Japan’s Policy on Fusion Research and Development

Ministry of Education, Culture, Sports, Science and Technology(MEXT)

September, 2022

MEXT
MINISTRY OF EDUCATION,
CULTURE, SPORTS,
SCIENCE AND TECHNOLOGY-JAPAN

Staged Approach toward Fusion Energy of Japan

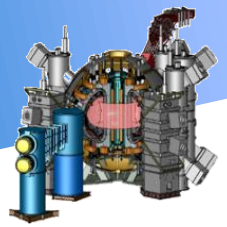
Scientific Feasibility

-To achieve break-even plasma condition

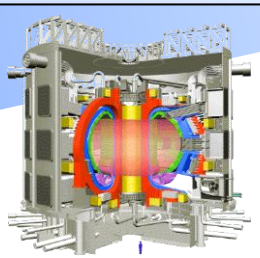
JT-60 (QST)

Scientific & Technological Feasibility

-To realize burning plasma and long-duration burning
-To establish physical and technological basis for JA-DEMO



JT-60SA
(QST–F4E)



ITER
(ITER Organization)

BA Activities | **ITER Project**

- Japan-EU Bilateral Collaboration in Japan supporting ITER and JA-DEMO R&D comprising following activities:
  - IFERC (DEMO design and R&D)
  - IFMIF/EVEDA (Engineering Validation for fusion material irradiation facility)
  - Satellite Tokamak Programme (JT-60SA)

Current Stage

Technological Demonstration & Economic Feasibility

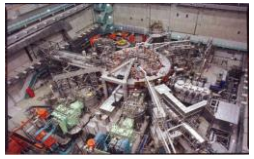
-To demonstrate electric power generation
-To Improve economic efficiency

JA-DEMO Reactor
[go-no-go decision in 2030s]

- 7 Members (EU, US, JA, CN, IN, KO, RF) collaboration
- Demonstrate burning plasma (Q>10, 300-500sec)
- ITER Organization assembles components as in-kind contribution by 7 Members (JA: Toroidal Field Coils etc.)

Academic Research

GEKKO XII,
LFEX
(Osaka Univ.)



LHD(NIFS)

Current Stage

Ready to commercialization

Having prospect in the mid-21 Century

Recent policy reviews

Policy Speech by Prime Minister KISHIDA Fumio to the 208th Session of the Diet
January 17, 2022

[Provisional translation]

<4. Responses to the problem of climate change>

・・・As we work towards the targets of a 46 percent reduction in greenhouse gas emissions by fiscal 2030 and achieving carbon neutrality by 2050, we will be engaged in not simply changes to the energy supply structure, but rather, a major transformation of our economy and society as a whole, spanning our industrial structure, our citizens' daily lives, and the way our communities should be overall.

In what kind of fields, by when, through what kinds of mechanisms, and how much of an investment will this draw? We will compile and then show to the public a path forward for economic and social changes, as our Clean Energy Strategy.

We will find future directions for many points at issue: power transmission and distribution infrastructure; storage batteries; non-carbon sources of power, notably, renewable energies as well as hydrogen and ammonia, innovative nuclear power, and nuclear fusion; demand-side and community-based decarbonization; changes in lifestyles; how financing is arranged; and carbon pricing.

Fusion Science in National Policy

6th Science and Technology Basic Plan （Cabinet Decision in March 2021)

◇CHAPTER 2 STI POLICY FOR THE REALIZATION OF SOCIETY 5.0
1. Transformation into a sustainable and resilient society that ensures the safety and security of the people
(2) Promoting social change and discontinuous innovation to overcome global issues
3) Concrete measures
b. Promotion of R&D and demonstration for utilization of various energy sources
・Based on the Basic Energy Plan, which is currently under review, the government will promote necessary research and development, demonstration, and international cooperation in energy conservation, renewable energies, nuclear power, and nuclear fusion. [MEXT, METI]

The 6th Strategic Energy Plan
(Cabinet Decision in October 2021)

◇Points of policy responses towards 2030 [Nuclear]

●Promotion of R&D
By 2030, while making the most of the private sector's ideas and wisdom, development of fast reactor will be steadily promoted by utilizing international cooperation; small modular reactor technology will be demonstrated through international cooperation; and component technologies related to hydrogen production at high temperature gas-cooled reactor will be established; as well as R&D of nuclear fusion will be promoted through international collaboration such as ITER Project, etc..

*an excerpt from the "Outline of The 6th Strategic Energy Plan"

The Long-term Strategy under the Paris Agreement
（Cabinet decision, June 11, 2019）

◇Chapter 3: Cross-sectoral Measures to be Focused
Section 1: Promotion of Innovation
2. Directions of Policy Measures
(4) "Visualization" of Issues in Individual Fields for Commercialization
e. Nuclear energy
・・・On nuclear fusion energy, in parallel with steady implementation of the ITER project, which uses the tokamak and the Broader Approach Activities, Japan will promote the research on helical and other types based on unique Japanese ideas, aims at establishing scientific and technological feasibility.

Progress in ITER Project

- The assembly and integration of ITER started in July 2020, and physical percentage complete for First Plasma at 77.0% by end of June 2022.
- In Japan, six out of nine superconducting toroidal field (TF) coils have been completed and delivered to the ITER site. The first sector sub-assembly of two Japanese TF coils and the Korean Vacuum Vessel has been completed and set in the tokamak pit.

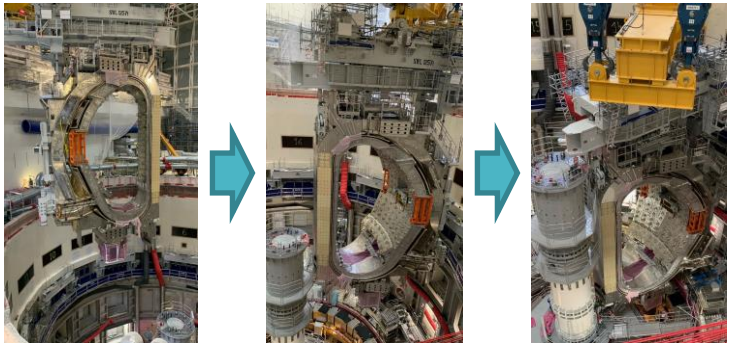
Tokamak Construction

(April 2022)

Tokamak pit
(December 2021)

Manufacturing of components in Japan

6th TF Coil : Delivered to ITER site (March 2022)



1st VV sub-sector set in the tokamak pit
(May 2022)

Gyrotron: All production completed (May 2021)

NBTF: High Voltage Tests for JA components completed (Nov 2019)

Progress in BA Activities

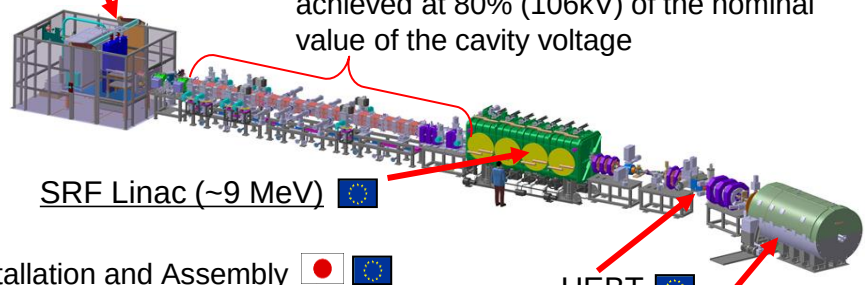
IFMIF/EVEDA (Rokkasho, Aomori)

Injector (~0.1 keV)

- The Injector achieved 135 mA beam with sufficient beam quality in 2016.

RFQ (~5 MeV), RF Power

- The test campaign with Deuterium beams has progressed steadily and completed the validation of the main diagnostics systems
- RFQ continuous wave conditioning was achieved at 80% (106kV) of the nominal value of the cavity voltage



Installation and Assembly

- Assembly of RFQ has been completed in March 2020.
- SRF Linac has been installed and assembly will start soon.

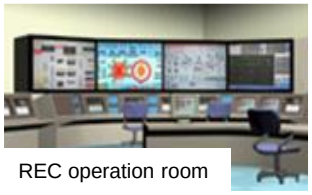
Building

Auxiary System

IFERC project (Rokkasho, Aomori)

- JET tile analysis provided important knowledge on the tritium behavior in ITER and DEMO.
- Remote participation in WEST experiment was successfully implemented in Nov.2018. Live monitoring tests between REC and ITER had started.
- New supercomputer started operation in Jun. 2018.

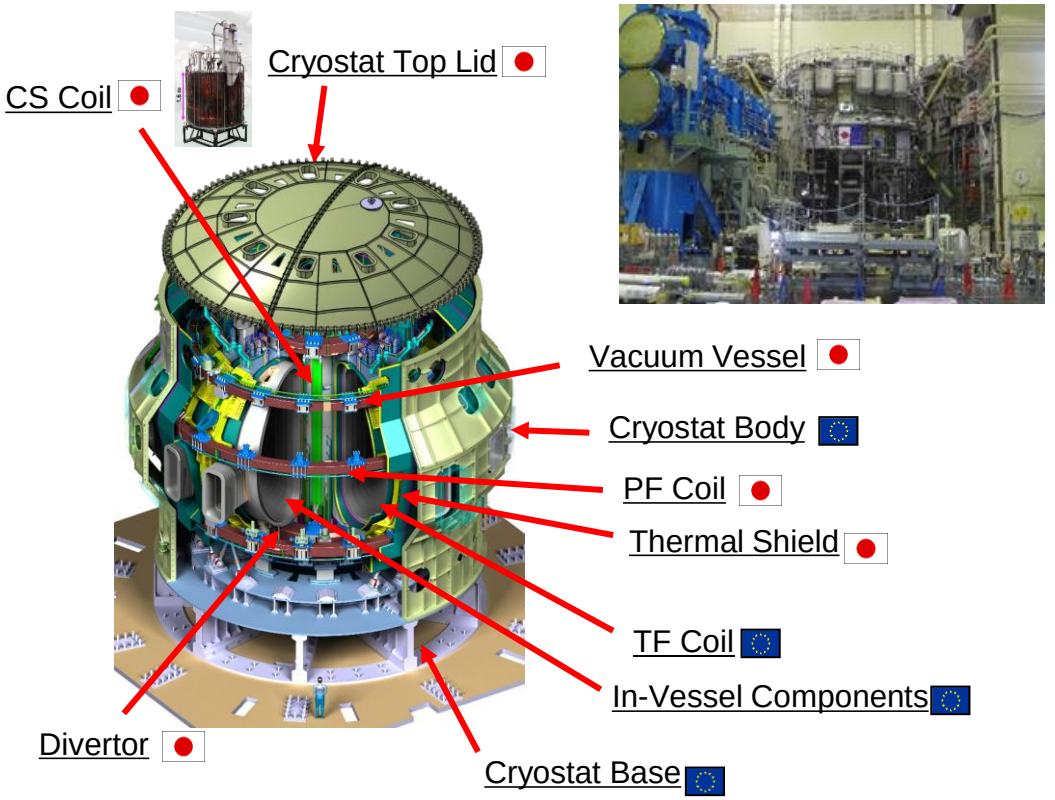

Demo


REC operation room

New supercomputer

JT-60SA (Naka, Ibaraki)

In Satellite Tokamak Project (JT-60SA), Japan procures key components for DEMO ; Vacuum Vessel, CS, PF coil, and Assembly & Installation (those are not procured in ITER Project).



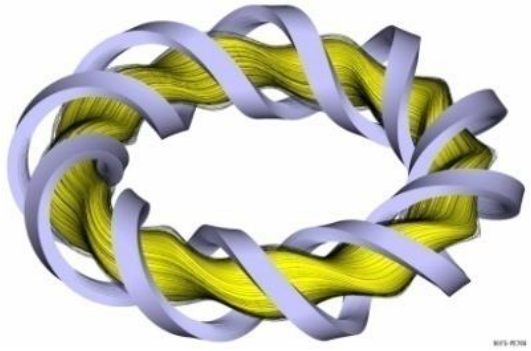
Installation and Assembly

- The assembly of JT-60SA was completed on Mar. 2020.

Research on Large Helical Device

Helical type

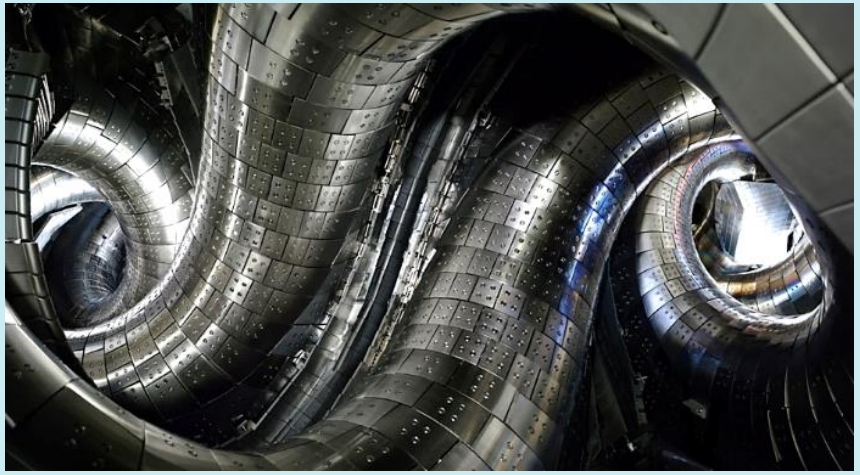
Twisting the external coils：
Helical type (LHD)



◆ Steady State Operation available for more than one year in principle

◆ Issue
Improvement of plasma performance to realize reactor- relevant plasma
→ **Realization of 120 million ℃** plasma demonstrates the steady progress

National Institute for Fusion Science Large Helical Device（LHD）



machine diameter: 13.5m
machine height: 9.1m
net weight: 1,500t
plasma volume: 30m^3

Features of Helical-type devices

- “Heliotron" configuration employed for LHD was invented and has been developed in Japan.
- “Steady-state operation” is intrinsically available.
- No plasma current is necessary.

Experimental achievements

- 2006: Highest beta value (plasma pressure) of 5%
- 2008: Highest density of 1.2x10^{21}/m^3 - *world record* -
- 2013: Long-pulse operation of 48 minutes - *world record* -
- 2017: Deuterium experiment started
  Identification of isotope effect
  - *first observation in helical devices* -
- 2018: Ion/electron temperatures of 120/64 million degrees
- 2019: Ion/electron temperatures of 80/150 million degrees
- 2020：Ion/electron temperatures of 120/94 million degrees,
  Ion/electron temperatures of 100/100 million degrees
- 2021: Nature Physics 1, Physical Review Letters 3

Japan's Policy on DEMO Reactor

The Science and Technology Committee on Fusion Energy of MEXT issued its strategies for the development of a DEMO reactor.

December 2017

- **Promotion of R&D for DEMO reactor**
- **Action Plan towards DEMO reactor**

July 2018

- **Roadmap toward DEMO reactor (first report)**

Phased Approach toward realizing of DEMO reactor

- ✓ Current : Pre-conceptual Design Phase
- ✓ **2021 : 1st Intermediate Check and Review (C&R)**
- ✓ Conceptual Design Phase
- ✓ Within a few years after 2025 : 2nd Intermediate C&R
- ✓ Engineering Design Phase
- ✓ In the 2030s : Final C&R
- ✓ Construction Phase

All-Japan framework for JA-DEMO

MEXT MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

Science and Technology Committee on Fusion Energy of MEXT

Discuss and decide the policy on fusion R&D, including Roadmap

Draw up/Formulate an Action Plan

Review

Task Force on JA-DEMO

- Grasp the situation of elemental technologies as a whole
- Optimize the overall strategy

Show the policy

Sharing information etc.

Propose/approve theme of joint research

JA-DEMO Concept Design

"Joint Special Design Team for Fusion DEMO" of Rokkasho Fusion Institute

- Plan and implement R&D to address issues
- Organize Workshops

QST, NIFS, Academia, Industry

Joint research toward JA-DEMO

WG for Joint Research

TF, QST, NIFS, Univ., Joint Special Design Team

- Close relations with universities to strengthen the JA-DEMO R&D framework
- Carry out joint research by universities
- Human resources development through research

Roadmap toward DEMO Reactor

Legend
- When to achieve the target
- Target to achieve
- When to decide transition to the next phase
- Figure of activities required

~2020~ | ~2025~ | ~2030~ | ~2035~ | ~2050~

1st Intermediate CR (CR1) | 2nd Intermediate CR (CR2) | Third phase | CR | Fourth phase

① ITER project (run by int'l collaboration)
- Construction phase
- First Plasma
- Plasma control test toward DT burning
- Operation phase
- DT burning and ignition
- Burn control & engineering test
- Long plasma burning at energy gain factor more than 10

BA activities (phase II) (run by int'l collaboration)

② JT-60SA (part of BA activities)
- Initial research phase
- Integrated research phase
- Extended research phase

⑨ 4th phase (DEMO) Decision to transition → Ready to commercialize

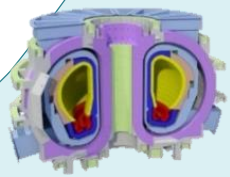
③ Fusion neutron source (run also thru int'l collaboration)
- First Plasma
- Technology demonstration & engineering design
- Construction
- Fusion neutron irradiation test
- Validation of steady-state operation
- Acquisition of irradiation data

④ JA-DEMO R&D (run also thru int'l collaboration)
- Concept design & elemental technology development
- Completion of engineering design based on prospective social acceptability & economic feasibility

Engineering design & full-scale technology development
(1) DEMO design activities
(e.g.: development test of full-scale superconductive coils, development of remote maintenance technologies for the DEMO, development of heating/current drive systems)
(2) Development of integrated plant simulator for JA-DEMO
(3) Safety research & tritium handling technologies
(e.g.: safety discussion including verification and validation (V&V), development of fuel system including technologies for handling a large amount of tritium)
(4) Reactor engineering and related foundation research
(e.g.: material development including design criteria, development of measurement/control units, divertor development including heat load test)

Construction & operation of JA-DEMO

Bird's-eye view by the Joint Special Design Team for Fusion DEMO



⑤ Blanket development
- Safety demonstration test
- Engineering test (test blanket module (TBM))
- Validation of tritium recycle

⑥ Research on Large Helical Device

⑦ Research on high-power lasers

Advancement from academic research to development research also anticipated

⑧ Social relations activities
- Social relations activities toward realization of the JA-DEMO

Structure of Check and Review

What/When is Check & Review?

To confirm the R&D progress as a guideline for R&D program toward the JA-DEMO design

When the basic conceptual design of JA-DEMO by the Joint Special Design Team is completed and the start of JT-60SA's operation is scheduled,

The 1st Intermediate CR (CR1)

Decide whether to start concept design and elemental technology development, based on the past achievements of BA and other activities.

Within a few years of ITER's First Plasma 2025 after completion of a conceptual design of the JA-DEMO reactor,

The 2nd Intermediate CR (CR2)

Establish the JA-DEMO concept and decide whether to start engineering design and full-scale technology development.

In the 2030s when ITER is expected to demonstrate DT burning,

Final CR

Make a decision on the construction of facilities for development tests of full-scale superconducting coils and facilities for developing remote maintenance technologies to be adopted for the JA-DEMO.

Science and Technology Committee on Fusion Energy of MEXT

Formulate Action Plan → Review and Follow-up of Action Plan

Task Force on JA-DEMO

Opinions from Industry

International Trend Analysis

Construction & Operation of JA-DEMO

Future Plans

■ **April 2022-**

Discussions on topics presented in CR1 in Committee and Taskforce

- Advancement of the date for the realization of fusion power generation
- Review the AP, CR and Roadmap toward DEMO Reactor etc.

The Government will formulate fusion strategy through the Integrated Innovation Strategy Promotion Council.

In this strategy, not only fusion research and development, but also the promotion of the fusion industry will be a point of discussion.