Fast Reactor development in Japan

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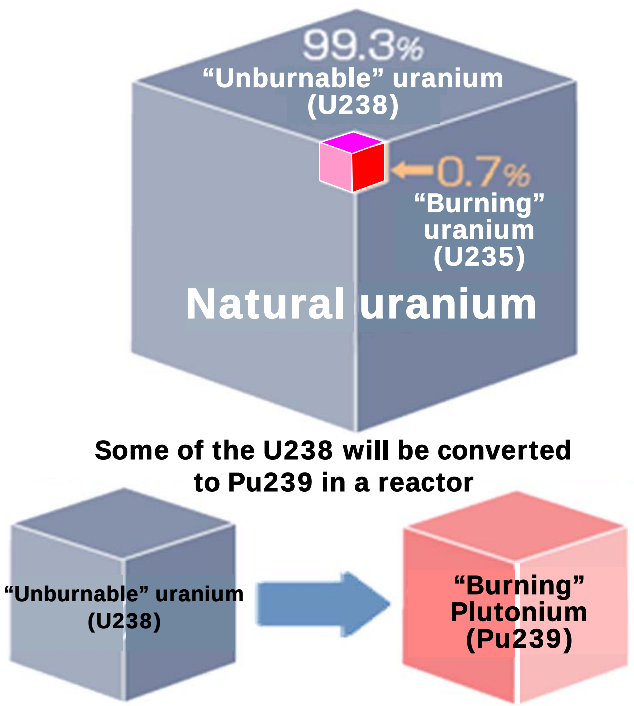
I. Significance of FBR development

Efficient use of uranium resources – securing stable energy supply

FBR produces more fissile plutonium from non-fissile uranium than they consume while generating power. FBR enables to secure domestic energy sources for centuries.

⇨ The FBR technology realizes long-term and sustainable energy supply and is the essential national benefit of Japan.

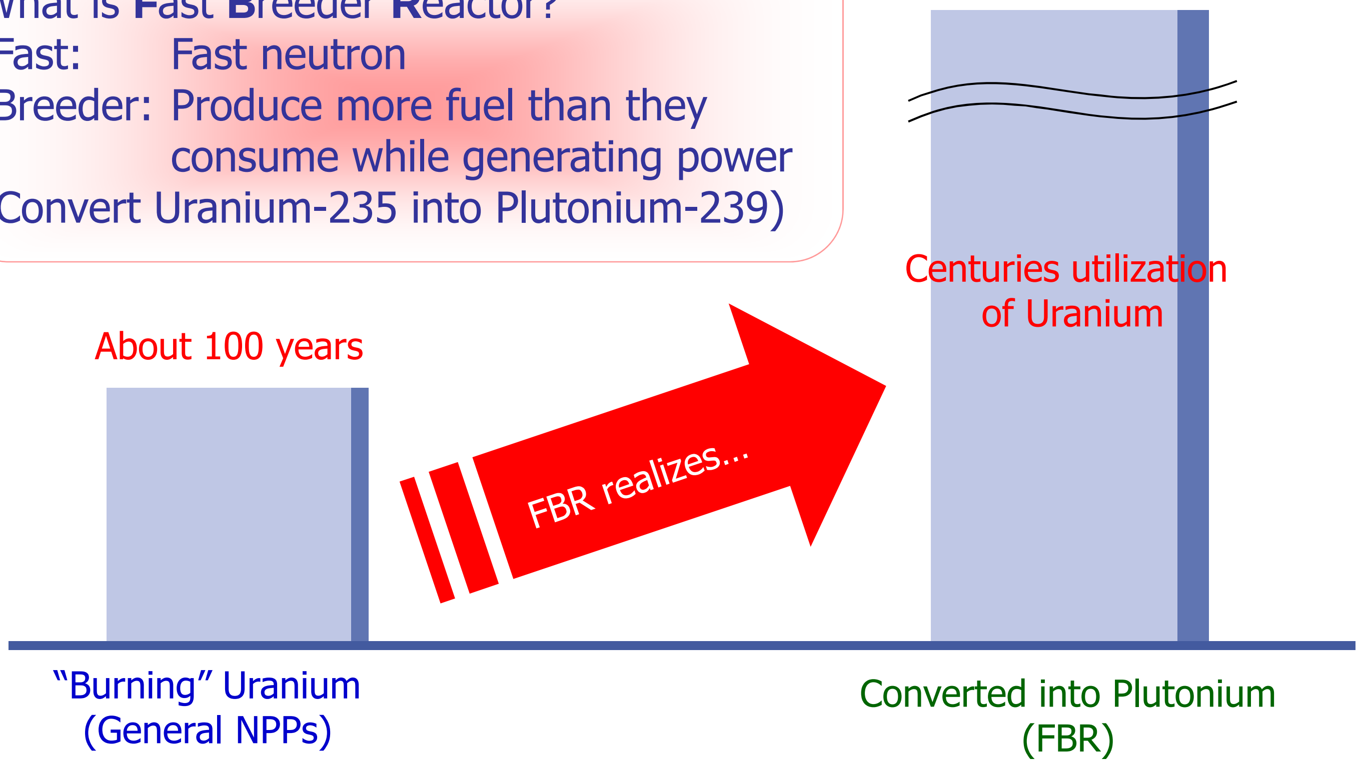


What is **F**ast **B**reeder **R**eactor?

Fast: Fast neutron

Breeder: Produce more fuel than they consume while generating power

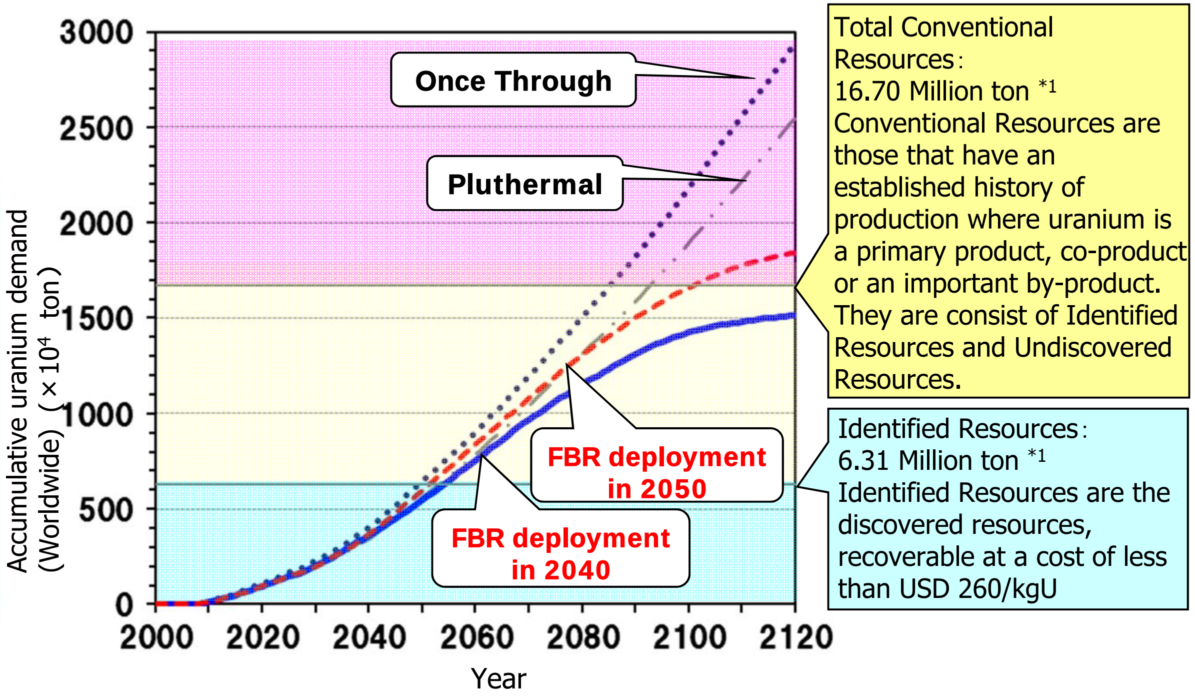
(Convert Uranium-235 into Plutonium-239)



Worldwide prospects of increasing Uranium demand for increasing nuclear power generation

- JAEA established Medium Nuclear Power Generation Scenario considering goals of Asian regions (especially in China and India) for expanding of nuclear power use
- Increasing use of nuclear power generation will make international competitions of securing uranium resources harder at the end of 21st century

- ✓ FBR cycle development for the future is critical worldwide in terms of energy security
- ✓ A country which commercializes FBR cycle at an early stage will be freed from competition for access to uranium resources



Change of accumulative uranium demand (FBR deployment and once through by LWR) *2

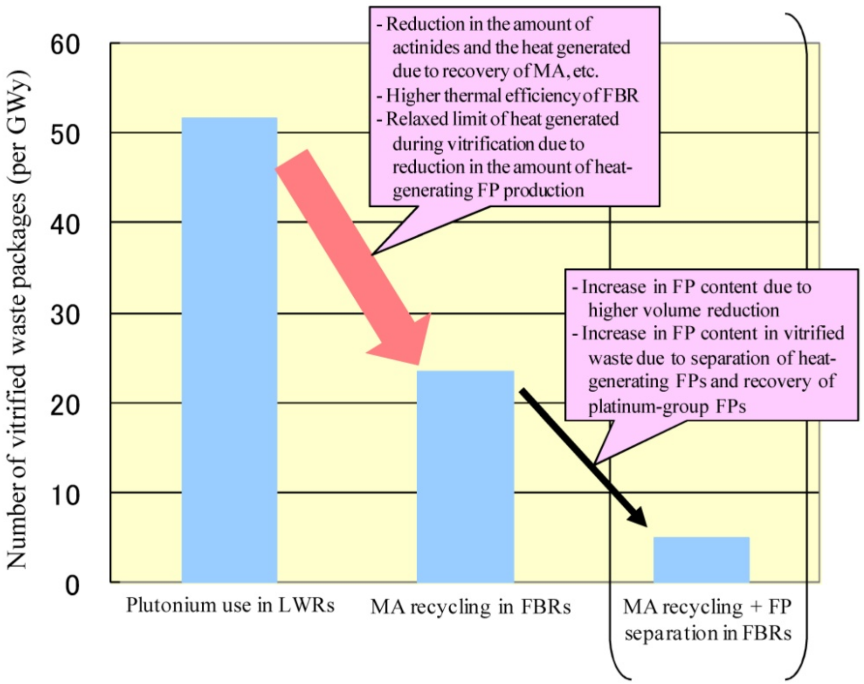
*1 Uranium 2009: Resources, Production and Demand (2010)
*2 Estimation by JAEA, Medium Nuclear Power Generation Scenario

FBRs Contribute to environmental burden reduction

Aiming to reduce the environmental burden ⇨ Focus on the challenges of nuclear energy

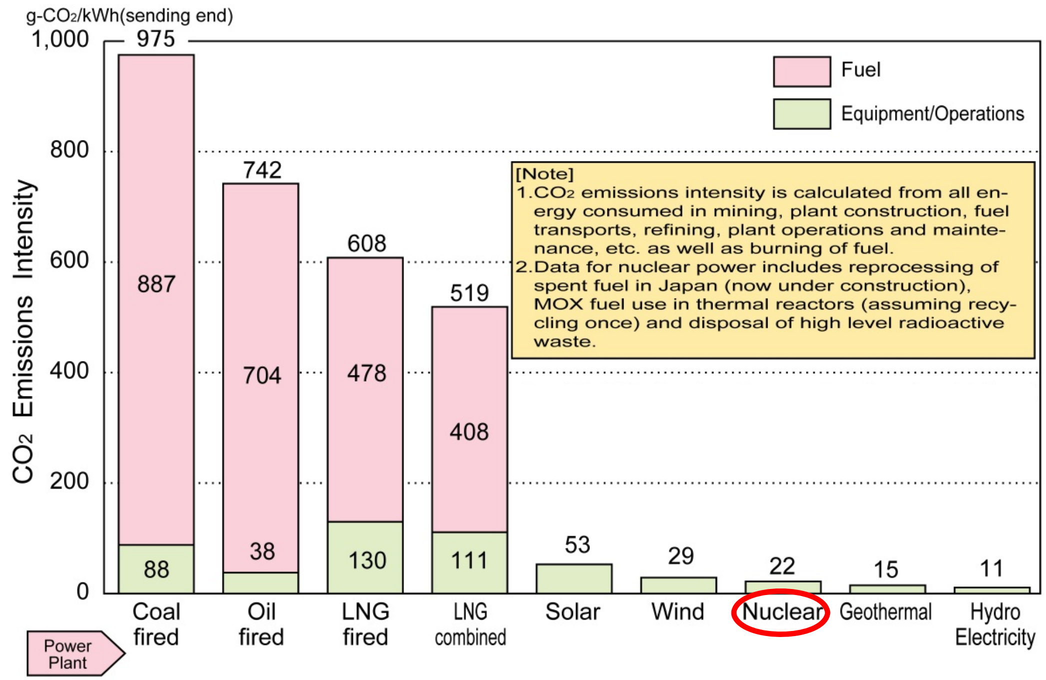
Reduction of environmental burdens due to high level waste

FBRs have a potential to burnup radioactive materials efficiently in the reactors. FBRs reduce management burdens on high level waste.



Long-term contribution to reducing CO_2 emissions

Nuclear energy generation produces very low levels of CO_2 compared to others. FBRs realize long term use of nuclear energy and contribute to global warming reduction.



(Source) Central Research Institute of Electric Power Industry Report etc.

Ⅱ. Fast Reactor Commercialization and Monju

2015

Responsible organization

Commercial scale adoption from 2050

Commercial FBR
(1500MWe)

Announcement of reactor and cycle facilities to commercialize and the relevant demonstration facility concept designs

To be realized in 2025

Demonstration FBR
(500-750MWe)

JAEA

Restarted commissioning in May 2010
Demonstration of reliability as a power plant
Establishment of Na handling technology

Monju, prototype FBR (280MWe)

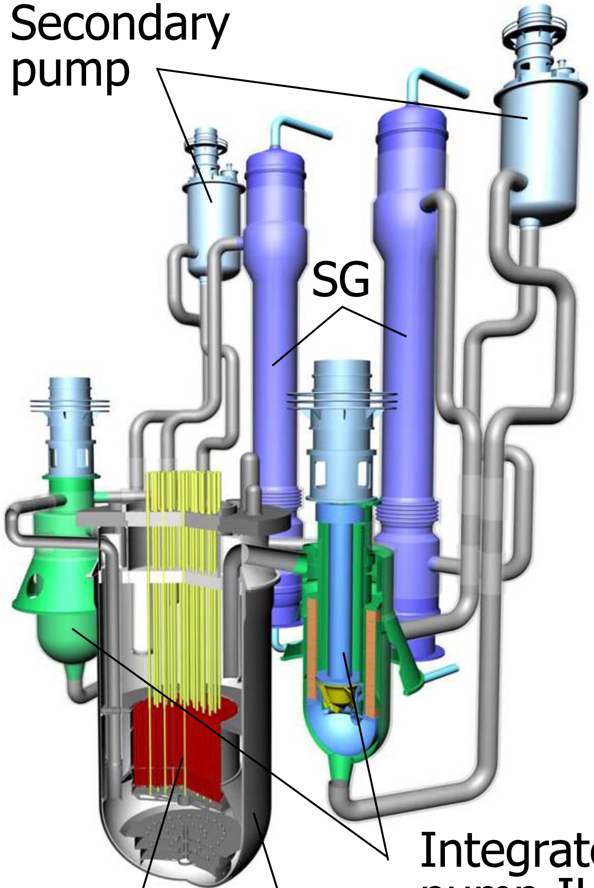
First criticality in 1977

Joyo, experimental FBR

\+

Commercialization R&D (FaCT)
for innovative technologies
and design study on commercial reactors

Japan Sodium-cooled Fast Reactor (JSFR)



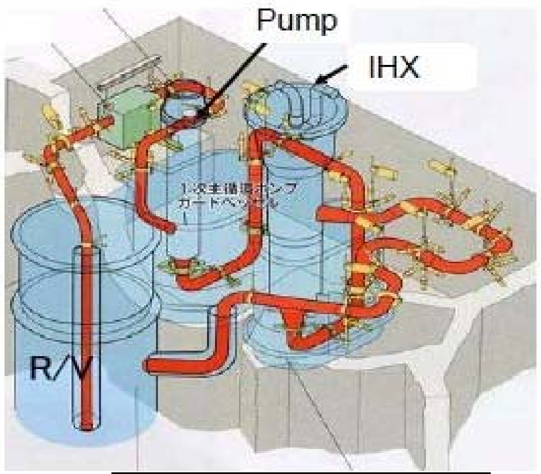
Items	Specifications
Output	3,530MWt / 1,500MWe
Number of loops	2
Primary sodium temperature (Reactor vessel inlet / outlet)	550 / 395 degree C
Secondary sodium temperature (IHX inlet / outlet)	520 / 335 degree C
Main steam temperature and pressure	497 degree C 18.7 MPa
Feed water temperature	240 degree C
Plant efficiency	Approx. 42%
Fuel type	TRU-MOX
Burn-up	150,000MWd/t (Reactor core average)
Breeding ratio	Break even (1.03) ~ 1.2
Cycle length Number of refueling batches	18-26 months 4 batches

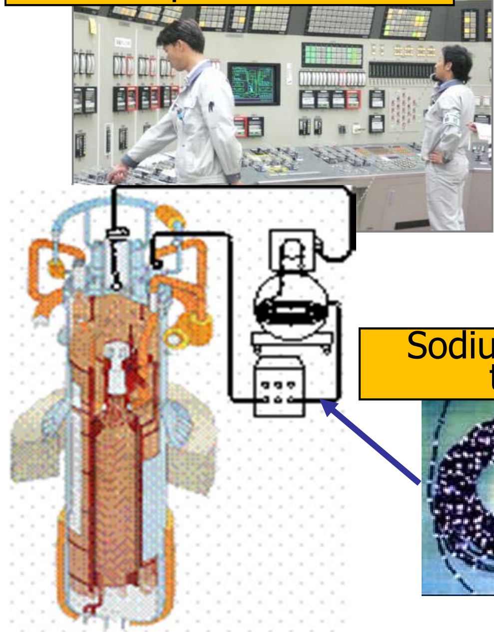
Significance of Monju development

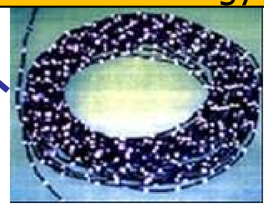
After the accident at the Fukushima Daiichi nuclear power plant, the world challenges of securing energy resources and preventing further global warming remain to be important
⇒Japan needs long-term and sustainable stable energy security without depending on resources from other countries

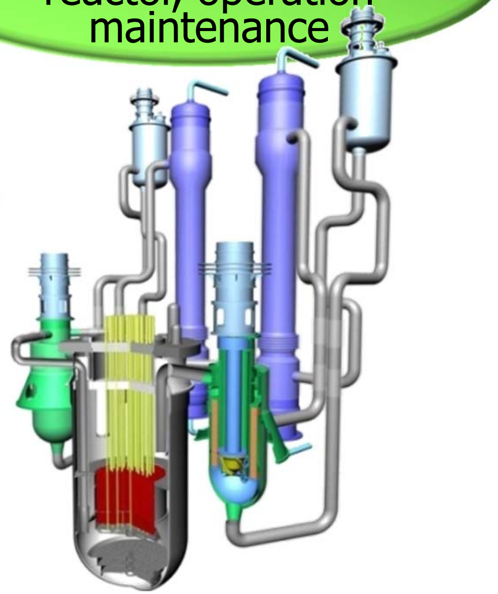
FBR is a technology that Japan with scare resources has developed over half a century as a state policy in public-private cooperation as a technology of high potential in order to tackle these problems

Monju has an important role to provide essential technical information for designs of demonstration reactor and commercial reactor, and operation maintenance as Japan's prototype reactor toward commercialization of FBR

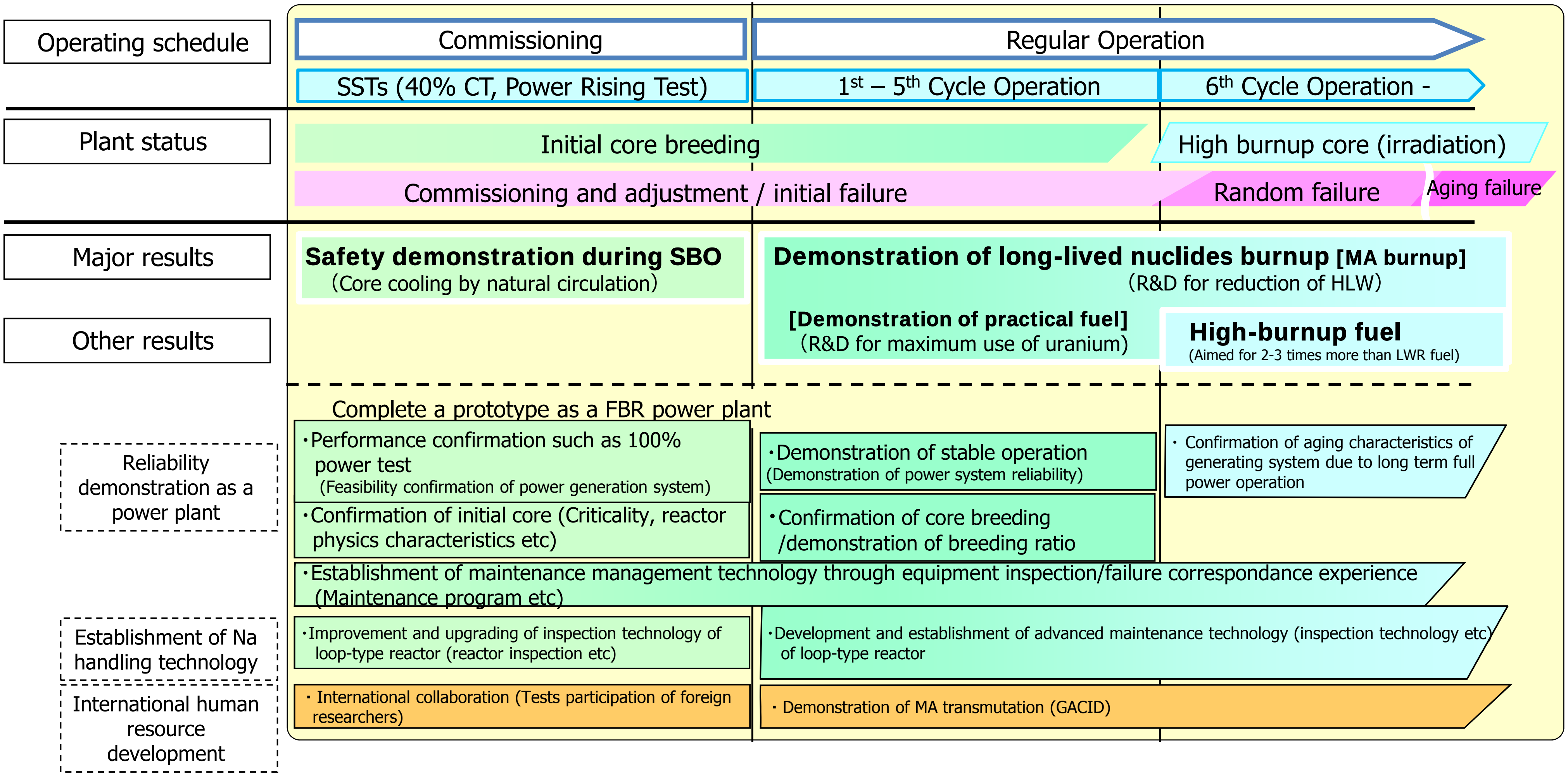








The goal of Monju

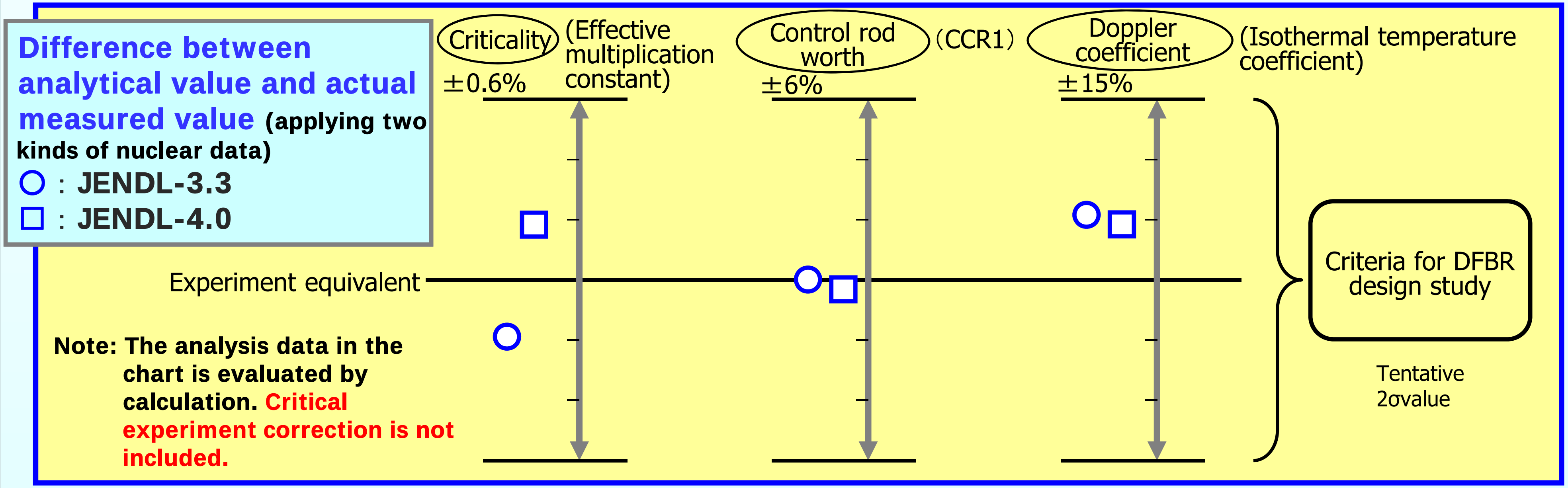


Core Confirmation Test results applied to FBR design study

Acquisition of reactor physics data

- Feature of the core : Most of fuels were irradiated or fabricated about 15 years ago.
  --> Increased Americium-241 content : ~1.5 wt% / MH
- Acquisition of world's valuable data of reactor core which contains approx. 1.5wt% of americium 241 for reactor physics study toward commercialization.

⇒ Core characteristics have been analyzed by JAEA method prepared for DFBR.
Results of calculation show higher accuracy compared to the design criteria for DFBR.



Utilization of data and offering results

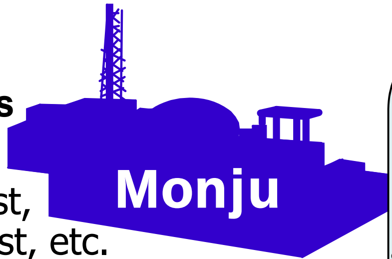
- Conducting detailed evaluation and verifying the affectivity of the latest nuclear data, JENDL-4.0 on americium 241 etc. Releasing the results at international conferences and in academic journals.

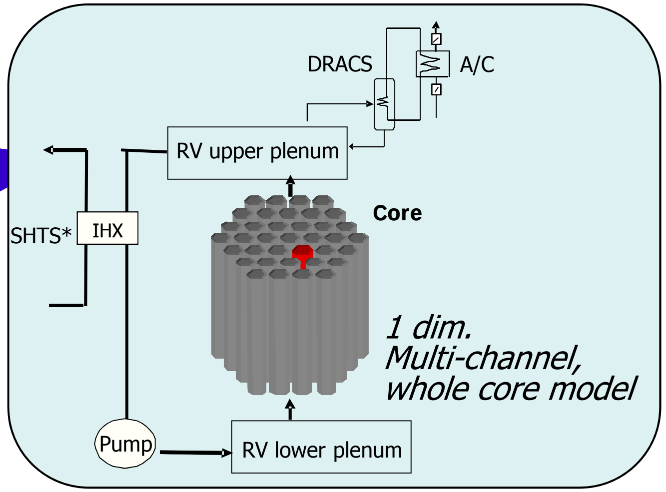
The findings to be obtained from the future System Start-up Tests (SSTs)

-Verification of Analytical Method for Decay Heat Removal by Natural Circulation-

System start-up tests (SSTs);

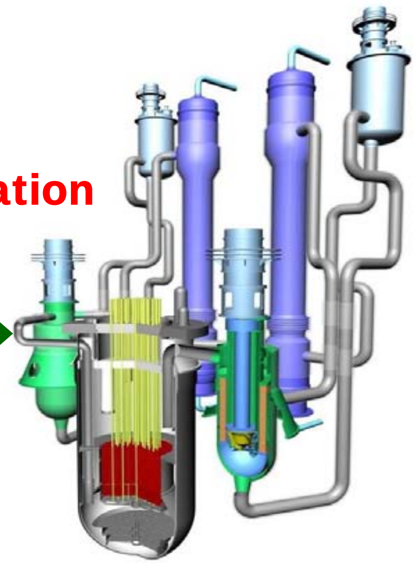
- Natural circulation test,
- Plant trip transient test, etc.





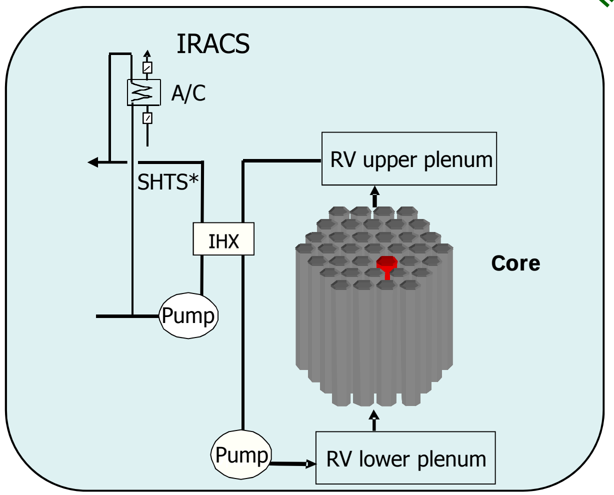
Natural Circulation Analysis Model of JSFR

Evaluation



JSFR

Verification



Natural Circulation Analysis Model of Monju

* **Secondary Heat Transport System**

Applicability of Monju natural circulation to JSFR

- Non-dimensional number describing heat transfer;
  $Pe_{Monju} \approx (4/5)Pe_{JSFR}$
- Scaled experiments enable to predict natural circulation of JSFR;
  $[Pe_{W} > Pe_{Monju} > Pe_{Na}]$
  Pe_{W}; 1/10 scaled water experiment Pe_{Na}: 1/5 scaled sodium experiment

Ⅲ. International Collaboration using Monju

- Expectation on Monju is considered to be significant because the other operable FBR prototype reactor in the Western countries, i.e. Phenix of France was shut down in 2009.
- Monju is actively offering prototype plant data to the world, which is important for FBR development. Extensive and detailed test data obtained from Monju will be an international benchmark of FR thermal hydraulics. Monju will make a contribution to validate the analysis codes for design/safety assessment for each country.
- Monju can contribute as a place to perform irradiation tests to acquire FBR fuel and material irradiation data critical for FBR development. Monju will also make a contribution by providing education and training critical for improving technical level of FBR engineers and researchers.

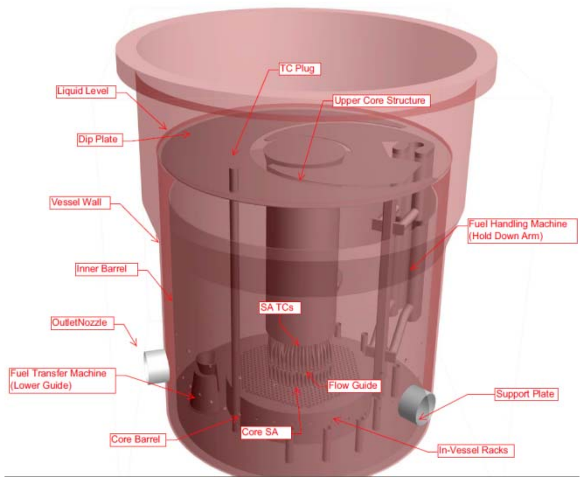
International collaboration using Monju [1]
Participation in IAEA Coordinated Research Project (CRP) #1

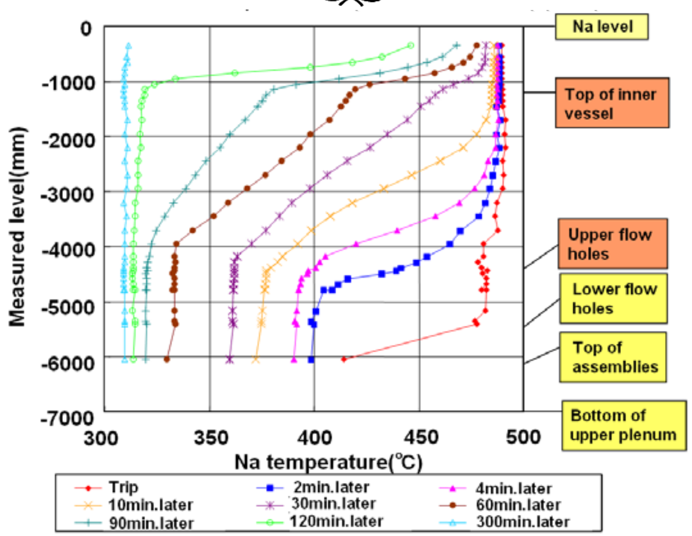
Objective : To improve numerical analysis technology to accurately predict post-trip thermal stratification inside the upper plenum of reactor vessel after, which is a common issue among various types of sodium-cooled fast reactors.

Inside the upper plenum of actual reactor vessel, acquisition of thermal stratification data produced an unprecedented result in the world (turbine trip test in a state of 40% operation, on 1995 December).

» Participating countries/organizations:

IAEA, USA (ANL), France (CEA), Russia (IPPE), India (IGCAR), China (CIAE), Korea (KAERI), Japan (UF, JAEA)

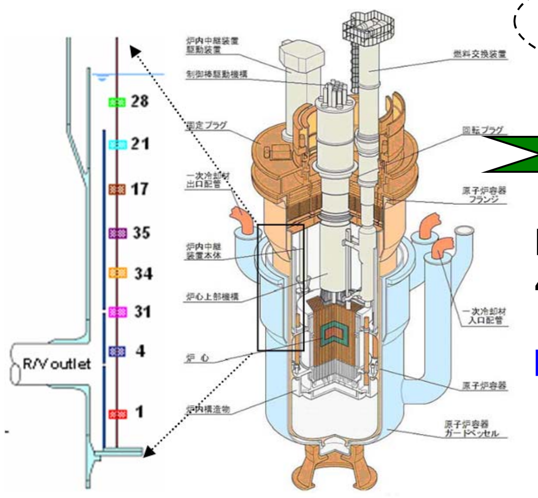




Participation in IAEA Coordinated Research Project (CRP) #2

International workshop on FR thermal hydraulics using Monju

(Scheduled for April 19, 2012 at University of Fukui)



Temperature measuring positions in the upper plenum

Shutdown

FFTF (USA) 400 MWt

Phenix (France) 563 MWt

Super Phenix (France) 3,000MWt : Shutdown

Monju
45% Thermal output
(321 MWt)
Benchmark analysis

Monju
Output (714 MWt)

Next generation reactors of the world
(Demonstration and commercialized reactors)
3,000～3,500 MWt

Analysis codes can be evaluated with high accuracy by extensive and detailed data

Extrapolation is applicable as the range is 4-5 times

Expected results

- » Extensive and detailed test data obtained from Monju will be an international benchmark of FR thermal hydraulics. Monju will make a contribution to validate the analysis codes for design/safety assessment for each countries.
- » Transient data obtained from the 100% output test of the system start up tests of Monju makes thermal high-accuracy stratification and structure evaluation possible for future reactors.

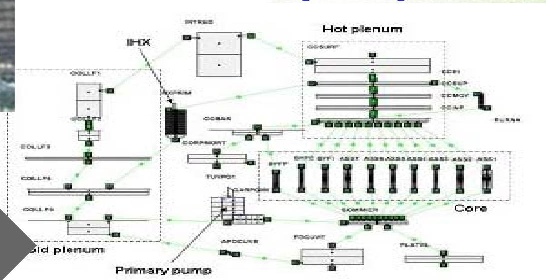
International collaboration using Monju [2]

- Establish analysis codes developed in each country based on the design data of Monju
- Utilize for FBR design

France(CEA)

Monju

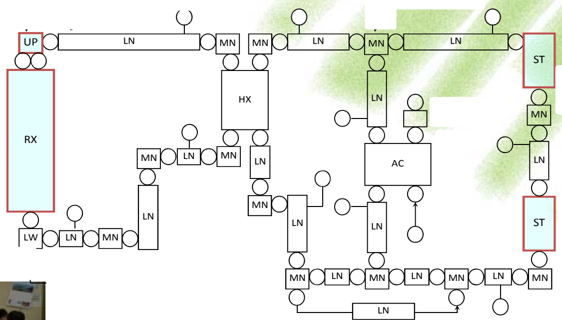
CATHARE(CEA)



(Source：website of CEA)

Phénix

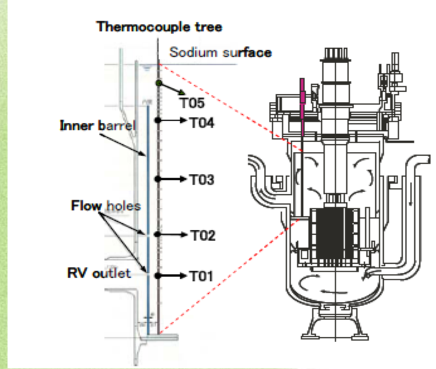
Super-COPD(JAEA)



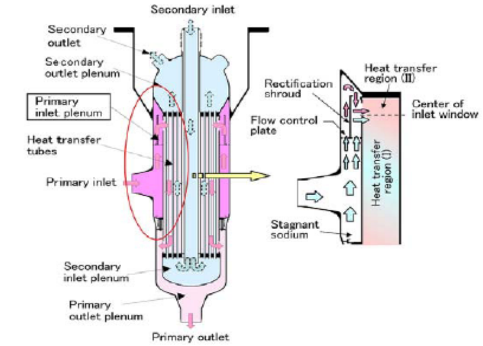
Exchange of views:
Reaffirm Monju based on the data obtained from 35-year-operation of Phenix → Reflect the results in operation of Monju

Korea (KAERI)

Provide information on plant specification and characteristics

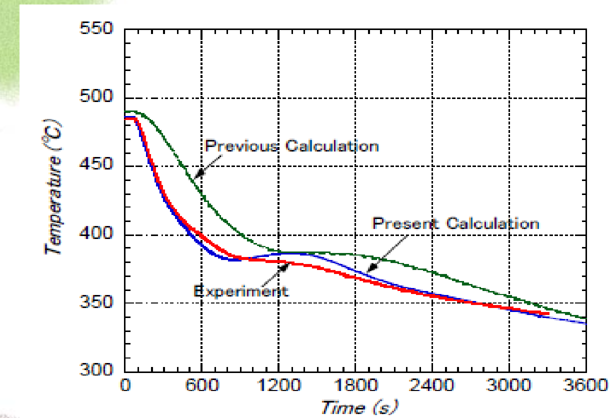


Reactor structure



Flux in IHX

Offering of test results

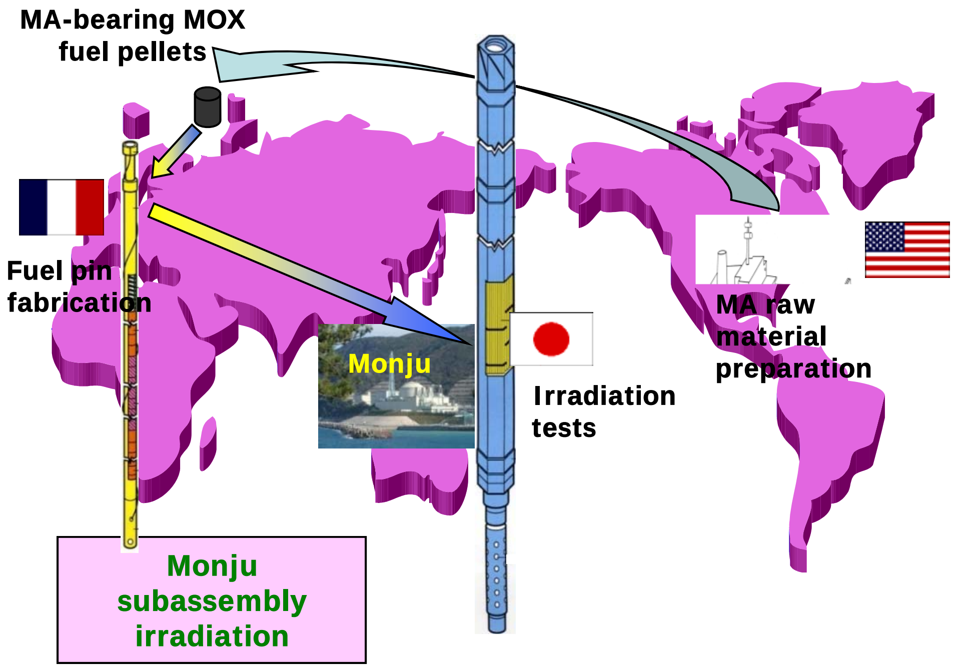


Temperature change in the reactor outlet due to plant trip

International collaboration using Monju [3]

"Global Actinide Cycle International Demonstration (GACID) Project"

Purpose:
Demonstration of a major candidate fuel for commercial FBRs: Minor-Actinide(MA) bearing fuel (also referred to as "TRU Fuel") making use of "Monju" and "Joyo"

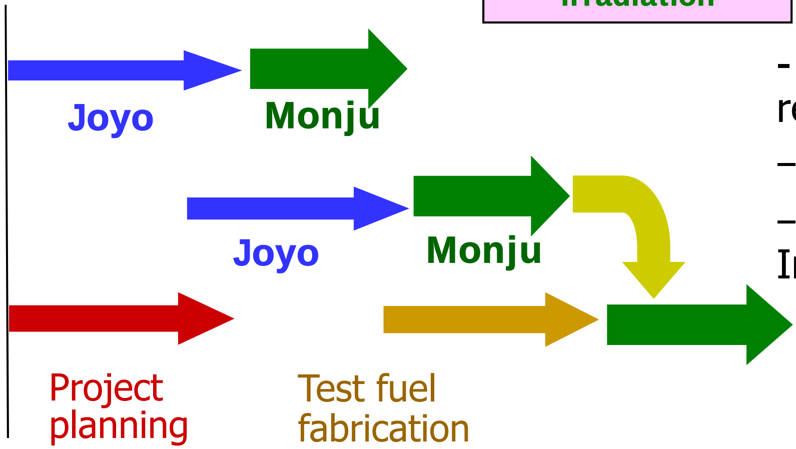


GACID Overall Schedule

Step-1
Pin irradiation of Np/Am bearing fuel

Step-2
Pin irradiation of Np/Am/Cm bearing fuel

Step-3
Subassembly irradiation of Np/Am/Cm bearing fuel



- Possibility demonstration of total MA recycle using transmutation in FBRs
– A phased approach in 3 steps
– SFR project in the Generation-4 International Forum

Contribution to America's nuclear future

The BRC's final report to the Secretary of Energy
(issued on January 26, 2012)

- New comprehensive strategy for back-end management of nuclear fuel cycle in the U. S.

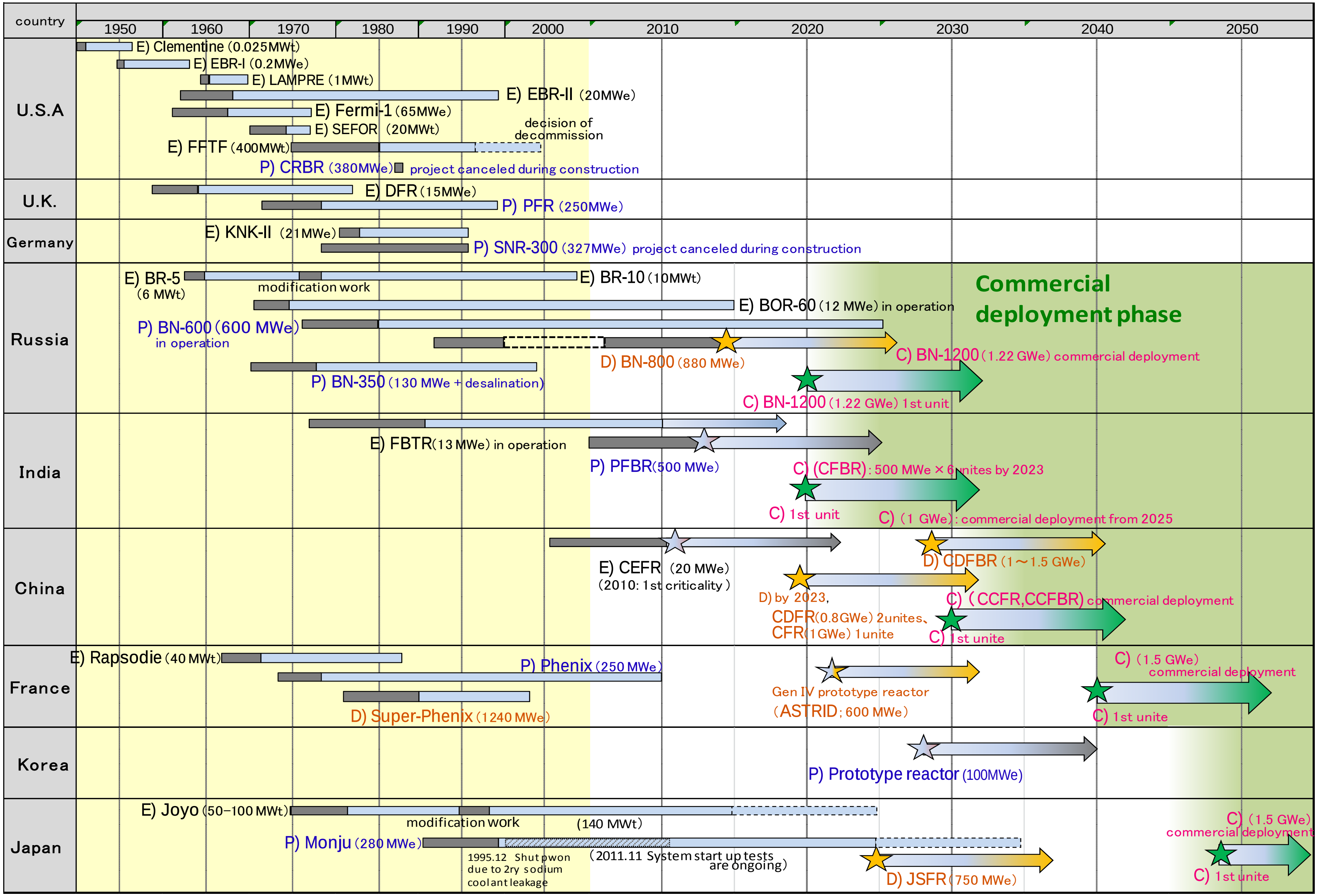
- The BRC report includes eight key elements :

(1 – 6, 8 omitted)

7. Support for continued U.S. innovation in nuclear energy technology and for workforce development.

The President's Blue Ribbon Commission on America's Nuclear Future at Monju (February 11, 2010)

History and Development Plans of FR Cycle in the World



Ⅳ. Conclusion

1. After the accident at the Fukushima Daiichi nuclear power plant, the world challenges of securing energy resources and preventing global warming remain to be important. Securing long-term and stable supplies of energy is essential.
2. FBR realizes long-term and sustainable energy supply. The technology is the essential national benefit of Japan.
3. Monju, as the Japanese prototype reactor for the purpose of FBR commercialization, has an important role to provide indispensable technical information for design, operation and maintenance of demonstration and commercialized FBRs.
4. Data obtained from Monju is an international benchmark and contributes to validate the analysis codes for each country. Monju also can make a contribution as a place for irradiation tests to acquire FBR fuel and material irradiation data and as a place for education and training improve technical level.