

Mitsubishi Technologies to Support the Effective Completion of the Nuclear Fuel Cycle



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Contents

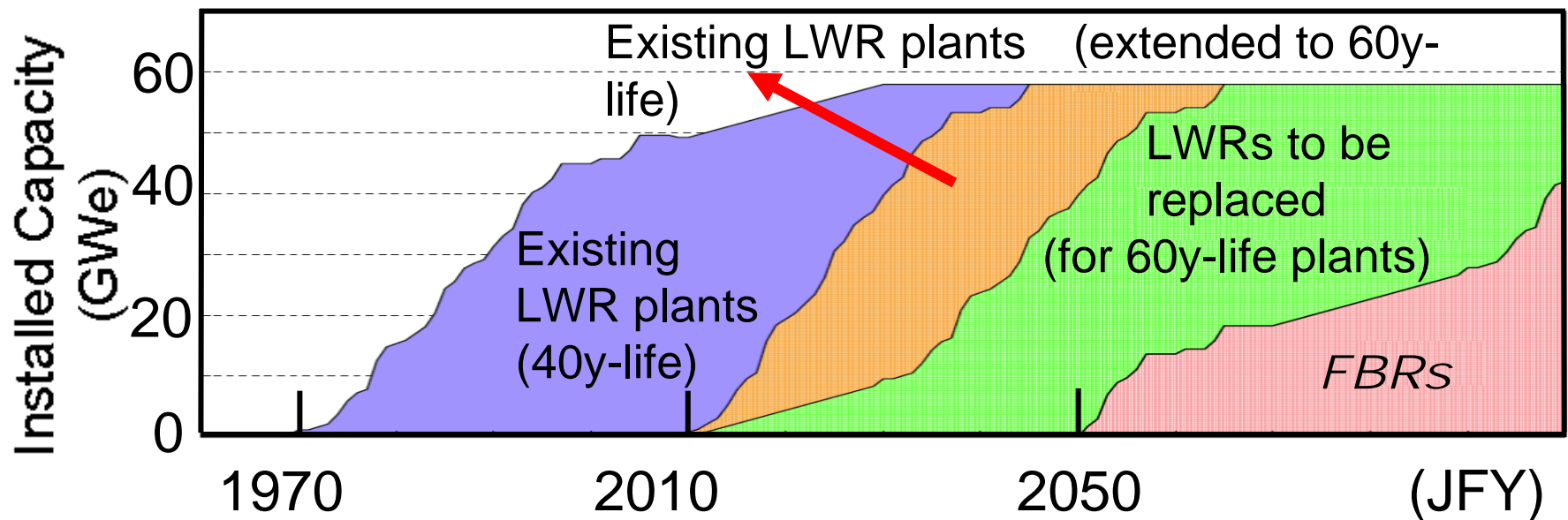
- I. National Nuclear Policy of Japan**
- II. Review of Mitsubishi's Fuel Cycle Activities**
- III. Innovations to Effectively Complete the Cycle**
 - (1) Gen-III+ PWRs to Add More Value to Nuclear Fuel Cycle**
 - (2) Development for Commercial FBR by Mitsubishi**
 - (3) Development of Fuel Cycle Technologies**
- IV. Conclusion**

I. National Nuclear Policy of Japan

■ National Nuclear Policy Documents

- ✓ Cabinet-Approved *“Framework of Nuclear Policy”* [1]
- ✓ METI’s *“Nuclear Energy National Plan”*[2], AEC’s *“Innovation RM”*[3]

■ Current Fleet, Advanced LWRs then FBRs [2]



The installed capacity is assumed to reach saturation at 58GW, for illustrative purpose

II. Review of Mitsubishi's Fuel Cycle Activities

■ Reliable PWR Fuel Design, Fabrication & Management

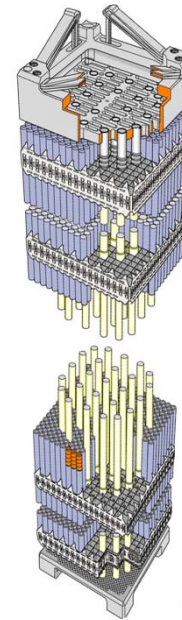
- ✓ *Up to 55GWd/t-Ass'y PWR Fuel : Rods / Assemblies / Reactor Cores*

■ Contribution to FBR Technologies Development

- ✓ *Development of **Joyo**, **Monju** leading to Ongoing Development of Demonstration / Commercialized FBR*

■ Contribution to “Rokkasho” Reprocessing Plant

- ✓ *Basic & Detailed Design, Construction to Commissioning*



III. Innovations to Effectively Complete the Cycle

(1) Gen-III+ PWR to Add More Value to Nuclear Fuel Cycle

■ Large Output / High Availability

- ✓ *High Thermal Efficiency & Large Output :*
US/EU-APWR : World Largest 1,700MWe class
ATMEA1 – Joint with AREVA: 1,100MWe 3Lp
- ✓ *High Availability > 90%*
24-month Extended Cycle Operation
3 to 4 –train Safety Systems to Enable On Line Maintenance



■ Reliability & Safety of Global Standard

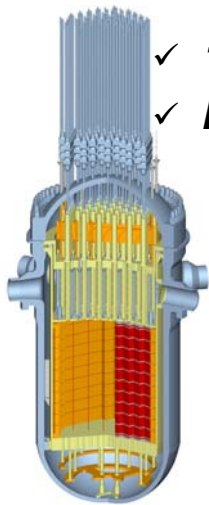
- ✓ *US-APWR Design Certification under Review by US-NRC*
- ✓ *EPRI-URD for US-APWR, EUR for EU-APWR*
- ✓ *IAEA Review for ATMEA1 Conceptual Design Safety Features*

US/EU-APWR : APWR technologies for Global Deployment

Large output and fuel economy

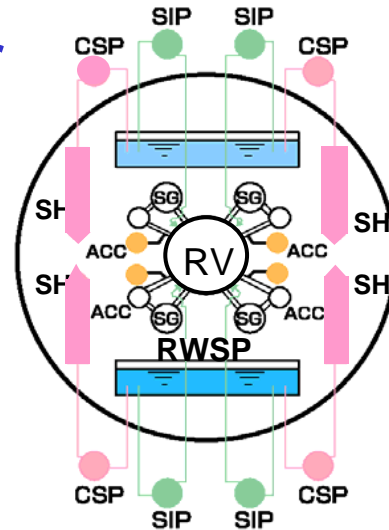
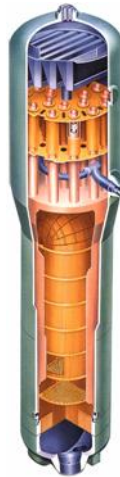
Improvement in safety, reliability and maintainability

■ Reactor Core



- ✓ 14ft fuel
- ✓ Neutron reflector
- ✓ High-performance steam-water separator
- ✓ High-function moisture separator
- ✓ Compact sizing

■ Steam Generator

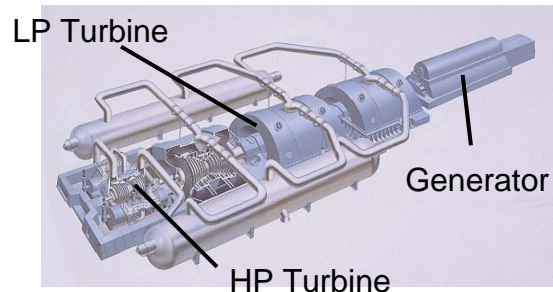


■ Engineered Safety Features

- ✓ Full 4 train safety systems with best mix of passive & active systems
- ✓ In-containment RWSP
- ✓ Advanced accumulator

■ Turbine

- ✓ 70-inch class long last blades, LP turbine
- ✓ Integral Shroud Blade structure



■ I & C

- ✓ Full digital I & C Systems
- ✓ Compact console



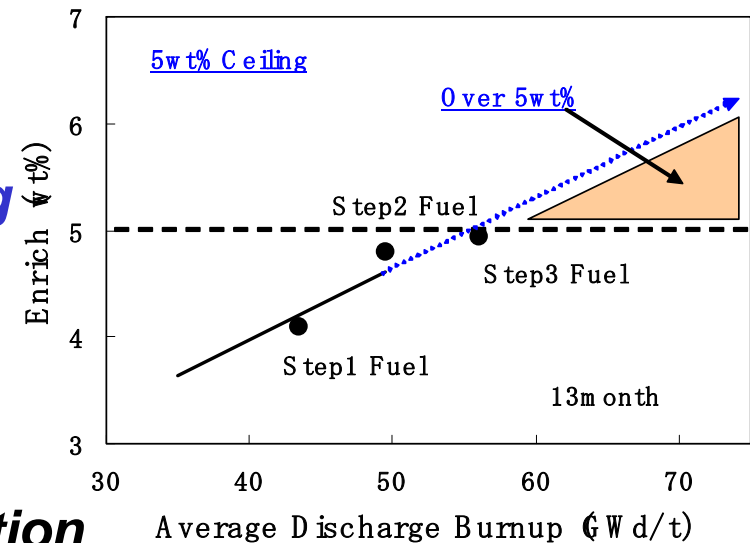
Development of "Next-Generation LWR"

■ Target: Reduction of Spent Fuel Assemblies and the Cost of Power Generation

- ✓ *High Discharge Burnup and Long Cycle Operation*
- ✓ *Need to Exceed 5wt% U-235 Ceiling*

■ Experiments and Studies

- ✓ *Benchmark Experiments of 5 to 10wt% Uranium and Burnable Absorber for Design Code Verification*
- ✓ *Study for the Overall Economy and the Conservativeness and Rationality of the Regulation for the Fuel Cycle Facilities*
- ✓ *Feasibility Innovation in fuel Cladding Material, Structural Materials*



(2) Development for Commercial FBR by Mitsubishi

- ✓ Indispensable Role in **JOYO, MONJU** Accumulated Key Technologies
- ✓ Selected to the **Sole Core Company** for FBR Development in Japan
Established **MFBR***, Specialized in Engineering for FBR Development.
- ✓ One of key industry members under **GNEP FOA****

* MFBR: Mitsubishi FBR Systems, Inc.

** FOA : Funding Opportunity Announcement

JOYO

Experimental FR
(140MWt)



- ◆ Verification of Breeding
- ◆ Irradiation Test

MONJU

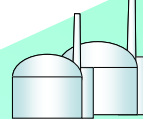
Prototype FBR
(280MWe)



- ◆ Demonstration of power plant systems
- ◆ Establishment of sodium handling technology

Demonstration

FBRs

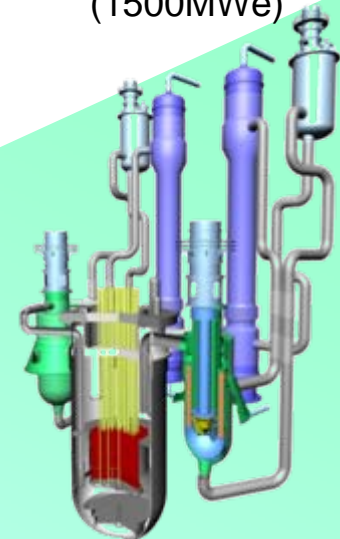


- ◆ Demonstration of commercial plant systems and economics

(2025 ~)

Improvement of economics

Commercial FBR
of Japan***
(1500MWe)



Mitsubishi
proposed
Concept

*** JAEA-Research 2006-042,
Table 2.1.1-4, p.69 (2006)

Major Concept of Japanese Commercial FBRs -13 Innovative Technologies-

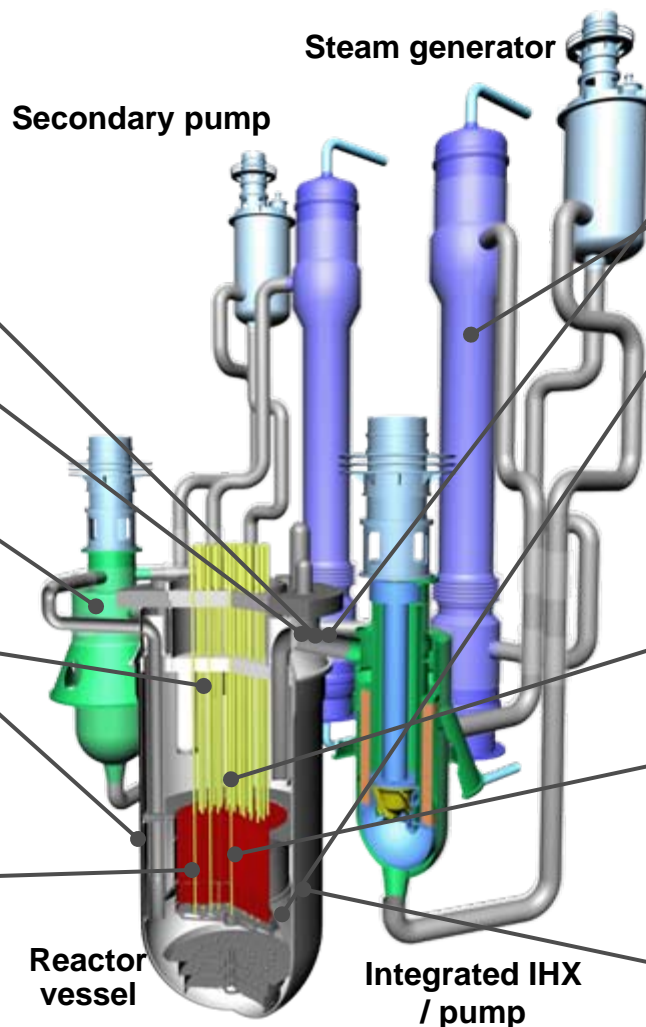
Economy

✓ Reduction in Material Amount and Building Volume

1. High-chromium steel structural material for shortened piping length
2. 2-loop arrangement for a simplified plant system
3. Integrated intermediate heat exchanger with primary pump for a simplified primary cooling system
4. Compact RV
5. Simplified fuel handling system
6. Steel plate reinforced concrete structure of CV

✓ Long Operation Life

7. High burn-up ODS(*) ferrite-steel cladding tube
- *: Oxide-Dispersion-Strengthened (alloy)



Reliability

✓ Sodium Technologies

8. Sodium piping with leak jacket
9. SG with double-walled straight heat transfer tube
10. Inspection and repair technology under a sodium environment

Safety

✓ Enhancement of Reactor Core Safety

11. Passive reactor shutdown system and decay heat removal by natural circulation
12. Recriticality-Free core concept during severe core damage

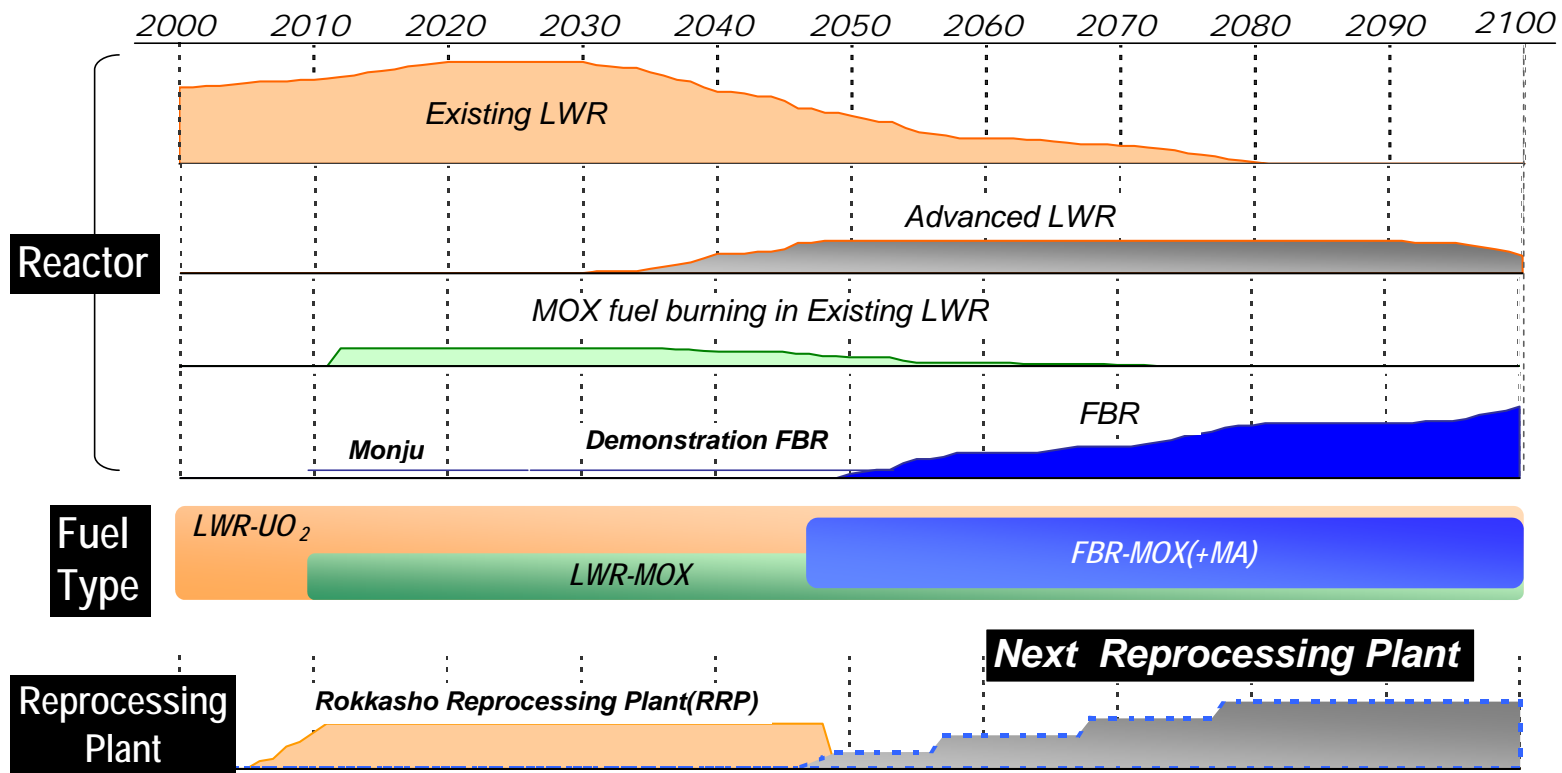
✓ Improvement of Seismic Reliability (Isolation Technologies)

13. Seismic reliability in core assemblies

(3) Development of Fuel Cycle Technologies

Requirement for Next Reprocessing Plant

■ Reprocessing during LWR to FBR Transition Period

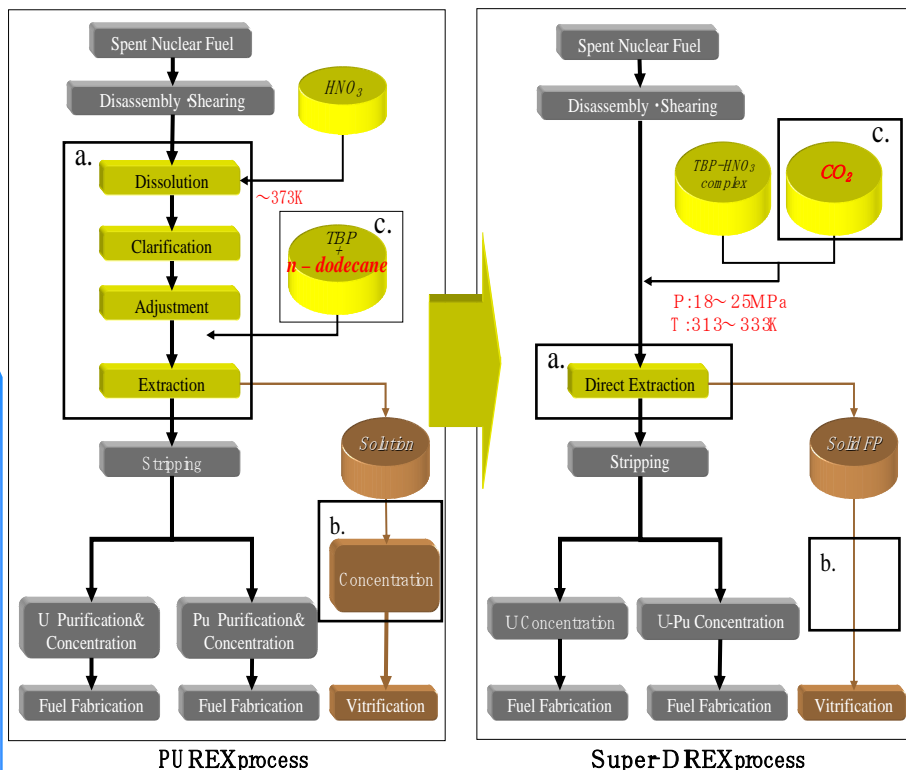


- ✓ **LWR-UO₂ fuel, LWR-MOX and FBR-MOX coexist**
- ✓ **Economic Reprocessing Technology Required to Meet Three Fuel Types.**

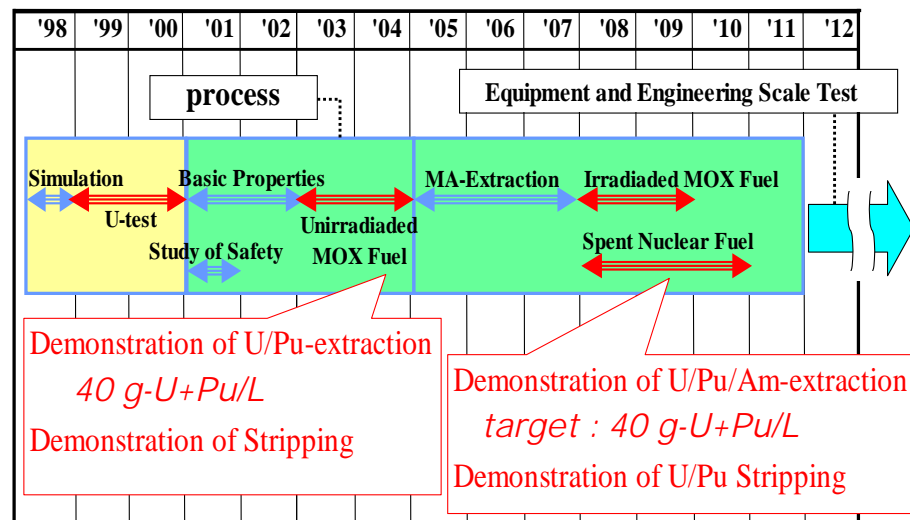
Development of MHI's Innovative Reprocessing Technology - Super-DIREX (Supercritical fluid Direct Extract) -

Advantage

- ✓ **Simplified Process & Equipment**
- ✓ **No HLW Concentration**
- ✓ **CO₂ to Replace Flammable Diluent (Lower Fire Risk)**



Development



Apparatus



IV. Conclusion

- **The nuclear energy is the viable solution both for the environment and energy security issues. The nuclear fuel cycle is the essential concept to maximize its potential.**
- **The fuel cycle technologies are composed of many pieces. Each of them requires technical innovation for its part. At the same time, each of them must be coordinated with others. Therefore it is essential to have the global picture of the fuel cycle to effectively promote the whole activities.**
- **MHI has played and will keep playing the key role to promote the fuel cycle policy in Japan. Also, we commit ourselves to deploy our technologies globally for the well being of all mankind.**

References

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- [2] Nuclear Energy Policy Planning Division, METI , “The Challenges and Directions for Nuclear Energy Policy in Japan - Japan’s Nuclear Energy National Plan -”, December 2006,
<http://www.enecho.meti.go.jp/english/report/rikkoku.pdf>
- [3] Japan Atomic Energy Commission, “Road Map for Development of Innovative Nuclear Technologies as Countermeasures against Global Warming”, July 15, 2008 (in Japanese)
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List of Abbreviations

AEC : (Japan) Atomic Energy Commission

CV : Containment Vessel

FBR : Fast Breeder Reactor

FOA : Funding Opportunity Announcement

FP : Fission Product

FR : Fast Reactor

GNEP : Global Nuclear Energy Partnership

GWd/t-Ass'y : Giga-Watt-day per ton
for Assembly average

HLW : High Level Waste

HP : High Pressure

IHX : Intermediate Heat Exchanger

JAEA : Japan Atomic Energy Agency

JFY : Japanese Fiscal Year
(April to March of the next calendar year)

Lp : Loop

LP : Low Pressure

LWR : Light Water Reactor

MA : Minor Actinide

METI : Ministry of Economy, Trade and Industry

MFBR : Mitsubishi FBR Systems, Inc.

MOX : Mixed Oxide

ODS : Oxide Dispersion Strengthened (Alloy)

PWR : Pressurized Water Reactor

RM : Road Map

RRP : Rokkasho Reprocessing Plant

RV : Reactor Vessel

TBP : Tri-Butyl Phosphate