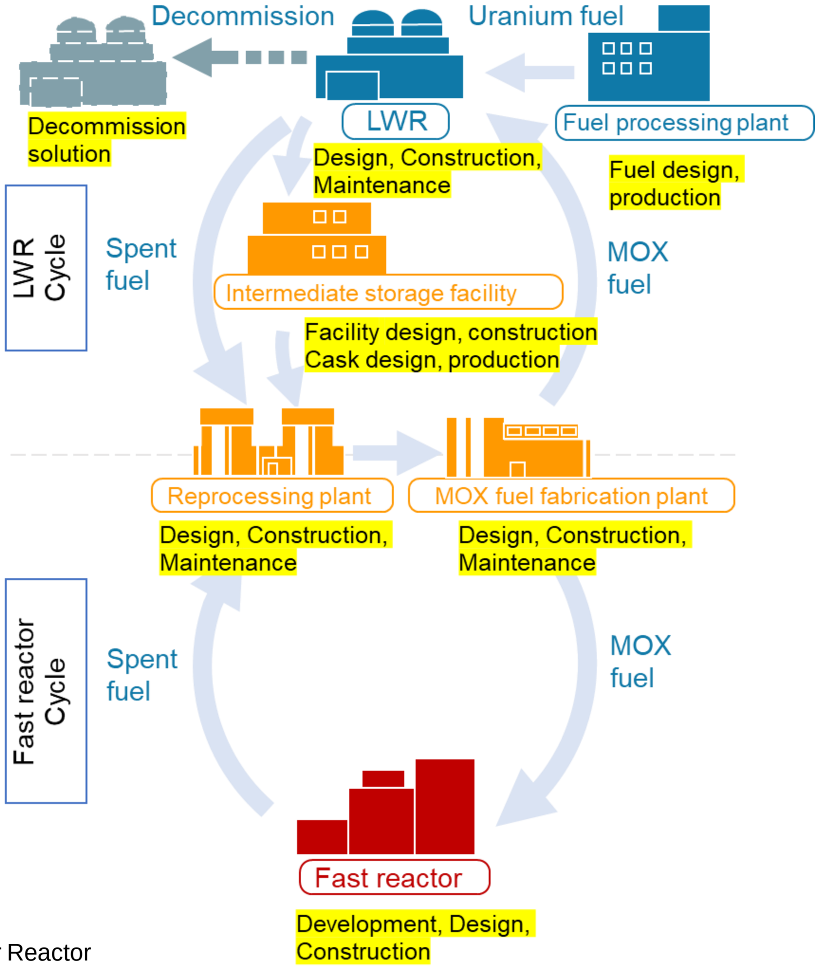
- Since the commercial operation of Mihama Unit 1 in 1970, **MHI has constructed all 24 PWRs in Japan.** MHI has continuously worked on technical improvements and ensured **these PWRs offer world-class safety, reliability, economy, operability and maintainability**. **MHI also supports the restart of these PWR plants (but also BWR).**
- In addition to **safe and stable operation of nuclear power plants**, MHI **acknowledges the importance of establishing a nuclear fuel cycle, and is contributing to various areas in the cycle (including Fast Reactor)**.



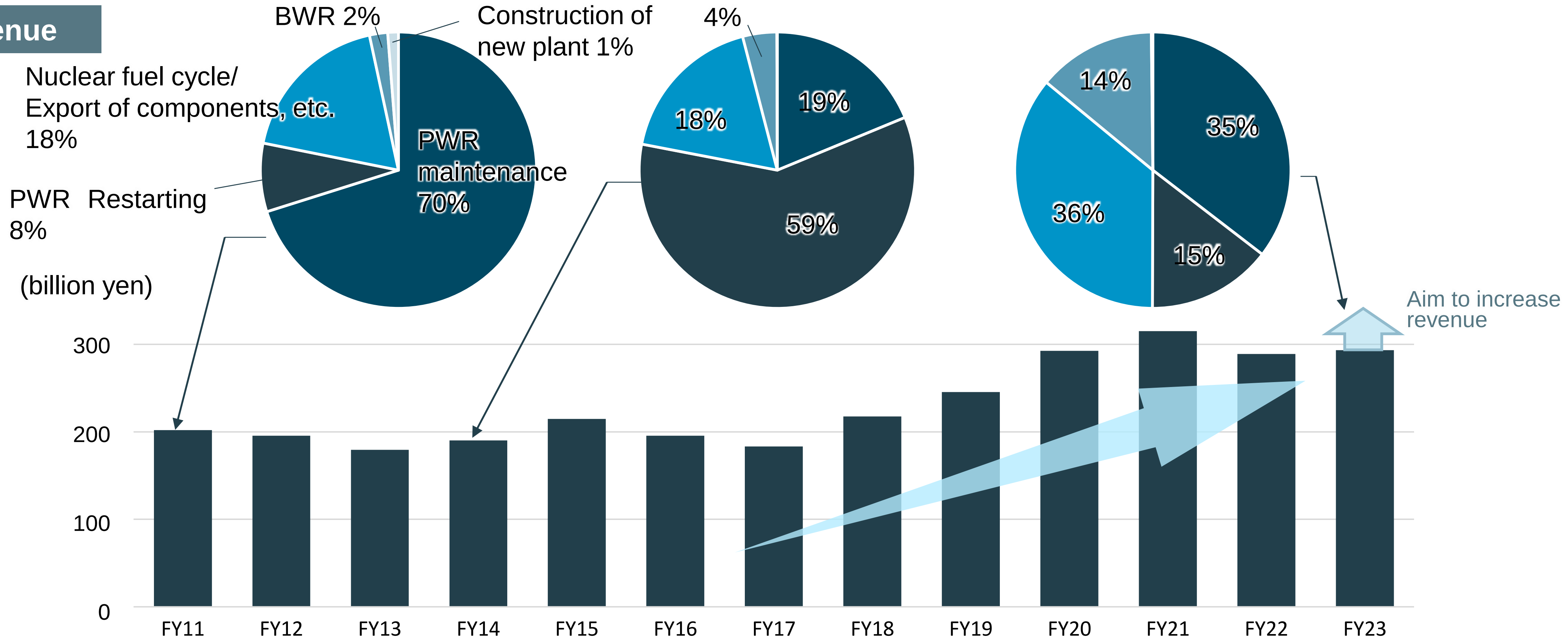
LWR: Light Water Reactor

LWR	PWR After Service	Restart, Specialized safety facility, Inspection, Maintenance, Operation enhancement, Fuel, etc.
LWR	BWR	Restart, Installation of specialized safety facility
LWR	Overseas	Export of components
LWR	New plant	SRZ-1200(mid-sized LWR)
Decommission		Decommission of plants, Fuel debris retrieval in Fukushima Daiichi
Fuel cycle	RRP/J-MOX	Construction of plants RRP: Rokkasho Reprocessing Plant J-MOX: MOX fuel fabrication plant
Fuel cycle	Cask	Production of cask (for transport / storage of spent fuel)
Advanced reactor	Fact reactor	Development as the lead company in Japan
Advanced reactor	SMR (Small LWR)	Development for distributed power source in small grid area
Advanced reactor	HTGR	Development as heat source for hydrogen production HTGR: High-Temperature Gas reactor
Advanced reactor	Fusion reactor	Development by participating in ITER program

Nuclear Energy Systems Revenue

- Before the Great East Japan Earthquake, the business structure of Nuclear Energy Systems centered on the maintenance works of existing PWR plants. But in response to the change in the business structure since the earthquake, MHI has expanded the scope of the support for the restarting BWR plants and the construction of nuclear fuel facilities.
- **MHI has diversified our business and moved away from the business model that relies on PWR plant maintenance works. Since this change, the revenue has been expanding after FY17**. In addition, maintaining and expanding revenue will be expected over the medium to long term.

Revenue



Nuclear Power Developments in Japan and Overseas

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- **From the viewpoint of energy security and in response to soaring natural resource prices, countries around the world are making a major shift toward the use of nuclear power. MHI recognizes that the movement toward the maximum utilization of nuclear power is taking shape in Japan as well.**

【Global】

- In order to achieve Carbon Neutrality (CN), major countries have reaffirmed the necessity of nuclear energy and will continue to use nuclear energy in the future.
- The European Commission announced they will include nuclear as 'green' energy in its final proposal for the Taxonomy Delegated Act. It was scrutinized by the European Parliament and Council, but has been approved and went into effect as of January 2023.
- In particular, the United Kingdom, France, and the Netherlands have successively announced their plans to build new large reactors (28 reactors) from the perspective of cost and timing of installation.

【Japan】

- In order to maximize the use of nuclear energy, the "Basic Policy for realization of GX", including the following points, was approved by the Cabinet on Feb 10. The law for operating nuclear power plants beyond the limit of 60 years went into effect on May 31.

①Restart existing reactors, ②Develop/construct next-generation reactors, ③Utilize existing plants, ④Nuclear fuel cycle

US	✓ Obtained 80-year operating license for multiple existing reactors Currently constructing 2 new reactors (1,000MWe class PWRs) ✓ Companies (startup ventures) are actively developing advanced reactors such as small reactors and high-temperature gas-cooled reactors. ※ ※ TerraPower is developing a sodium-cooled fast reactor (concluded MOU with MHI to cooperate on such development)
UK	✓ Currently constructing 2 new reactors (1,600 MWe class PWRs) ✓ Announced plan to construct a maximum of 8 new large reactors by 2050s. ✓ Subsidy of tens of billions of yen for advanced reactor development (small reactor/high temperature gas reactor/fast reactor/nuclear fusion reactor, etc.)
France	✓ More than 70% of energy power is nuclear ✓ Currently constructing 1 new reactor (1,600 Mwe class PWR) ✓ Announced that the construction of 6 large reactors+8 additional reactors is currently under consideration ✓ Subsidy of approximately 130 billion yen for the development of small LWRs, etc.

Germany	✓ Extending the life of the existing reactors (3 units in total) until April 2023, but giving up further extension of operation due to the dispersion of technology and human resources, the difficulty in securing fuel, etc. ✓ Although more than half of the public were in favor of keeping the nuclear plant operating, the last nuclear plants were retired.
Belgium	✓ Announced the extension of operation of existing reactors (two units) scheduled to be closed by 2025 (also exploring extension of operation of one additional reactor)
Netherlands	✓ Announced plans to extend the operation of existing reactors and to consider construction of 2 to 6 new large reactors
Korea	✓ Under the slogan of "building the strongest nuclear nation," the policy is to extend the operation of existing reactors and resume construction of two new reactors.
Other EU	✓ Czech Republic: Western countries are planning to bid for 1 to 4 new large reactors ✓ Poland: Planning the construction of 6 new large reactors

Government Policy Towards Carbon Neutrality: Basic Policy for Realization of GX

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- At the 5th meeting of GX (Green Transformation) Implementation Council on Dec 22, the “Basic Policy for realization of GX” was reported, which is approved by the Cabinet on Feb 10.
- The Basic Policy states that nuclear energy shall **“play an important role as carbon free baseload power to achieve supply stability and carbon neutrality”** and calls for action in the following four areas.

  ①Restart existing reactors, ②Develop/Construct next-generation reactors, ③Utilize existing nuclear power plants, ④Nuclear fuel cycle
- **The Basic Policy is consistent with MHI’s nuclear power business policy, and MHI will continue to promote initiatives in all fields of nuclear power in cooperation with electric power companies.**

＜Basic Policy for realization of GX (Actions related to utilization of nuclear energy) ＞

Objectives	Main Actions
① Restart existing reactors	• Obtain public acceptance through actions led by Central Government and improvement of operating system of Utilities
② Develop/Construct next-generation reactors	• Work on development and construction of next generation innovative reactors with new safety features • First, target the replacement of decommissioned reactors with next-generation innovative reactors
③ Utilize existing nuclear power plants	• Develop new rule of operation period, satisfying safety requirement by NRA • Maintain 40 years (base) + 20 year (extension), but could be further extended by excluding offline period for inspections
④ Nuclear fuel cycle	• Progress nuclear fuel cycle such as completion of RRP

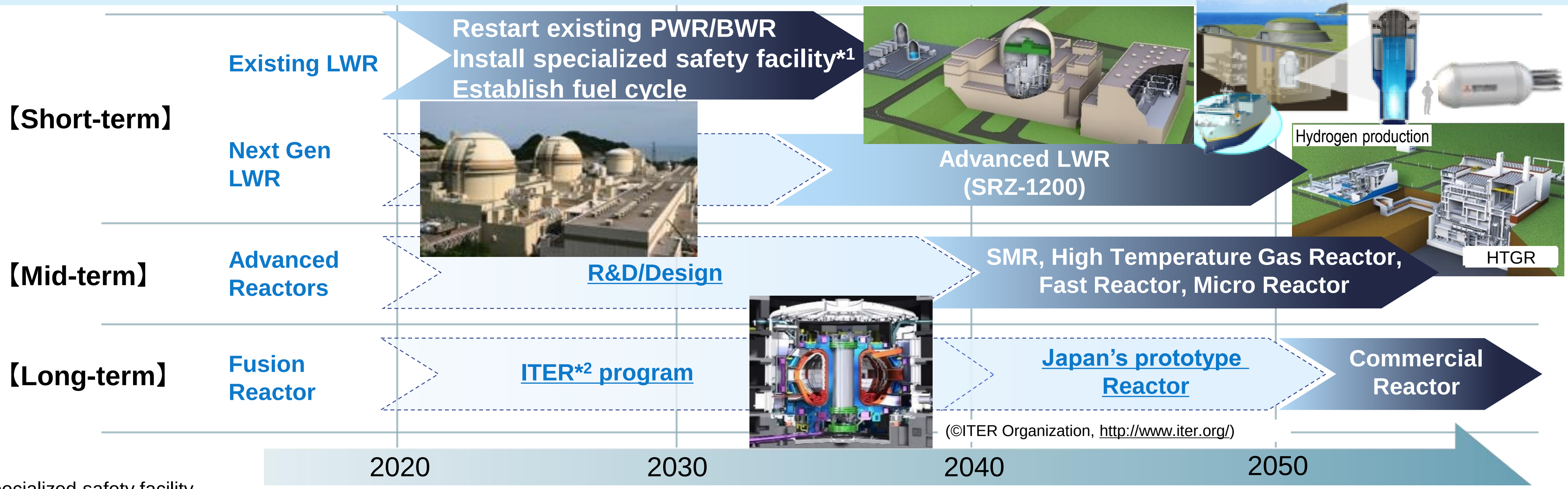
MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

3. Initiatives by Business Area

三菱重工

Roadmap of MHI Nuclear Power Business

- Nuclear energy, **as an important base load power source** due to it being a carbon-free, large-scale, stable power source, helps achieve energy security and is **a crucial tool in achieving carbon neutrality by 2050.**
- MHI **supports the restart and enhancement of safety for existing plants**, as well as **establishment of a fuel cycle**.
- MHI is contributing to **carbon neutrality and energy security** by **commercialization of an advanced LWR, called SRZ®-1200,** which achieves **the world's highest-level of safety**.
- Further, MHI is **developing various advanced reactors to meet diverse and future social needs**, along with continuing to work on **fusion reactor** as a "perpetual energy source".

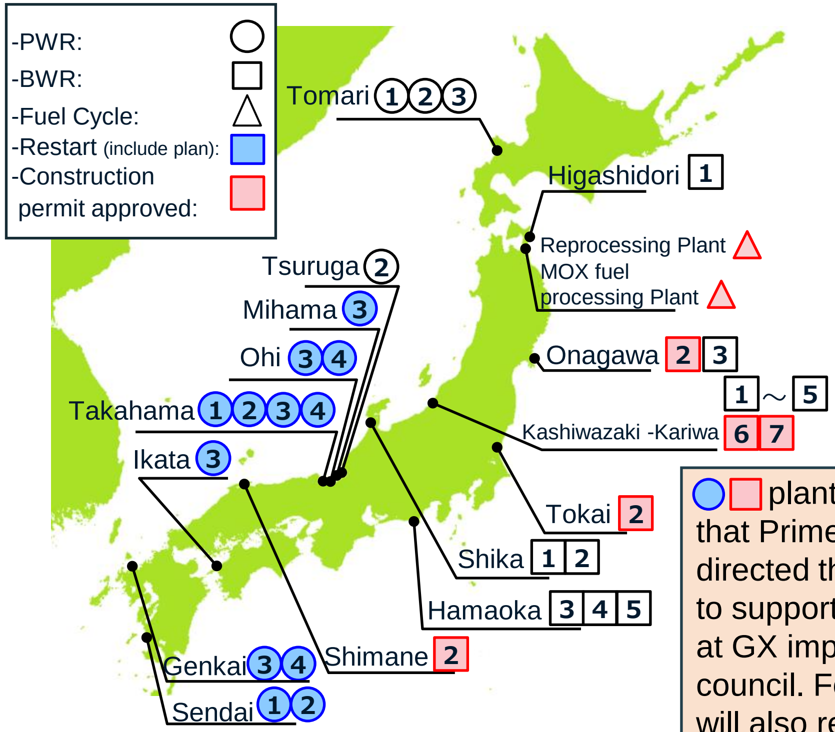


*1 Specialized safety facility
Facility designed to safely shut down the plant in the event of of intentional airplane clushes or other terrorism.

*2 ITER program:
International project aimed at the early realization of the fusion demonstration reactor through the international cooperation of seven parties (Japan, EU, US, Russia, China, South Korea and India)

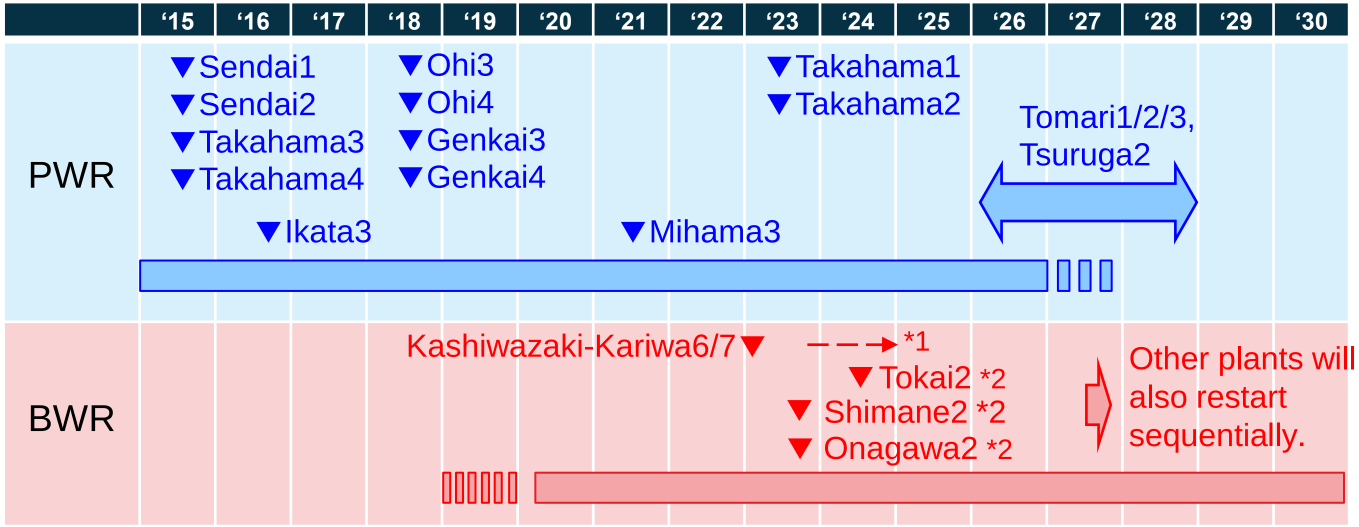
Restart of Existing Nuclear Power Plant in Japan

- In order to achieve a target **nuclear share of electricity generation of 20-22% in Japan**, which is a prerequisite for 46% reduction in greenhouse gases by 2030, **it is essential to operate 25-28 nuclear power plants.**
- Conversely, confidence in nuclear power has declined since the Great East Japan Earthquake and **restoring this confidence is a top priority**. **MHI contributes to restart of both PWR and BWR to conform to new regulations**, by providing support on **safety measures and installation of "Specialized Safety Facilities"**.
- Restart of PWRs including **Mihama Unit 3 and Takahama Unit 1/2 which operated beyond 40 years is progressing successfully with Mihama Unit 3 restarting operation**. **Takahama Unit 1/2 plans to restart in the summer of 2023**.



plants are 17 plants that Prime Minister Kishida directed the government to support in restarting at GX implementation council. Follow-on plants will also restart sequentially.

<Restart Status>



*1: Kashiwazaki-Kariwa restart schedule (Publicized by TEPCO)
unit 7: Oct. 2023, unit 6: Apr. 2025

*2: Target date for completion of safety measures(Publicized by Utilities)

Support for BWR Plant Restarting

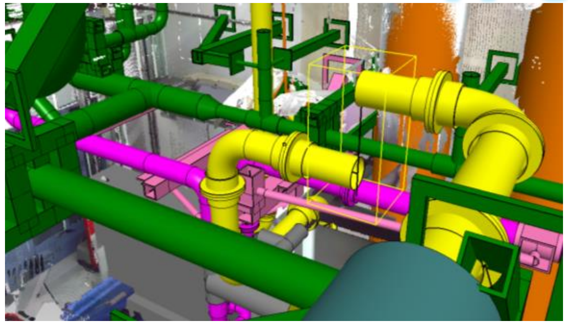
- Construction works for additional safety measures are being implemented at BWR plants[*1] approved for reactor installation license. By leveraging know-how gained from our experience with PWR plants, MHI has received **many requests for support from BWR utilities**. **The scope of MHI's support has expanded to include licensing support, safety measures/installation of Specialized Safety Facilities (Onagawa 2, etc.) and support on project management from the licensing stage.**

*1: Kashiwazaki-kariwa 6/7, Onagawa 2, Shimane 2, Tokai 2

● : MHI is supporting, □ : Proposing support

MHI's support		Plants approved for installment license					Follow-on Plants		
		Plant A	Plant B	Plant C	Plant D	Plant E	Plant F	Plant G	Plant H
Restarting support	Licensing support	●	●	●	●	●	□	□	●
Restarting support	Seismic reinforcement work for existing piping/equipment, Piping installation	●	●	●	●	●	□	●	●
Restarting support	Expansion of power supply facilities (Gas turbine/Diesel generators)	–	–	●	●	●	–	□	□
Restarting support	Measures against Tsunami, fire and internal flooding protection (Sealing of building penetrations)	●	●	●	●	●	□	□	●
Restarting support	Measures against Tornado/volcanic ash	●	●	●	●	●	□	●	●
Specialized Safety Facilities		●	●	●	–	●	□	□	●

Seismic analysis and reinforcement work for piping

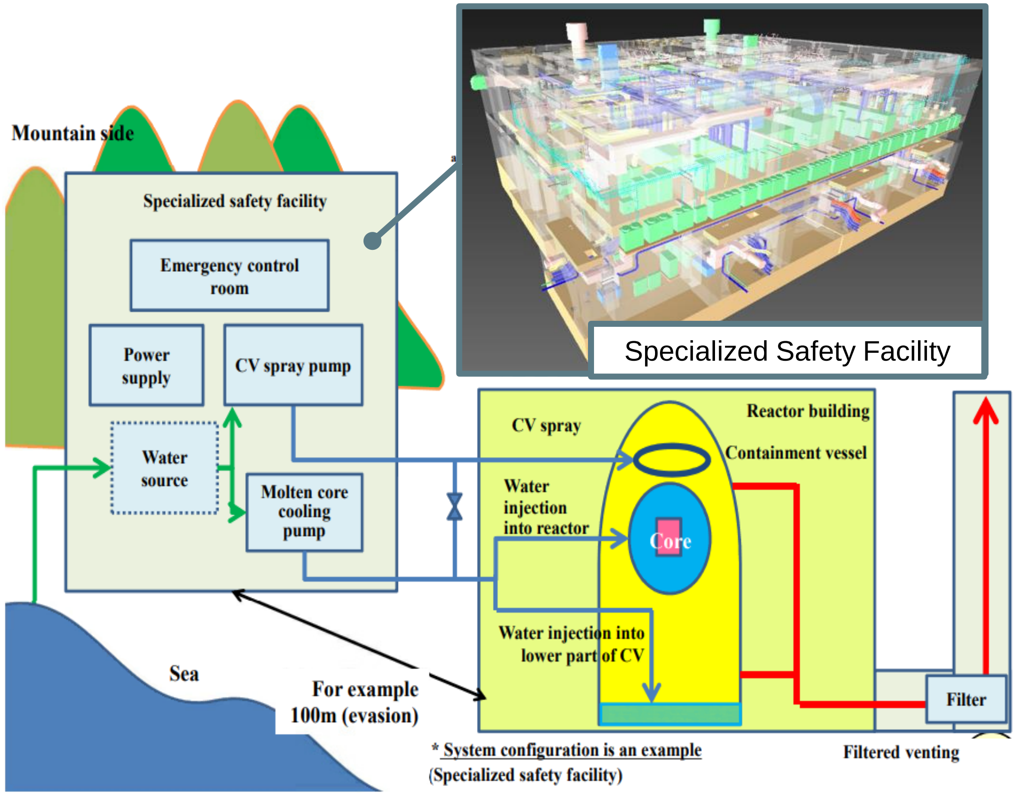


Expansion of power supply facilities

Installation of Specialized Safety Facility

- The new regulatory standards require installation of a "Specialized Safety Facility (SSF)" that is an independent large-scale facility to safely shut down the reactor in the event of an emergency[*1]. (Total construction fee: Hundreds to 100 billion yen)
- **MHI has been installing SSFs in all domestic PWR plants**. The installation of SSFs for Sendai 1/2, Takahama 3/4, Ikata 3, Mihama 3, Ohi 3/4 and Genkai 3/4 are completed.
- **By leveraging know-how gained from our experience with PWR plants**, **MHI is also progressing SSFs construction work for some BWR plants.**

*1 Airplane crash (APC), terrorist attacks etc.

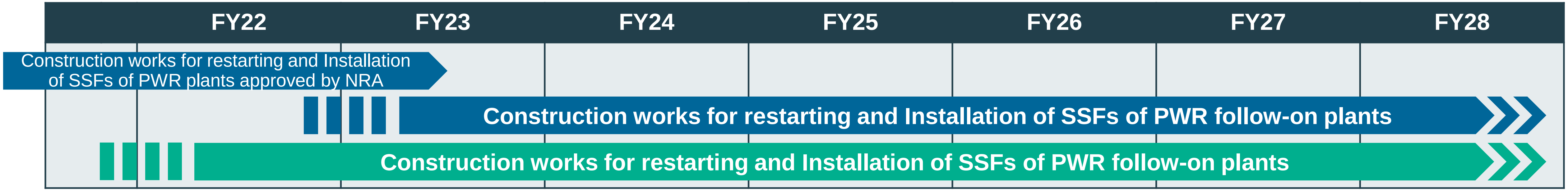


	Utilities	Plants	Manufacturer	Status
PWR	Kansai Electric	Takahama3/4	MHI	Completed
		Takahama1/2	MHI	Under construction
		Mihama3	MHI	Completed
		Ohi3/4	MHI	Completed
	Kyushu Electric	Sendai1/2	MHI	Completed
		Genkai3/4	MHI	Completed
	Shikoku Electric	Ikata3	MHI	Completed
	Hokkaido Electric	Tomari3	MHI	Under review by NRA
		Tomari1/2	MHI	Planned
	Japan Atomic Power Company	Tsuruga2	MHI	Planned
BWR	Tohoku Electric	Onagawa2	MHI	Under review by NRA
	—	Plant a	MHI	—
	—	Plant b	MHI	—
	—	Plant c	MHI	—
	—	Plant d	TBD	—
	—	Plant e	Other company	—
	—	Plant f	MHI performed the conceptual design.	—
	—	Follow-on plant	TBD	—

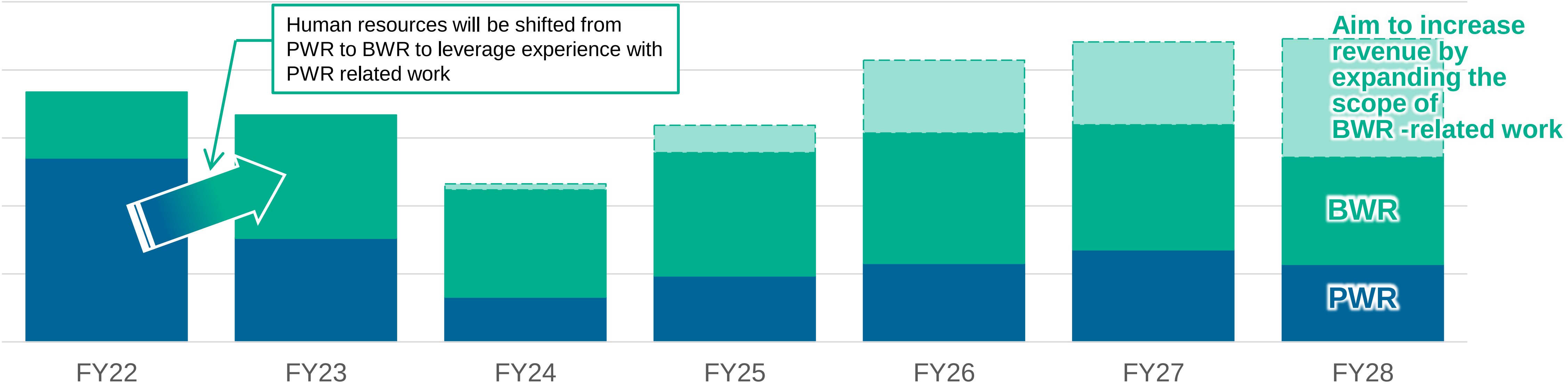
Business Scale Related Restart of Existing PWR/BWR Plants

- Both the construction works for restarting and the installation of SSFs of PWR plants approved by NRA will be completed by this fiscal year. However, **the construction work for PWR follow-on plants** (Tomari, Tsuruga) and **BWR plants will start in earnest from FY24**. Therefore, **these types of project will continue until around FY30**.

【Schedules of Construction works for restarting and installation of SSFs(MHI estimates)】



【Revenue of Construction works for restarting and installation of SSFs (Excluding maintenance work after restarting)】

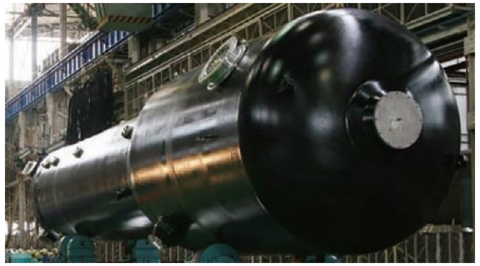


Maintenance of Existing Plants After Restarting

- With a view achieving 60 years operations from existing nuclear power plants, MHI is systematically carrying out **various major maintenance works** (SGR[1], CIR[2], Turbine replacement etc.) to secure long-term integrity of the plants. Recently, **a SGR was announced for Kansai Electric Power Co.'s Takahama Unit 3/4.** (Press release in Apr. 2023)
- In addition, **safety improvement assessments and maintenance works**(CBR[3] etc.) **incorporating latest knowledge and technology** are implemented.
- From the standpoint of **strengthening the competitiveness of nuclear power**, MHI is working **to enhance the plant operating rates** (extending the operating cycle length and shortening period of the periodic inspection).

1 SGR: Steam Generator Replacement, 2 CIR: Core Internal Replacement, 3 CBR: Control Board Replacement

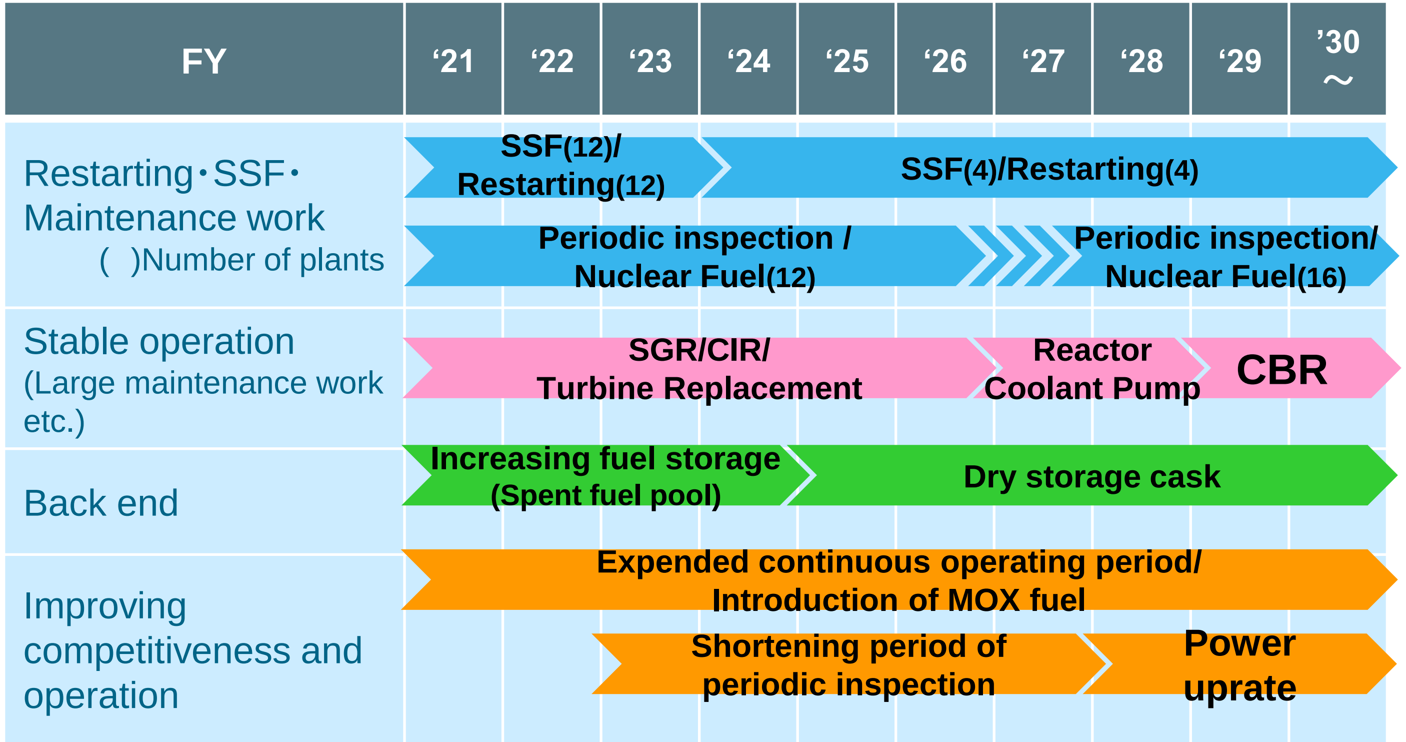
【Example of major maintenance works】



Steam generator

Core internal

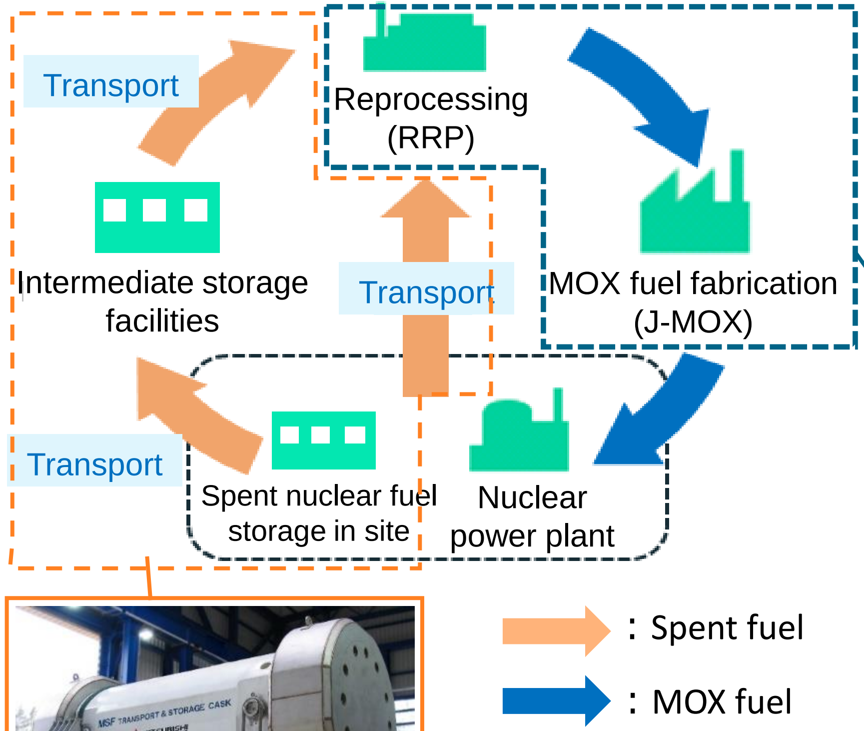
Control Board



Nuclear Fuel Cycle Initiatives

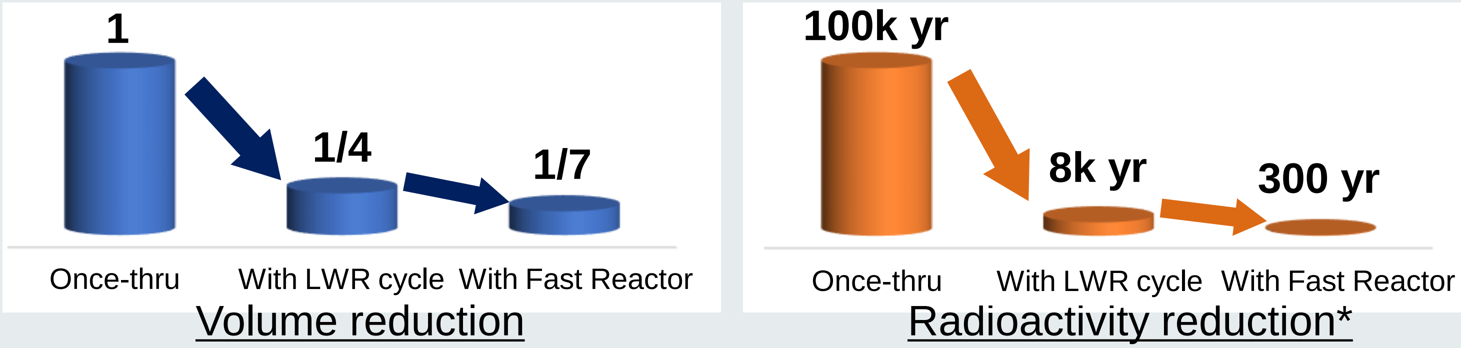
- Establishing a nuclear fuel cycle is essential for long-term use of nuclear power, including effective resource utilization, reduction of surplus plutonium (an international commitment), and reduction of the hazard level/the volume of high-level radioactive waste. In order to complete the Rokkasho Reprocessing plant (RRP) and the MOX fuel processing plant (J-MOX) as soon as possible, MHI is supporting Japan Nuclear Fuel Limited (JNFL) in licensing, construction and inspection.
- Dry casks for transport/storage of spent nuclear fuel are designed and fabricated for intermediate storage.

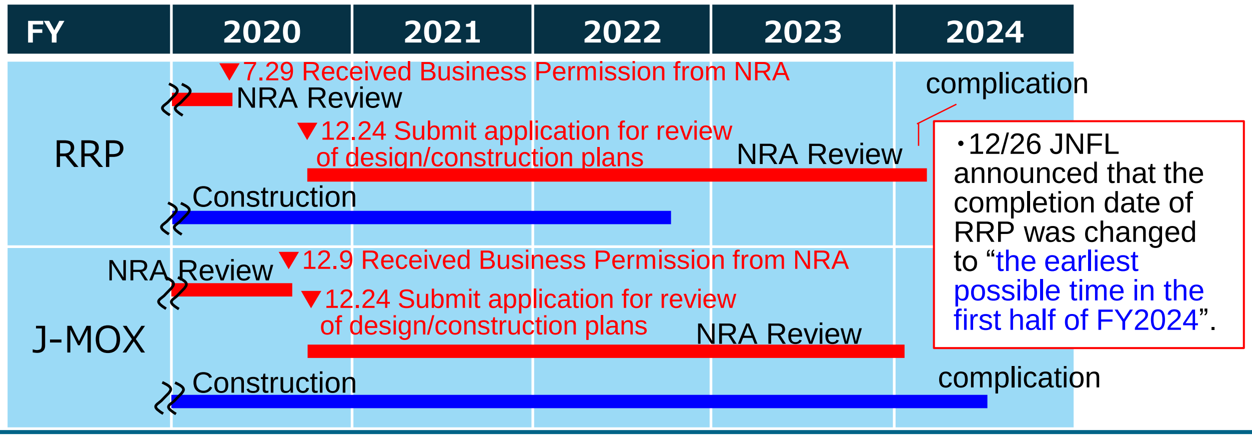
⇒To support the safe and stable operation of nuclear fuel cycle facilities after completion, MHI is developed their maintenance plans



【Dry cask for transport/storage】

Volume/ Radioactivity reduction of High-level waste with Nuclear Fuel Cycle





*years needed to radioactivity equivalent to natural uranium

Establishing Stable Operation of Nuclear Fuel Cycle

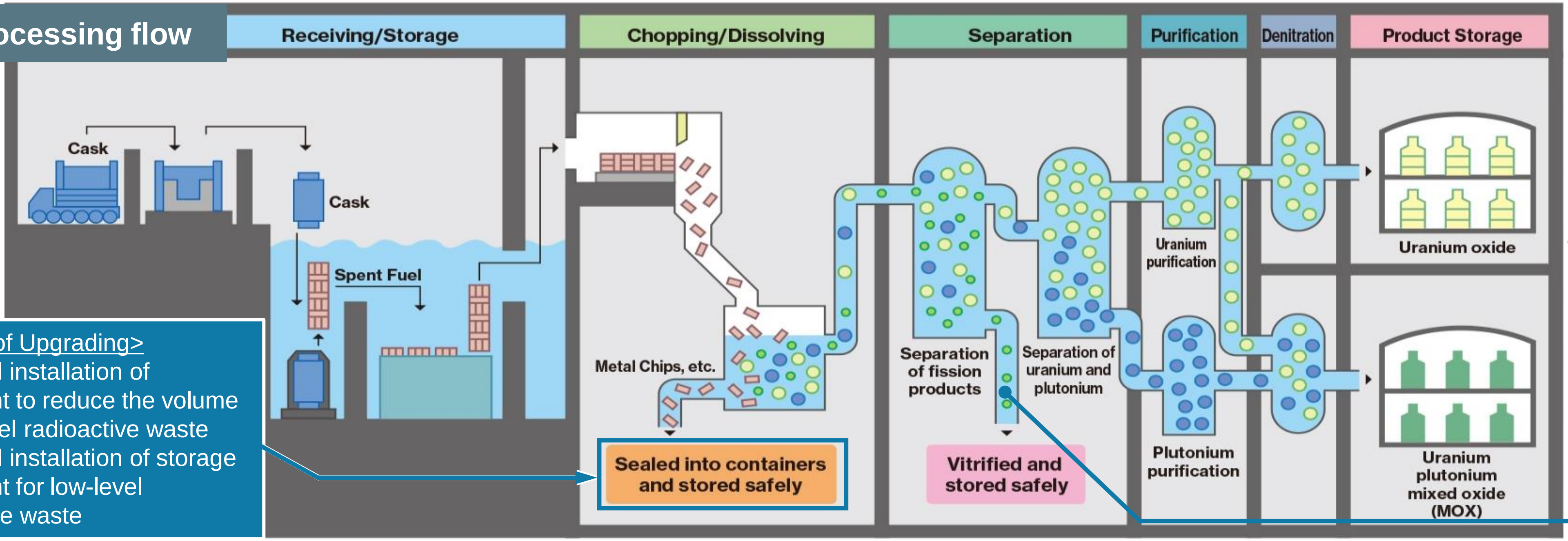
- In order to start up the operation of the nuclear fuel cycle facility and to ensure its stable operation, it is necessary not only to maintain the integrity of the equipment but also to enhance the safety/reliability and the drivability/maintainability by improving them.
- Moreover, it is necessary to work on upgrading the facilities in consideration of aging/deterioration in order to realize plant operation lasting 40 years after completion. MHI is developing a post-completion maintenance plan to support safe and stable operation of these fuel cycle facilities
- To further ensure energy security, MHI is also supporting the construction of the Uranium Enrichment Plant.

FY	'20	'25	'30

Operation plan of Nuclear fuel facilities

- **Construction work**
- **Establishing stable operation** (Maintenance and renewal of various equipment such as analysis equipment and control panels)
- **Upgrading of facilities** (Major maintenance work and installation of facilities)

Reprocessing flow



- Uranium
- Plutonium
- Fission products (High-level radioactive waste)
- Metal chips, etc.

※ Reference：
"Graphical Flip-chart of Nuclear & Energy Related Topics"
Japan Atomic Energy Relations Organization

<Example of Upgrading>
- Additional installation of equipment to reduce the volume of low-level radioactive waste
- Additional installation of storage equipment for low-level radioactive waste

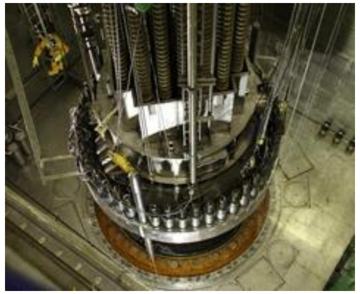
<Example of Upgrading>
- Additional installation of equipment to concentrate high-level radioactive liquid waste

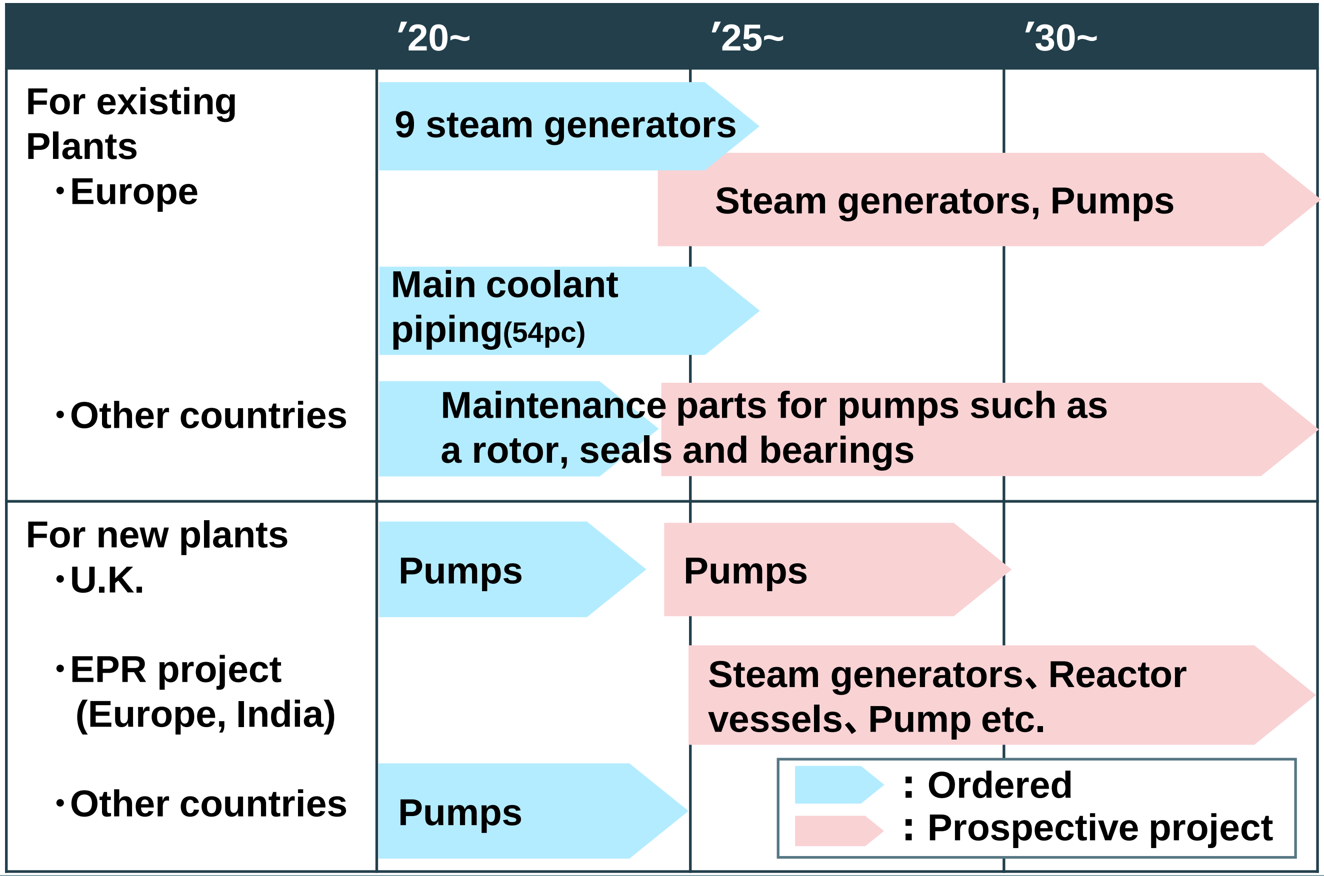
Major Activities in Overseas Market

- MHI has a strong heavy component delivery record to France, United States and other countries and remains committed to continuing to export the replacement components for existing nuclear power plants.
- New nuclear power plant construction is taking shape in Europe, including nuclear power as "green energy" in EU taxonomy along with French President Macron's announcement to resume construction of new nuclear power plants. The U.K. government has granted a development consent order (DCO) for EDF Energy's proposed Sizewell C plant. Leveraging the cooperative relationship with EDF, MHI will focus on supplying heavy components, pumps, etc.

Components	Delivered	Manufacturing
Reactor vessel	4	
Reactor vessel head	22	
Steam generator	31	9
Pressurizer	1	
Safety related pump	38	23
Main coolant piping	23	31
Turbine	10	


<Steam generator>


<Reactor vessel head>



4. Development of Advanced Reactors

Development of Advanced LWR “SRZ-1200”

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- MHI is developing an **advanced LWR “SRZ-1200”** with innovative technologies, **which achieves the world’s highest-level of safety.** Commercialization target is **in the mid 2030s**.
- **New plant construction** is essential to **sustain the industrial infrastructure and workforce**.
- Also, MHI is **developing a small LWR to meet future social needs**, which will leverage the technologies obtained through development of the SRZ-1200.

~2020 | 2030 | 2040 | 2050~

Current safety standard

New Standard for SMR

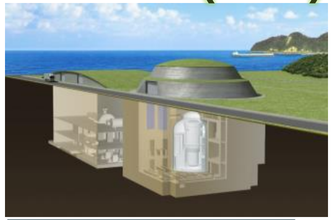
“SRZ-1200”

1,200MWe class

- Achieves enhanced safety and competitiveness based on proven technologies
- Limit radioactive effect inside of plant site even in a postulated accident scenario.

Distributed power source

Small LWR (SMR)



300MWe class

- Simplify systems by integrating main components into reactor vessel

Supreme Safety

- Highly resistant to earthquakes, tsunami, and acts of terrorism, etc.
- Confine radioactive materials and limit its effects within the plant site.

Environmentally Friendly

- Zero CO_2 emission, and flexible operation in coexistence with renewable energy.

Large and Stable energy supply

- Large and stable power supply unaffected by international situation and weather change.

“SRZ” represents;

S: **S**upreme **S**afety, **S**ustainability
R: **R**esilient light water **R**eactor
Z: Ultimate type (**Z**) contributing to society by **Z**ero carbon emission.
(In Japan, “Z” also has a meaning of “ultimate type”)

Features of "SRZ-1200" (1/3)

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- **Achieve the highest level of safety** with safety measures against natural disaster (earthquake, tsunami, etc.), airplane crash and acts of terrorism, adoption of passive safety system and provision for severe accident.
- **Enhanced flexible operation capability** (coexistence with renewable energy) according to social needs.

Enhanced cooling and confinement functions

Enhancing redundancy and diversity of safety systems such as core and containment vessel cooling system

Passive safety system

Adopting passive safety system, functioning without power source ※1

Measures for core melt

Core catcher prevents molten core release outside of Containment Vessel (CV)

Prevention of radioactive material release

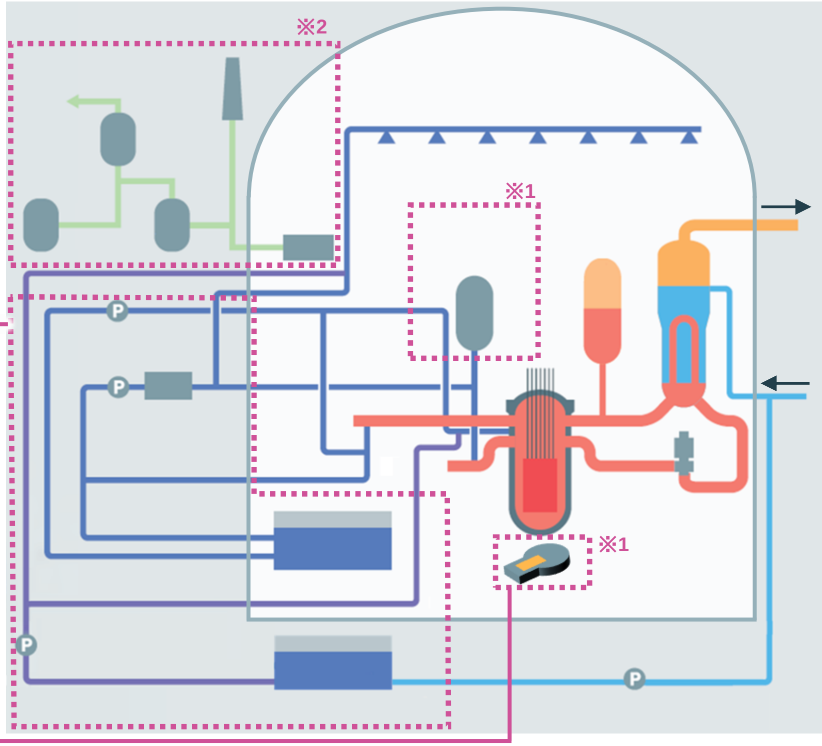
Capturing radioactive noble gases and confining them in dedicated tanks to limit the impact of postulated accidents to the power plant site ※2

Cyber Security enhancement

Cyber security using the latest digital technologies

Airplane crash resistance

Reinforcing outer shielding wall of containment vessel



Improved seismic resistance

Underground structure (rock embedding)

Resilience to natural disasters

Strengthen resistance to natural disasters such as tsunamis, tornadoes, typhoons, and volcanoes

Coexistence with renewable energy

Enhanced flexible operation capability (frequency control, load following)

Hydrogen production

Hydrogen production with carbon-free electricity (electrolysis)

Features of “SRZ-1200” (2/3)

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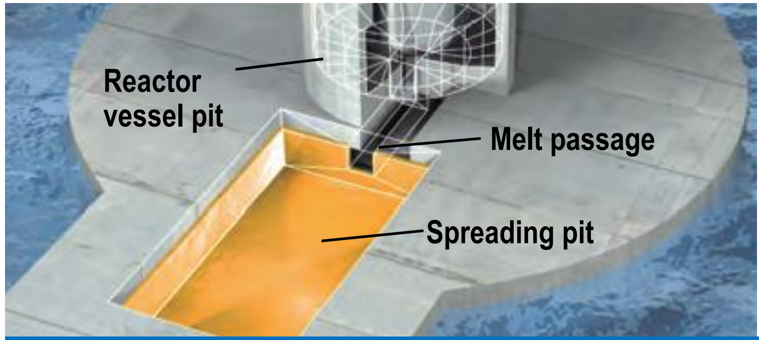
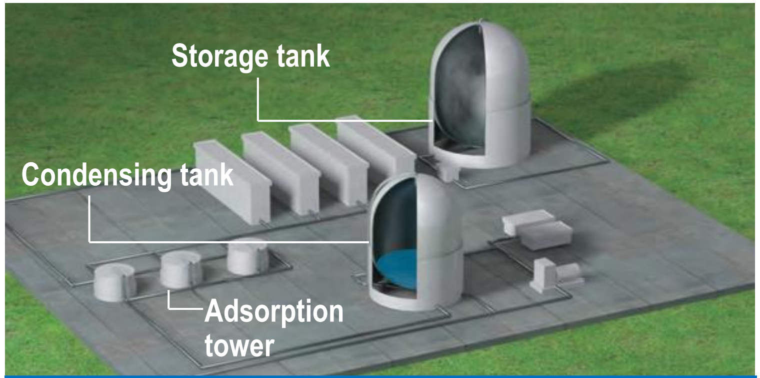
- Strengthen **measures against severe accident** by introducing the world’s latest technologies such as **core catcher, radioactive materials release prevention system,** and **significantly enhanced safety throughout the plant**.



Core catcher

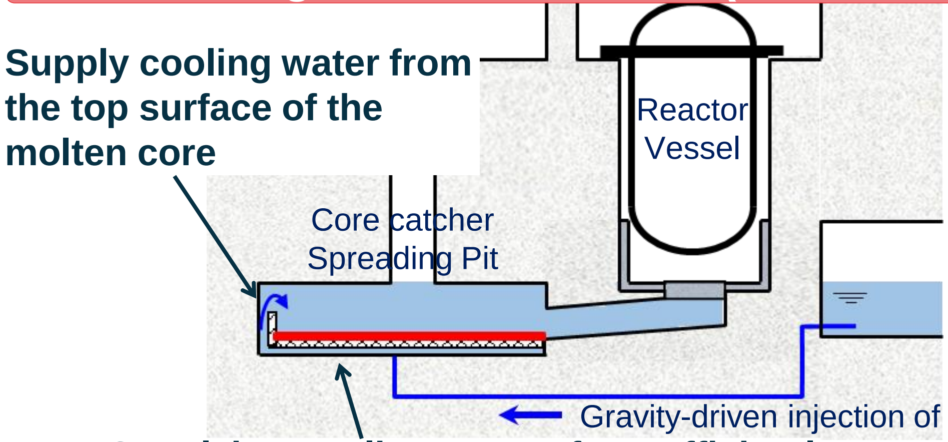
Retain molten core within CV



Prevention of radioactive material release

Radioactive noble gas release prevention (MHI original technology)

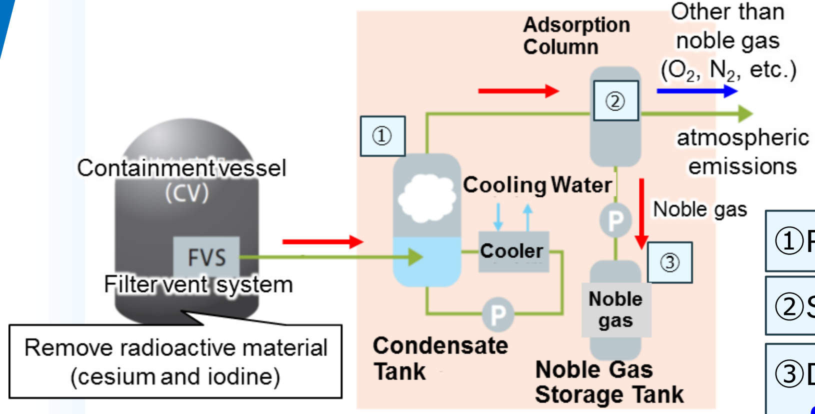
Measures against Molten core (Core catcher)



Supplying cooling water after sufficiently spreading the molten core

Cooling performance is enhanced by **sufficiently expanding the molten core** in the spreading pit

Prevention of radioactive material release



- Even in the unlikely event of containment venting, adsorb and separate radioactive noble gases
- **Limiting the accident impact within the plant site**

①Remove by **condensating vapor** in the vent gas

②Selectively **adsorb and separate noble gases**

③Desorb noble gases and store them in **dedicated storage tank**

Features of “SRZ-1200” (3/3)

- Considering the expansion of renewable energy toward decarbonization, in addition to the role of **baseload power sources,** the function of **flexible power operation**, which contributes to **demand-supply adjustment** and **power grid stabilization**, is enhanced
- Instead of power output adjustment, surplus electricity can be used for **hydrogen production**

Enhanced power adjustment function

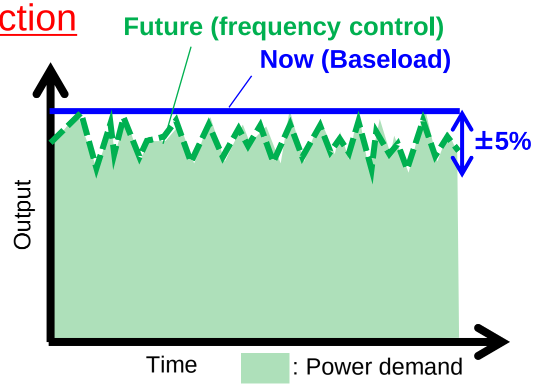
- Thermal power generation is currently being used to adjust to power fluctuations and electrical system instability at night and in rough weather associated with the expansion of renewable energy
- Enhance the power adjustment function of nuclear power and contribute to power grid stabilization

	Renewable	Thermal	Nuclear
Now	Fluctuating	Base load + Load follow	Baseload
Future	Fluctuating (increase)	Load follow (decrease)	Baseload+ Load follow (increase)

Enhance the power adjustment function of nuclear power

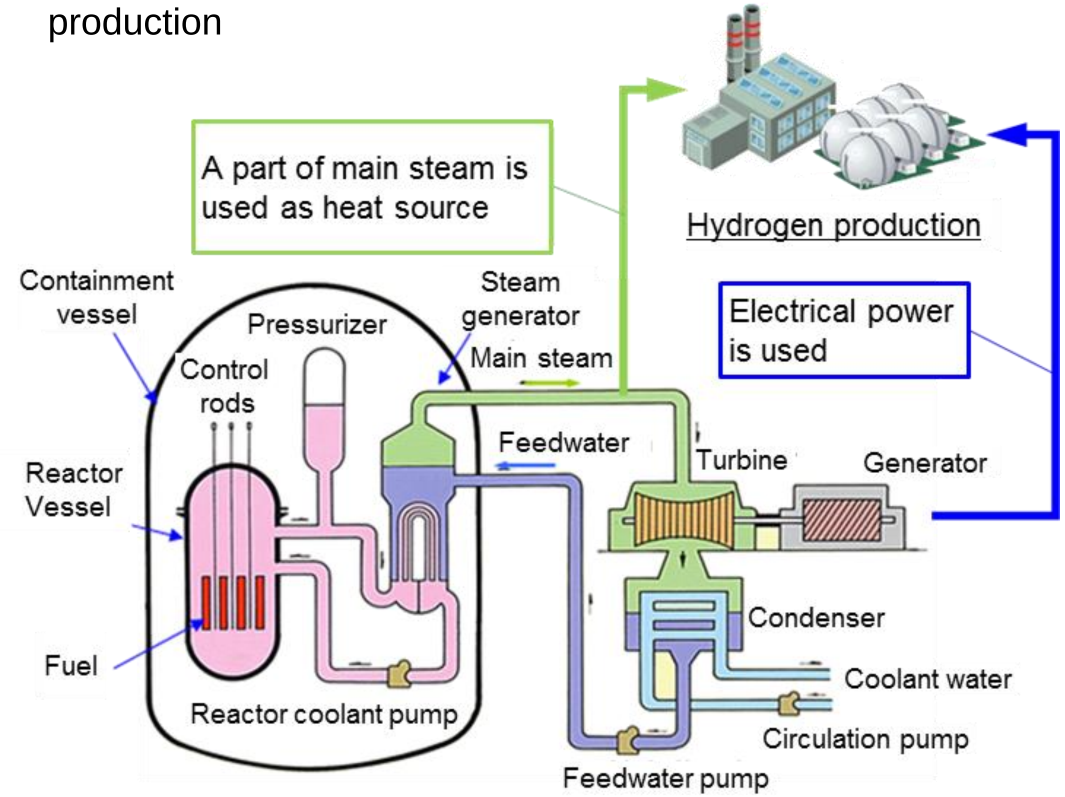
【Load follow】
- Enhanced ramp rate 0.8% / min → 3% / min

【Frequency control】
- Power output adjustability ± 3% to ±5 %



Hydrogen production using LWRs

- Hydrogen production by water electrolysis using electric power
- Main steam is extracted and used as a heat source for hydrogen production



(Example)

SRZ-1200 Development Schedule (MHI estimates)

MITSUBISHI HEAVY INDUSTRIES

- **Jointly developing advanced light water reactor with Japan's 4 PWR electric utilities***. **80% of basic design for standard plant SRZ-1200 complete**.
- In order to **acquire and improve data for permissions**, **executing full-scale tests** through opportunities **provided by governmental projects**. Going forward, will complete **basic and detailed design for individual plants**, aiming for **commercialization in mid-2030s**.

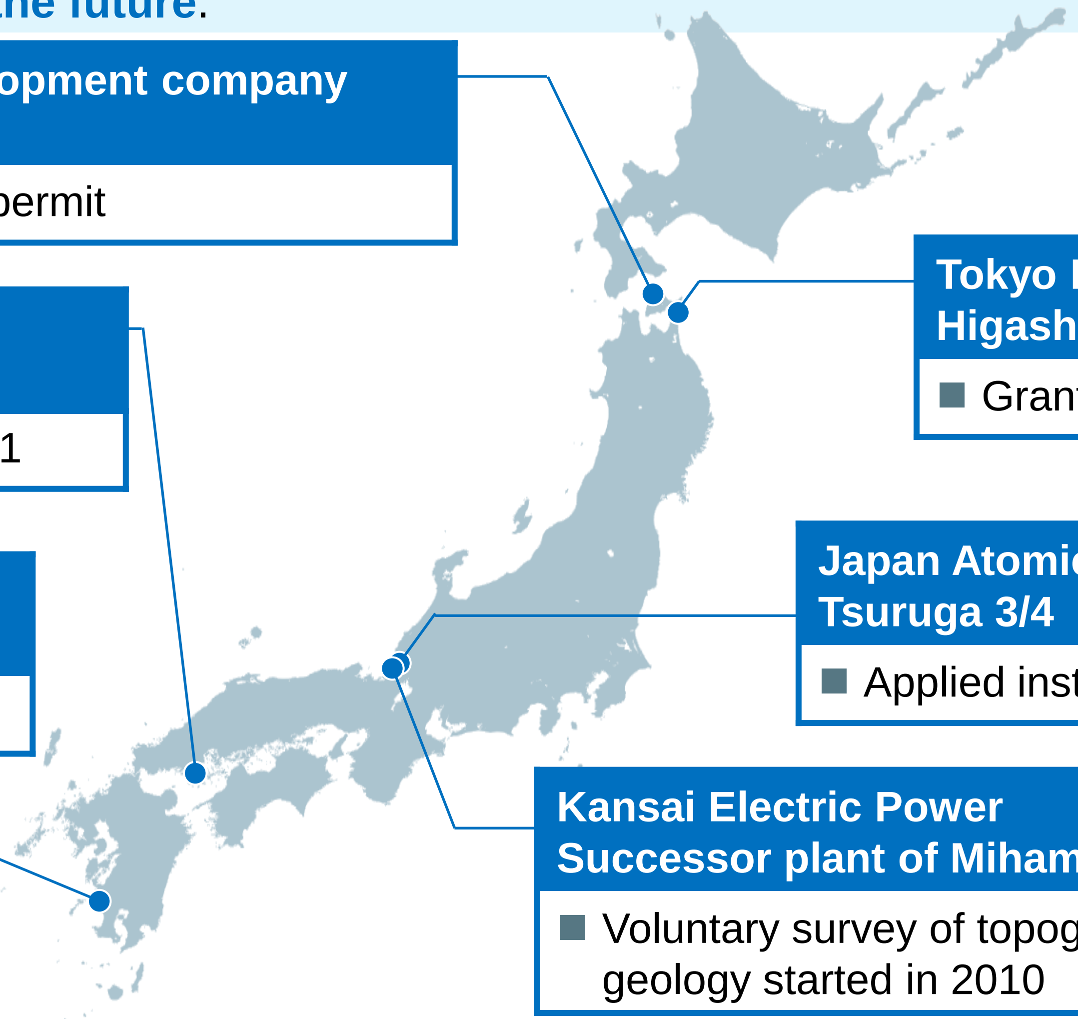
*Hokkaido Electric Co., Kansai Electric Co., Shikoku Electric Co. and Kyushu Electric Co.

SRZ-1200 Development Schedule (MHI estimates)

FY	'20	'25	'30
Standard Plant Design (4 electric utilities)	Conceptual Design → Basic Design	Basic Design → Consideration of plant systems specifications for permissions	
Validation Testing (Government Projects)	Testing	Testing → Full-scale testing to acquire and improve data for licensing	
Individual Plants	Design of specific plants considering individual conditions including site	Basic Design → Application of installation permit ▼ Detailed Design	Start Construction ▼ Manufacture/ Construction → Commercial Operation ▼ Operation

Potential Site for New Plant Construction

- **Many new nuclear power plants were planned** before the Great East Japan Earthquake (the applications for installation permits of 6 plants were submitted). Given that the GX Basic Policy states that the government will consider the development and construction of next-generation innovative reactors, **it is expected that these plans will be gradually resumed in the future**.



Electric Power Development company Ohma (ABWR)
- Applied installation permit

Chugoku Electric Power Kaminoseki 1/2
- Applied installation permits of Unit 1

Kyushu Electric Power Sendai 3
- Applied installation permit

Tokyo Electric Power Higashidori 1/2
- Granted installation permit of Unit 1

Japan Atomic Power company Tsuruga 3/4
- Applied installation permits of Unit 3/4

Kansai Electric Power Successor plant of Mihama 1
- Voluntary survey of topography and geology started in 2010

※ : Prepared based on public information

Domestic Utilities' Business Policies to achieve Carbon Neutrality

- Domestic utilities released business policy to achieve carbon neutrality. These management policies state that utilities is utilizing the existing nuclear power plants and developing next-generation reactors in order to maximize the use of nuclear power.
- In addition, These management policies announce plans to investigate hydrogen production by using the nuclear energy.

		Kansai Electric	Kyushu Electric	Shikoku Electric	Hokkaido Electric
PWR	Existing Plants	Improving the operation rate by advanced operational protocols	Improving the capacity factor	Continuing safe and stable operation	Restarting Tomari Nuclear Power Plants
	New Plants	Realizing installation or replacement of next-generation LWR, SMRs and HTGR, etc.	Investigating next-generation LWRs, SMRs and HTGRs[1]	Investigating new nuclear reactors	
	Hydrogen	Hydrogen production by using HTGRs			

		Tokyo Electric	Tohoku Electric	Hokuriku Electric	Chugoku Electric	Chubu Electric
BWR	Existing Plants	Restarting Kashiwazaki-Kariwa Nuclear Power Plants	Stable and efficient operation	Maximally utilizing of existing plants	Restarting existing plants and continuing stable operation	Utilizing Hamaoka Nuclear Power Plants
	New Plants	Resuming construction of Higashidori Nuclear Power Plant				Utilizing next-generation nuclear reactors (SMRs, HTGRs)
	Hydrogen					Hydrogen production by using HTGRs

1：High Temperature Gas-cooled Reactor

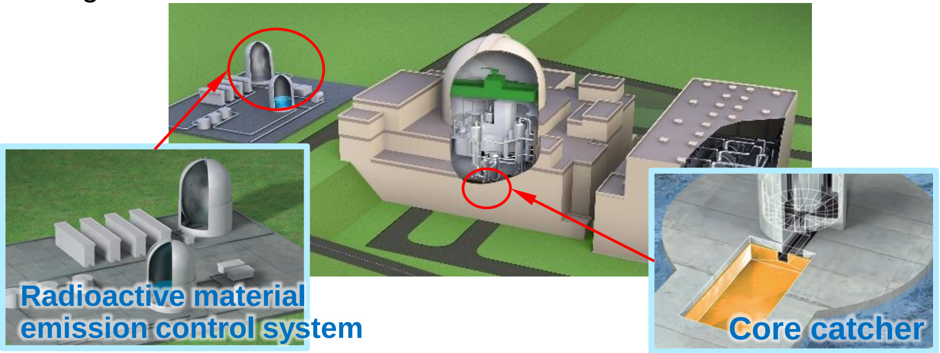
※：Prepared based on public information

Line-up of MHI's Advanced Reactors

- In addition to the **Advanced LWR "SRZ-1200"**, MHI promotes the development of **additional advanced new reactors (Small LWR, High-Temperature Gas Reactor, Fast Reactor and Micro Reactor) to meet future social needs**.

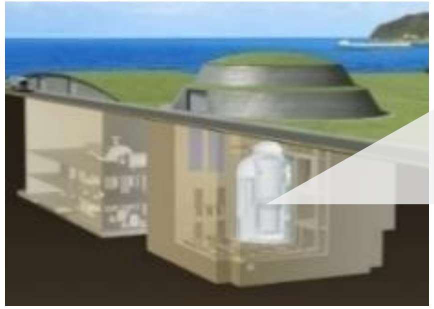
Advanced LWR "SRZ-1200"

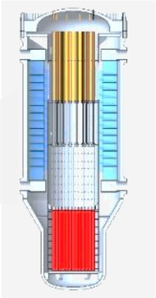
- ✓ Power source for existing grids (1,200MWe)
- ✓ Achieves world's highest-level safety with innovated technologies, aiming the commercialization in the mid 2030s

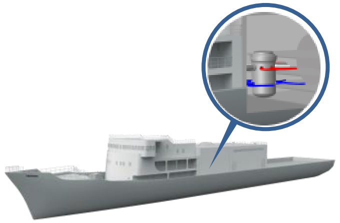


Small LWR (SMR)

- ✓ Distributed power source for small grids (300MWe)
- ✓ Full-passive safety system, integrated reactor incorporating main components of the primary system into the vessel
- ✓ Ship-mounted SMR for maritime usage is also being developed

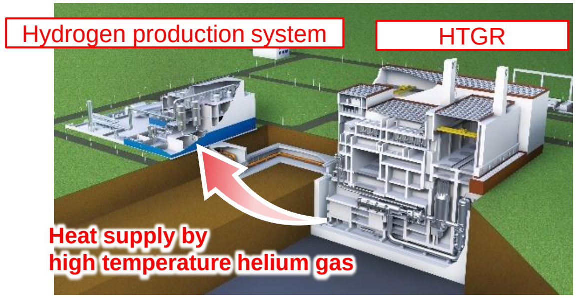






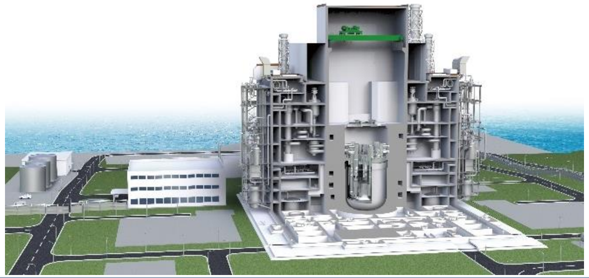
High-Temperature Gas Reactor(HTGR)

- ✓ Large-scale & stable hydrogen production using high temperature heat (over 900°C)
- ✓ Contributes to the decarbonization of industrial sectors (steel industry, etc.)



Fast Reactor

- ✓ Realization of a closed nuclear fuel cycle, leading to the effective use of resources, reduction in volume and toxicity of high-level radioactive waste



※

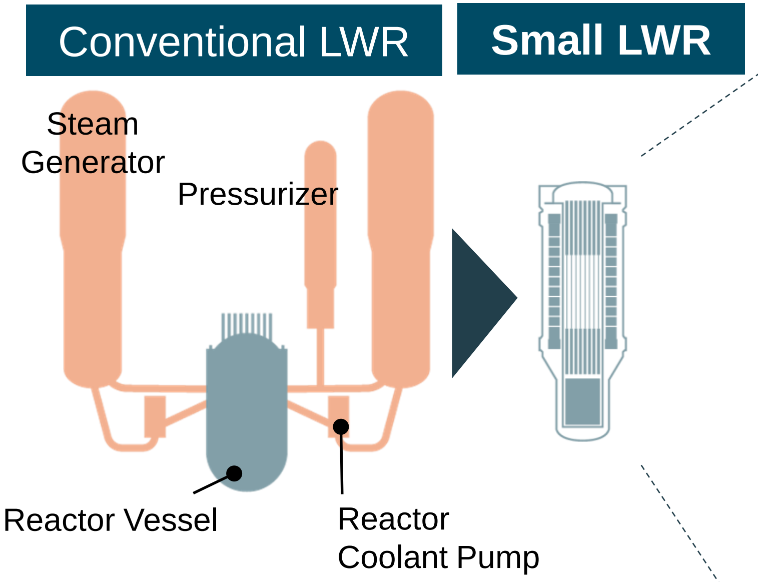
Micro Reactor

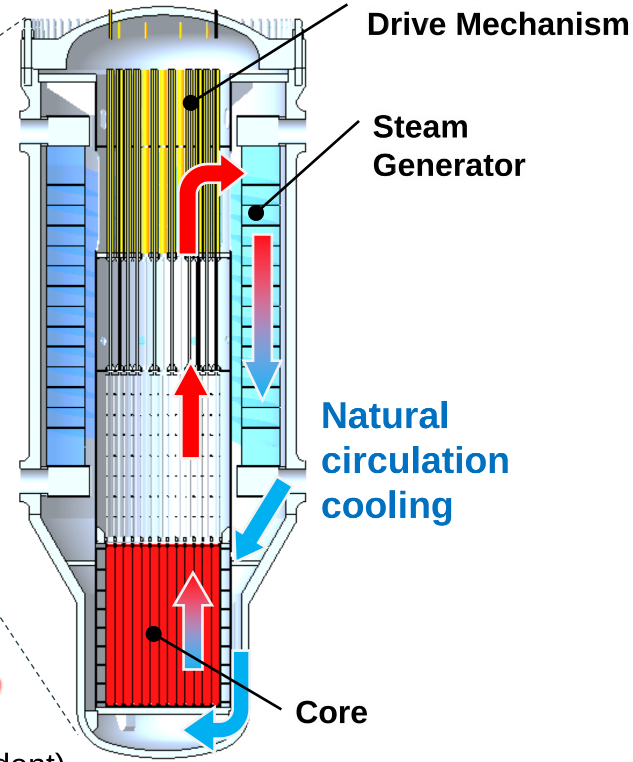
- ✓ Multi purpose portable reactor (for remote island, disaster affected area, etc.)
- ✓ Full solid reactor core (MHI original design)

※This figure includes an outcome of R&D program entrusted by METI.

Development of Small LWR

- **MHI's small LWR for power generation is being developing for small-scale grid and distributed power sources.** (Jointly developing with Japan's electric utilities)
- **Natural circulation cooling** and **integrated reactor** eliminate potential of LOCA (Loss of Coolant Accident)
- **Passive safety system** (dynamic equipment eliminated and safety level enhanced)
- Airplane crash resistance is improved by **embedding the reactor building underground** and confinement capability is improved by **double-wall containment structures**





✓**Integrated Reactor**
(eliminates main coolant piping/pump)

➡ **Elimination of accident possibility***

*such as LOCA (Loss of Coolant Accident)

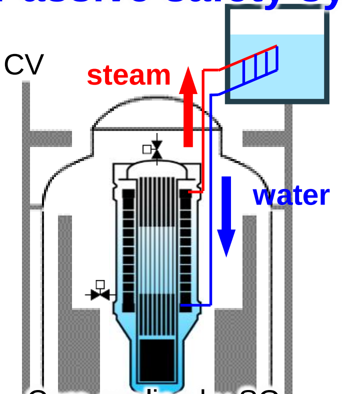
✓**Reactor building embedded underground**

➡ **Resistant to airplane crash**

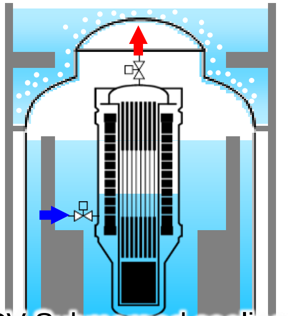
✓**Double-wall containment structures**

➡ **Confinement of radioactive materials**

✓**Passive safety system**



Core cooling by SG



CV Submerged cooling

Development of High Temperature Gas-cooled Reactor

MITSUBISHI HEAVY INDUSTRIES

- To realize a carbon-neutrality by 2050, decarbonization of **the industrial sectors** (Iron and steel, chemical fields and other manufacturing industries) **and the transportation sector with high CO_2 emissions is essential**, and **large-scale hydrogen demand is expected.**
- **The use of a HTGR, which is characterized by the use of nuclear heat* at extremely high temperatures (above 900℃),** as a carbon-free source of high-temperature heat **enables large-scale and stable hydrogen production. 43 billion yen is budgeted** for development of HTGRs as GX support measures.
- MHI has been conducting a study on the concept of HTGR under a subsidy program from Japanese government (since FY19). In addition, in 2022, launched **demonstration of hydrogen production was launched** and **a study of CO_2-free hydrogen production technologies, using JAEA's HTTR (High Temperature engineering Test Reactor),** has been funded by METI.

Hydrogen production/utilization using HGTR

HTGR

- CO_2-free heat supply

↓ Heat

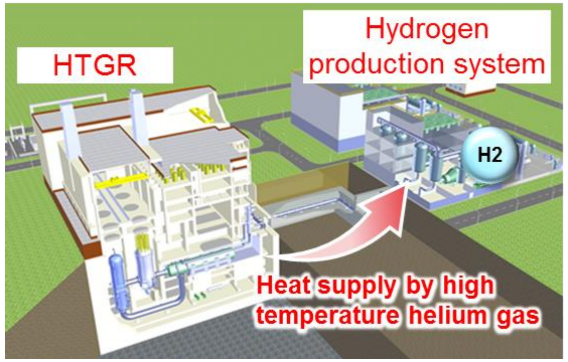
Hydrogen production

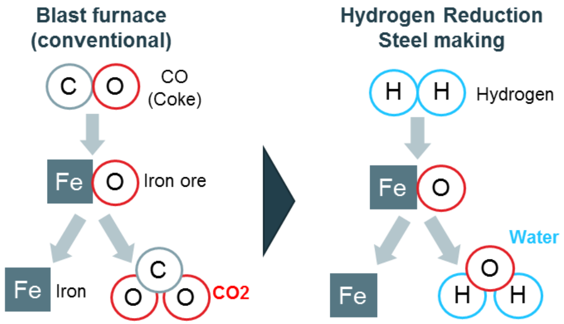
- Steam Methane Reforming method (CO2 is emitted)
- CO_2-free hydrogen production (Future)

↓ Hydrogen

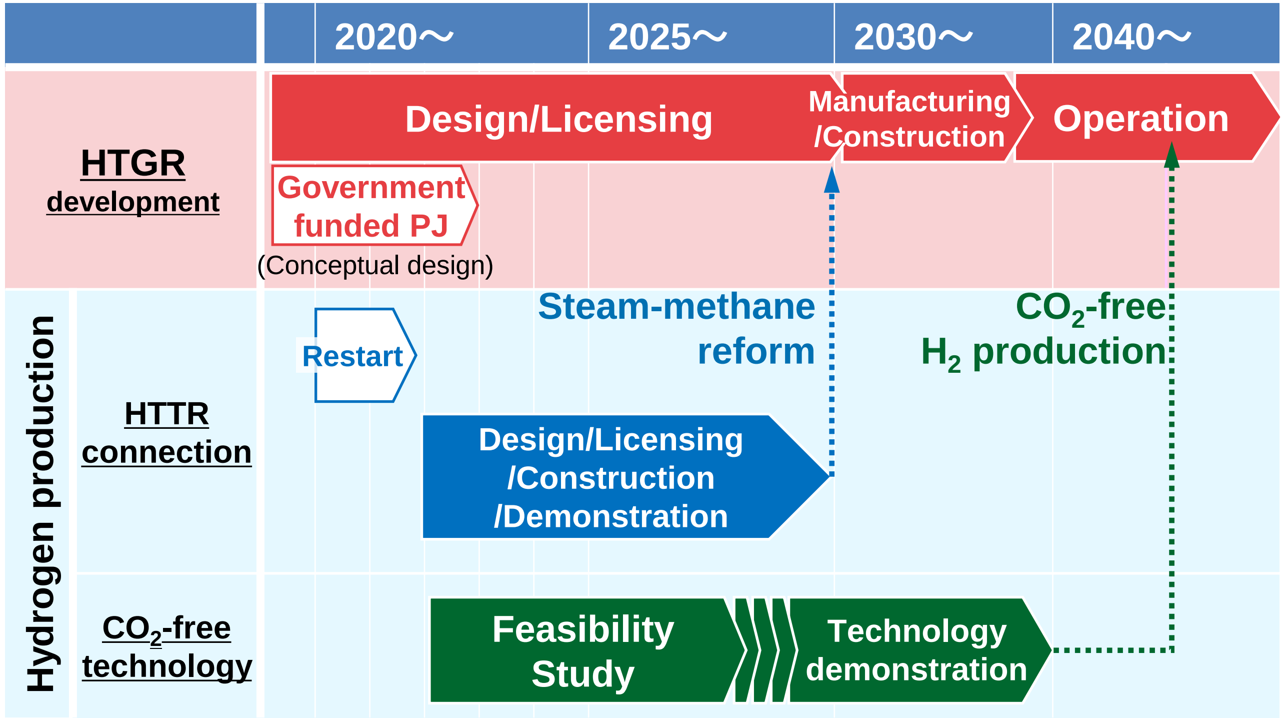
Industry

- Hydrogen reduction ironmaking, etc





【Development roadmap】

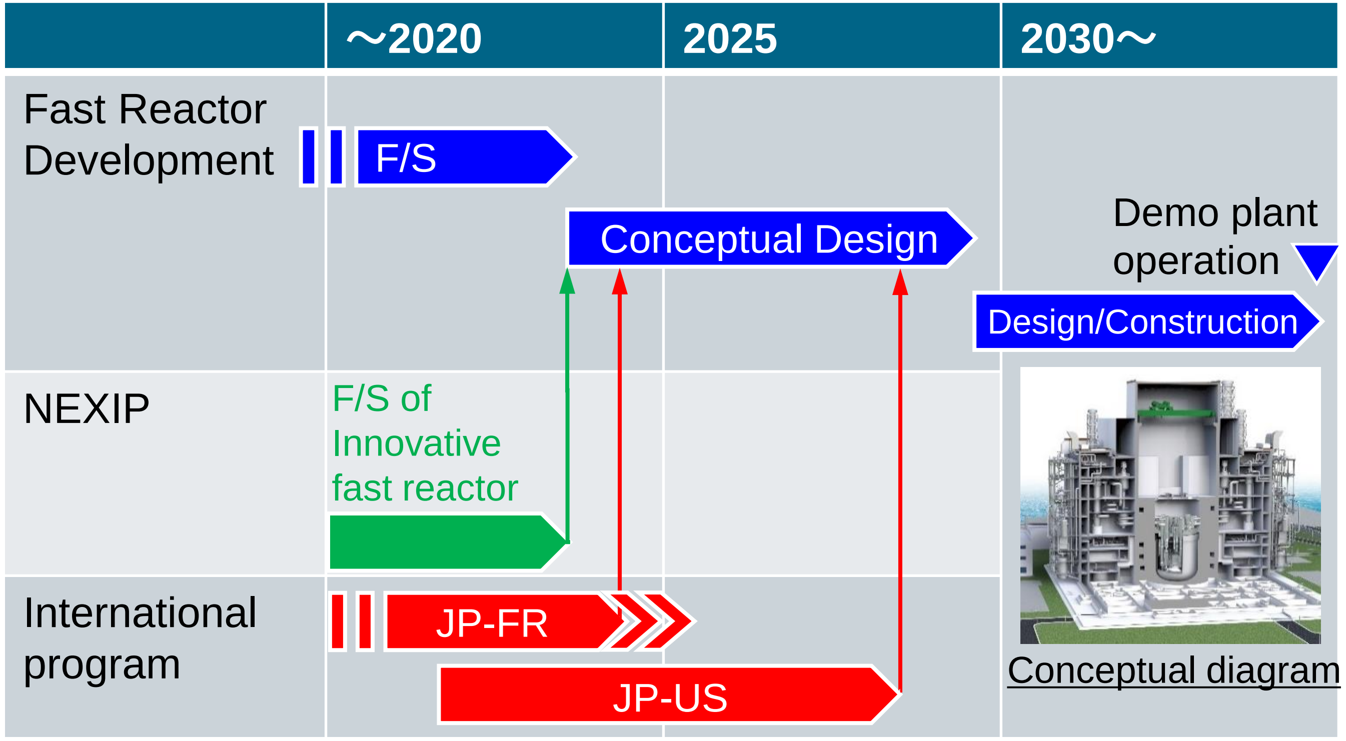


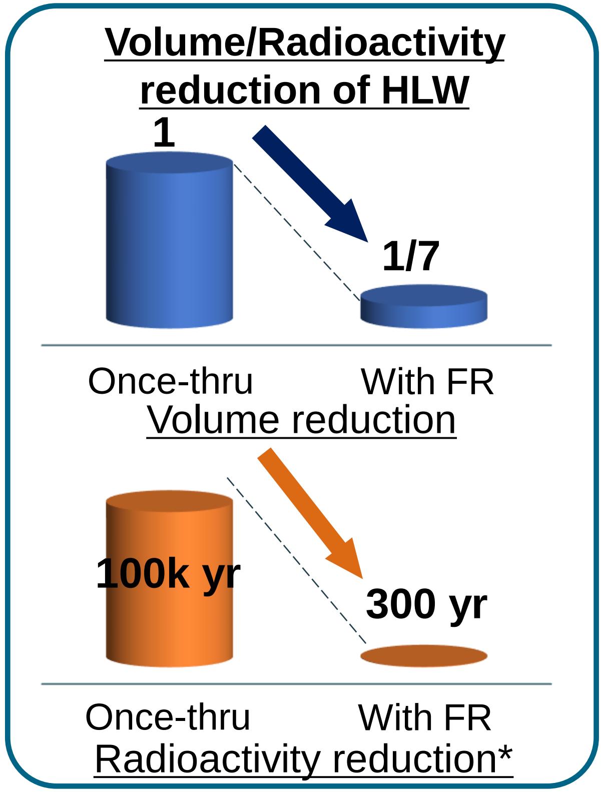
* HTTR achieved **the world's highest heat temperature (950°C)**. Japanese HTGR technology surpasses that of other countries.

Development of Fast Reactor

- A fast reactor utilizes a fast neutron spectrum which contributes to **the effective use of resources and reduction of volume/radiotoxicity of high-level radioactive waste**. **46 billion yen is budgeted** for development of a fast reactor as GX support measures.
- The MHI group, as a lead company of fast reactor development in Japan, is developing a sodium-cooled fast reactor with **the goal of an operational start by 2050** in Japan. Additionally, MHI is participating in **Japanese government program, along with Japan-France and Japan-US (cooperation with TerraPower) international programs**.

<Development Schedule>

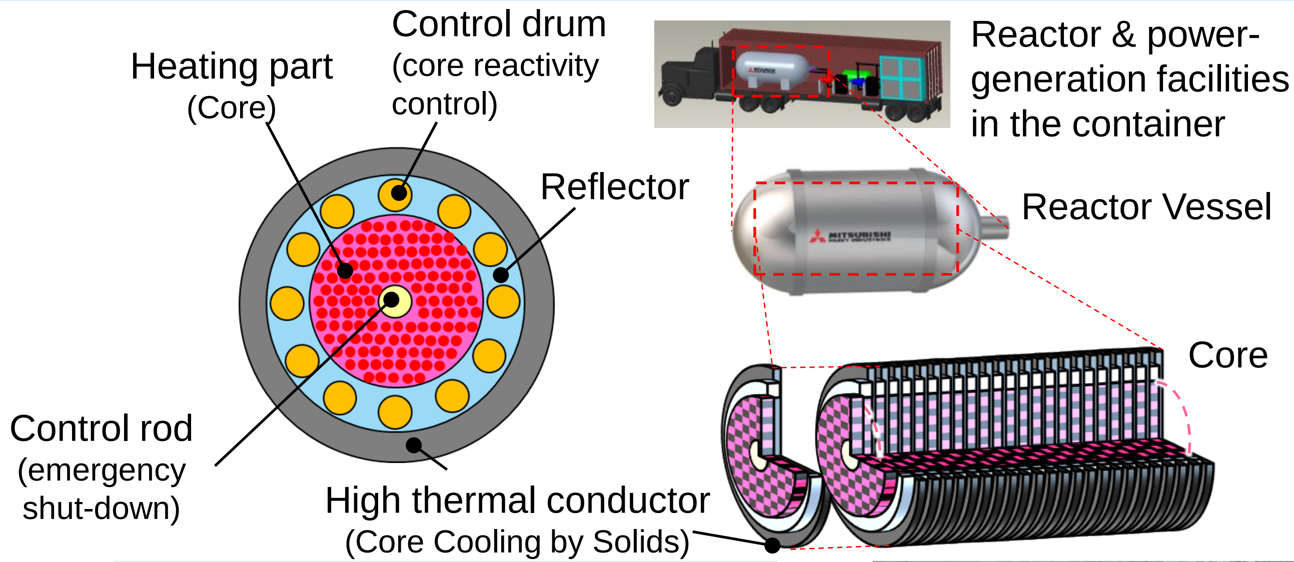




*years needed to radioactivity equivalent to natural uranium

Development of Micro Reactor

- **Portable reactor** for **multi-purpose** (energy security (storage), energy source for remote island, disaster area, etc.) **is being developed under a subsidy program from the Japanese government** (since FY19)**. MHI is also working in concert with the United States for specific technological development topic areas.**
- **Maintenance free, remotely and automatically operated** for a long time **without refueling**
- **All-solid-state reactor** by utilizing high thermal conductors (leakage incident can be avoided)



[Main Specifications of Micro-reactor]

Cooling system	Primary side：Heat transfer by high thermal conductive materials Secondary side：CO_2 gas cooling
Output	1MWt~/500kWe~
Operating cycle	5 years or more
Design life	25 years

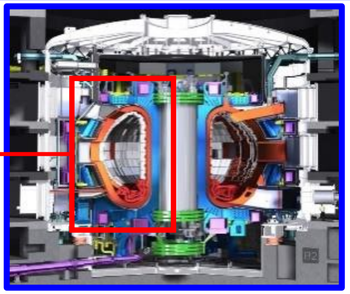
Development of Fusion Reactor

MITSUBISHI HEAVY INDUSTRIES

- **The International Experimental Reactor ITER Project and the Domestic Research Reactor JT-60SA Project are being promoted**. Based on these findings, **power generation will be demonstrated by a prototype reactor in the 2050s**, aiming for the practical use of a fusion reactor
- **The global momentum for nuclear fusion development is growing. In Japan, the government has begun studying ways to accelerate development** (power generation demonstration in the 2040s ahead of schedule). **Fusion venture activity also picked up**
- MHI will **contribute to fusion development by actively participating in the ITER project and the response to prototypical reactors.**

ITER (France)

【Toroidal Field(TF) Coil for ITER】
Long and large equipment required high-precision manufacturing
MHI is the world's first to ship 4 TF coils



(©ITER Organization, http://www.iter.org/)

【Purpose】
・Scientific/Technical Demonstrations of Fusion

Prototype Reactor
【Purpose】
Stationary power generation /demonstration of economy

Practical use

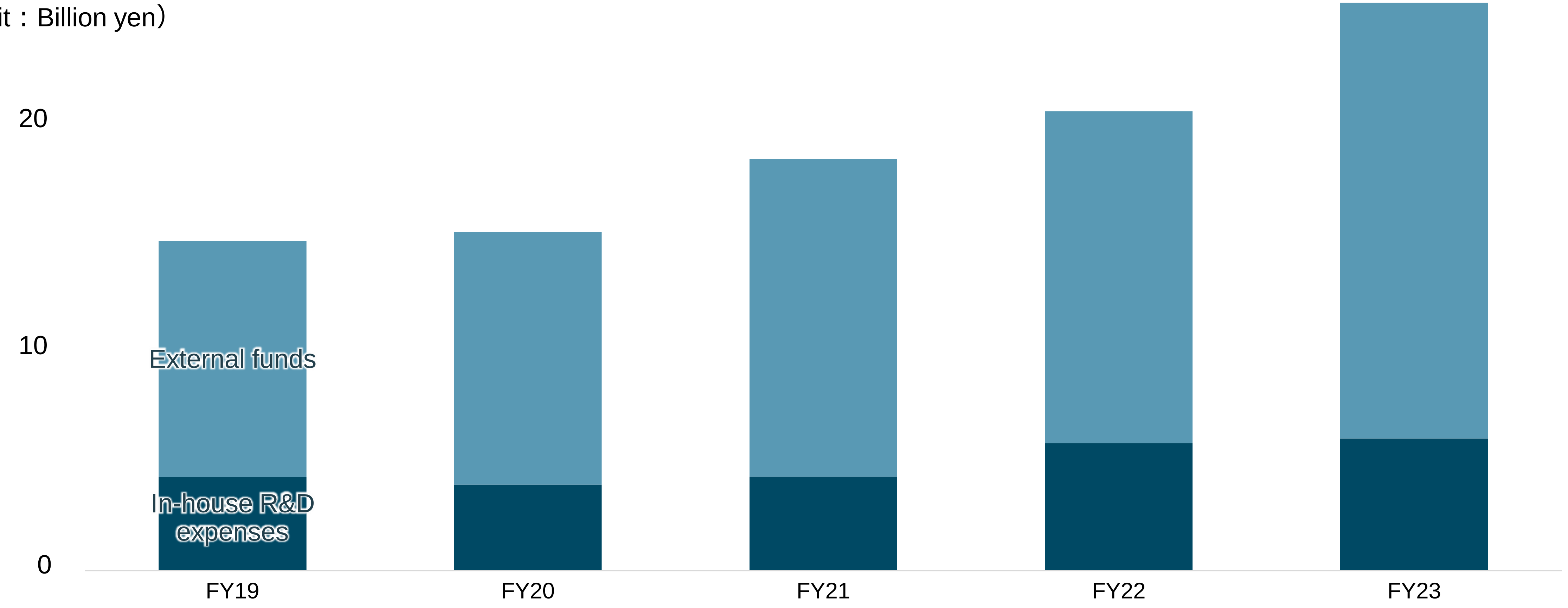
JT-60SA (Ibaraki)
【Purpose】
Supporting research for ITER/prototype reactors

		2020	2025	2030	2035	2040	2050~
Experimental Reactor	ITER	Construction	▼First Plasma; Plasma control test		▼D-T operation(fusion); Long burning test		
	JT-60SA	▼First Plasma; Supporting research for ITER/prototype reactors					
Prototype Reactor		Conceptual Design	Full-scale technology development		Design/Manufacturing/Construction	Demonstration for practical use	

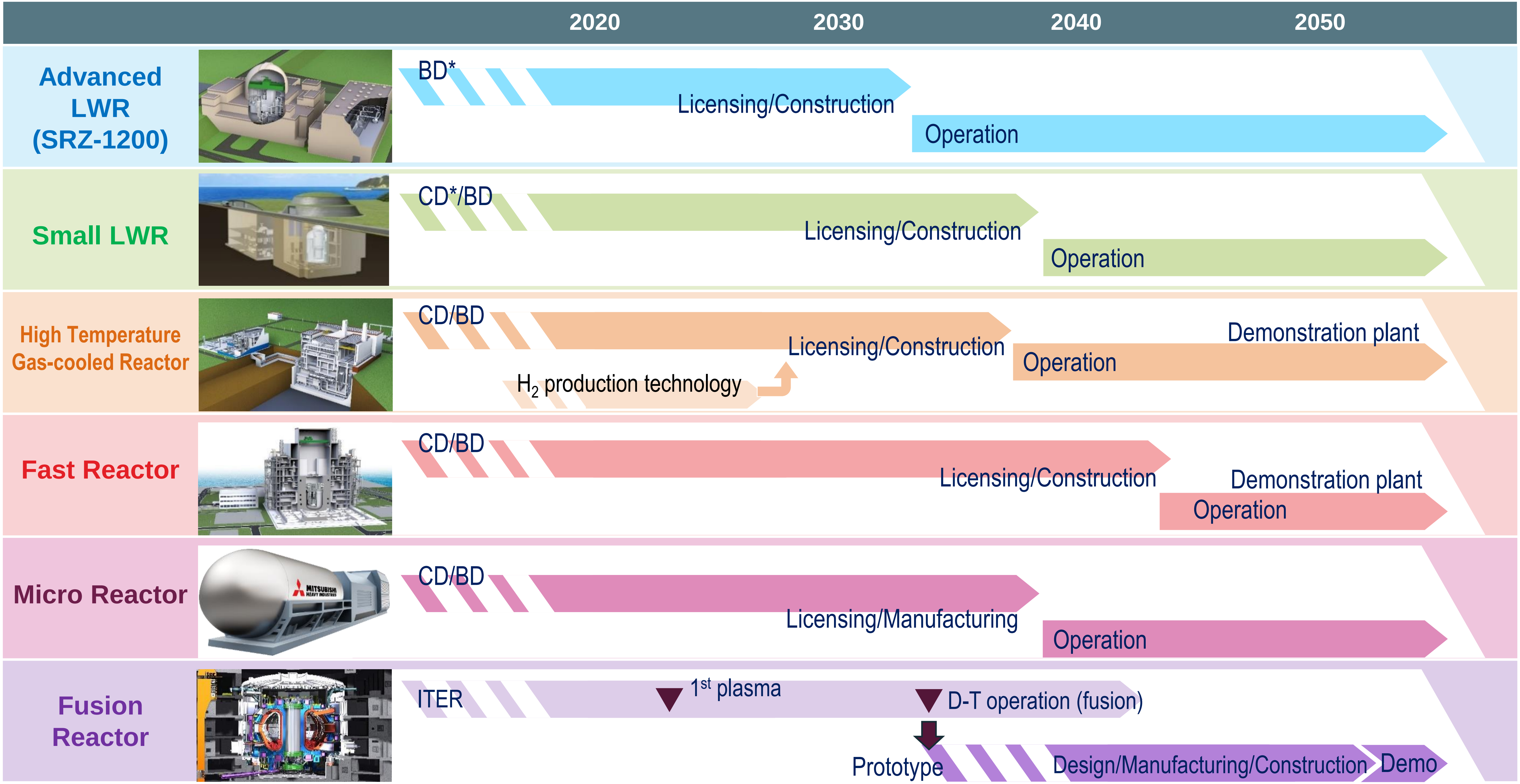
R&D Expenses Related to Nuclear Power in MHI

- **Government R&D Expenditure increases significantly after Cabinet approves GX basic policy including maximum use of nuclear power.**
- **In-house R&D expenses are about 4-6 billion yen per year, while total R&D expenses, including external funds, are around 20 billion yen.** MHI will steadily promote nuclear technology development for the future in collaboration with the national government and business operators.

(Unit：Billion yen)



Development Roadmap of Innovative reactors



CD: Conceptual Design, BD: Basic Design

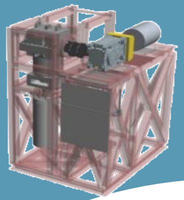
Development of Nuclear Technology into New Fields

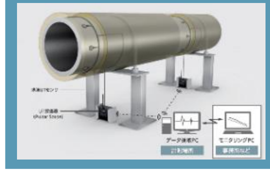
- Utilizing technologies developed in the nuclear power business, we are developing a wide variety of new products and expanding into new fields.

Oil & Gas/Hydrogen

Explosion-Proof Plant Inspection Robot

Liquid Hydrogen Boost Pump for Hydrogen Station





Explosion-Proof Thin-Film UT Sensor

Disaster prevention

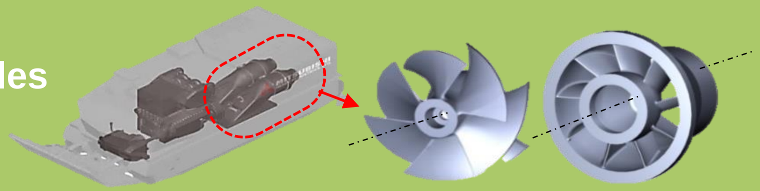
Disaster/Emergency Decision Support System

Clean Air Shelter (for emergency evacuation)

Mobility(Water Jet Propulsion Pump)

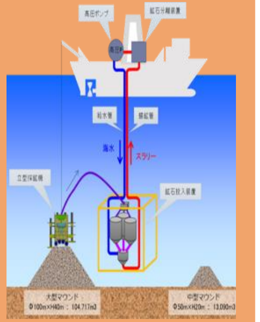
Crew Transfer Vessel

Amphibious Vehicles



Lifting and Collecting Seabed Resource

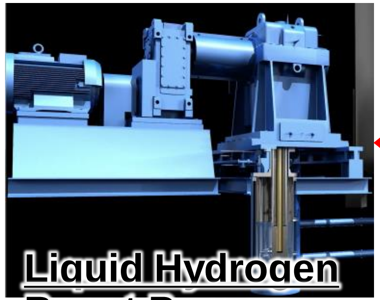
Hydrothermal Deposit Ore-lifting Pump



Crude Oil Mining Pump

Liquid Hydrogen Boost Pump for Hydrogen Station (ST)

- Construction and running costs need to be reduced to spread the use of hydrogen STs, even though they are becoming concrete around the world, with **plans to construct 1000 hydrogen STs (until 2030)** each in Japan and the United States. To solve this problem, there is a growing need for liquid hydrogen booster pumps that can **save space** and **reduce operating costs**.
- **MHI has developed an ultra-high pressure (90MPa-class) liquid hydrogen booster pump. Long-term durability tests of our pump in the United States is well underway** (More than double the performance of competitive pumps)**.** Expected to launch in domestic and overseas markets after test completion
- **Signed a memorandum of understanding with Iwatani Corporation to introduce our pumps** to domestic hydrogen STs. **Leveraging MHI's engineering capabilities, We will also promote the development of packages that consolidate and streamline hydrogen ST components, aiming to further reduce construction costs.**



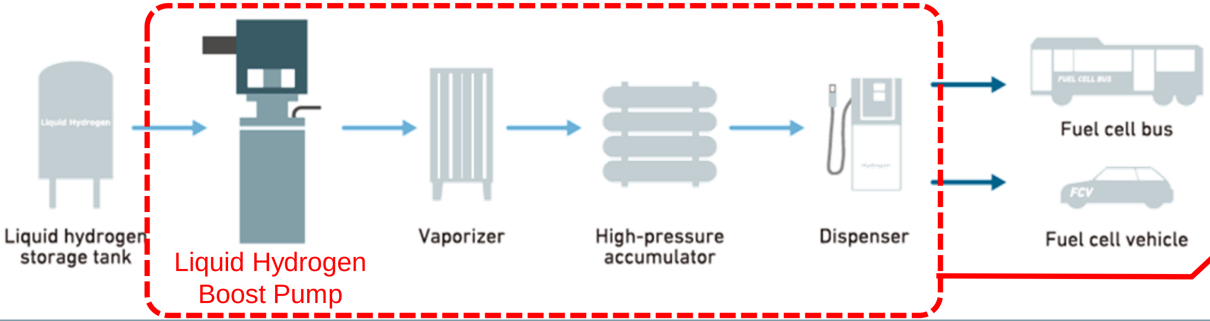
Liquid Hydrogen Boost Pump

Hydrogen Station

FY	2022	2023	2024	2025	2026
Pump Development		long-term durability tests			
Market Launch				Japanese market Overseas market	

Adoption of a liquid hydrogen booster pump reduces energy consumption to about 1/10 of that of conventional gas compression systems.

<Example of equipment configuration of hydrogen ST>



Considering package that consolidates/streamlines component equipment

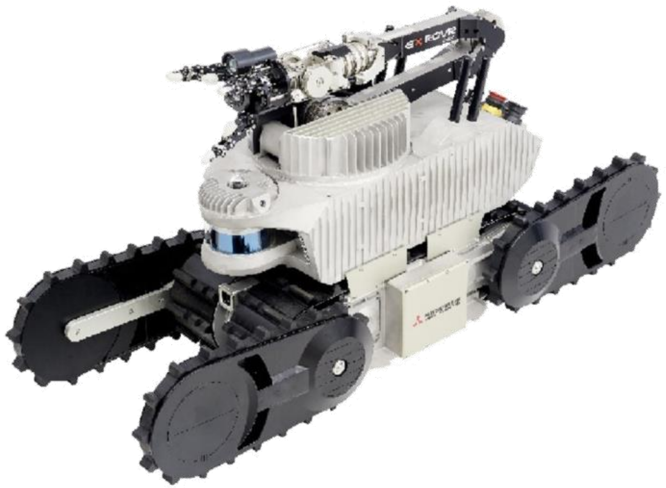
Explosion-Proof Plant Inspection Robot “EX ROVR”

- **MHI, in collaboration with ENEOS Corporation, has completed development of “EX ROVR,” a plant patrol inspection and explosion-proof robot that enables automatic inspection work in high combustible environments such as petrochemical plants, by utilizing technology developed for LWR maintenance and Fukushima Daiichi decommissioning. The robot’s explosion-proof qualification has been certified both domestically and globally, and has been launched to the market (Press Release 2022-04-11).**
- Robots have started to be used sequentially in explosion-proof areas such as domestic LNG terminals and robots have also been manufactured for overseas oil majors. We will continue to aggressively expand sales not only in Japan but also overseas.
  (Delivered to 5 domestic and overseas companies (including trial operations). MHI receives numerous inquiries and is currently manufacturing 5 units.)

PRESS INFORMATION

MHI Completes Development of Second-Generation “EX ROVR” Explosion-Proof Plant Inspection Robot
-- Market Launch This Month under “ASCENT” Product Name --

・Jointly developed with ENEOS, robot will enable realization of safe, human-friendly plant environments
・Efficient inspections and effective data usage contribute to swift, safe resolution of incidents
・MHI wins best 100 prize at Good Design Award 2022 hosted by the Japan Institute of Design Promotion

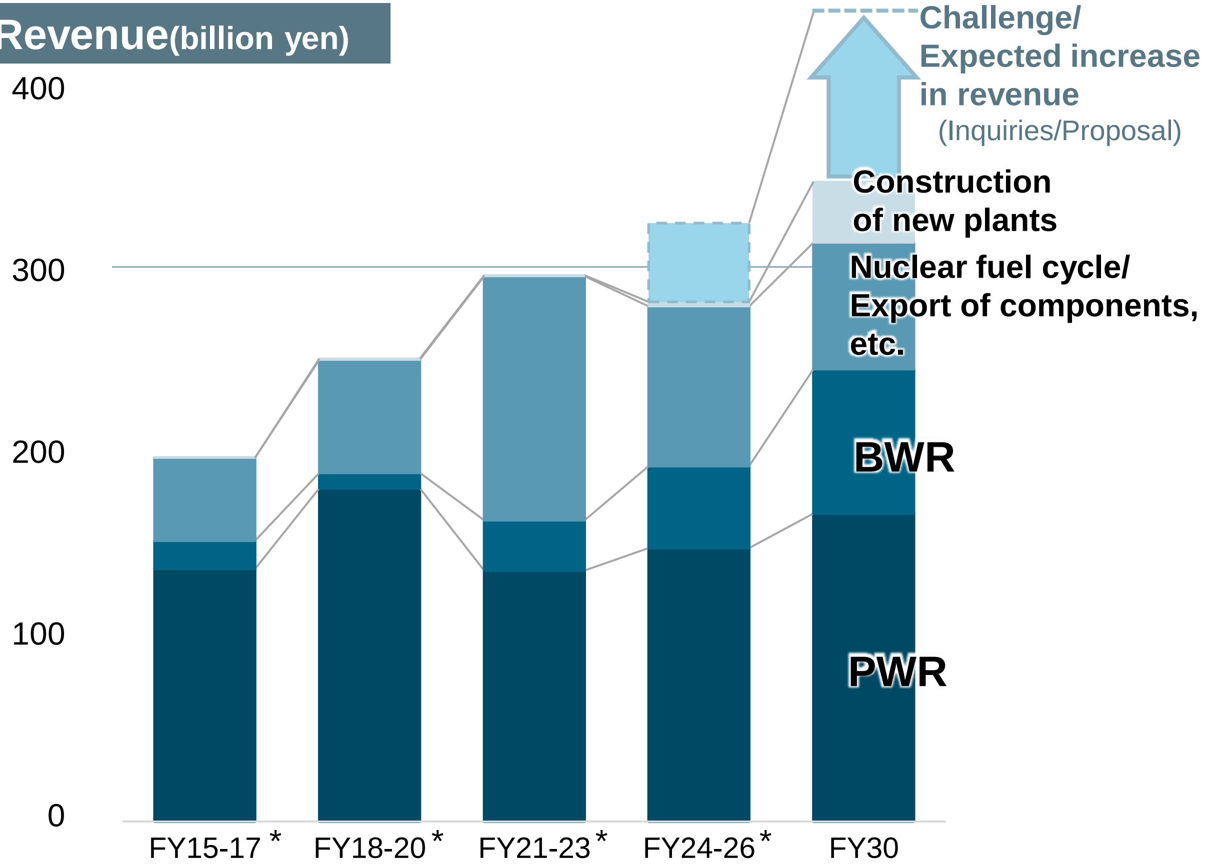


5. Business Plan

MITSUBISHI HEAVY INDUSTRIES

- By restarting existing PWR plants / installing "Specialized Safety Facilities", constructing nuclear fuel cycle facilities, and expanding business for BWR plants, MHI's nuclear business has expanded to a 300billion yen scale under the 2021 Medium-Term Business Plan.
- Thereafter, MHI will continue to expand its nuclear business through the restart of BWR plants / installment of "Specialized Safety Facilities" / related maintenance works, expansion of market share in maintenance works for RRP, export of reactor components, and construction of new plants in Japan. MHI expects further expansion in each business field in response to the rising momentum for the use of nuclear power worldwide.

Revenue(billion yen)



- Restart of PWR plants are progressing smoothly. Construction of 5 "Specialized Safety Facilities" was completed in FY22. **Major maintenance works such as steam generator replacements are planned** in FY23 and beyond.
- Efforts are maximized on restart of BWR plants / construction on "Specialized Safety Facilities", Utilizing the current knowledge on PWRs. **Construction is on the rise and sales revenue is expected to increase in FY23 and beyond**.
- Construction work and support on licensing procedures are underway for the early completion of Rokkasho Reprocessing Plant and MOX fuel fabrication facility. MHI will **continue to support JNFL for the safe operation of the plant after its commissioning**.
- MHI will **supply major components, pumps, etc**. to NPPs abroad, taking advantage of the cooperation with EDF.
- MHI is **developing the advanced LWR "SRZ-1200"** equipped with innovative technologies, which achieves world's highest-level safety and competitiveness.

* 3 years average

Conclusion

- Nuclear power is a carbon-free, large-scale, and stable power source, and MHI recognizes that it is essential to use nuclear power in the future with the major precondition of ensuring safety.

- Domestic plant manufacturers have gathered wisdom together with their business partners to maintain advanced technology and quality. This is a valuable asset for Japan that has been cultivated over a long period of time. Nuclear power is wide-ranged and is an important power source from the viewpoint of maintaining the technological self-sufficiency rate.

- MHI, as a manufacturer, is striving to continuously improve safety by restarting existing plants (PWR/BWR), installing “Special Safety Facilities”, realizing safe and stable operation after restarting of such plants and establishing nuclear fuel cycle.

- In addition, MHI will also contribute to realize a carbon neutral society and stable power supply by focusing on the development and commercialization of the advanced light water reactor SRZ-1200, which achieves the world's highest level of safety.

- Furthermore, MHI will promote the development of future reactors (small reactors, high-temperature gas-cooled reactors, fast reactors, micro-reactors) that meet the diversifying needs of society, and nuclear fusion reactors, which is a dream energy source.

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

MITSUBISHI HEAVY INDUSTRIES