Nuclear Energy Status in Japan

INSC 2022 Workshop on national nuclear programs and nuclear societies

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PREMISE

- Japan lacking in natural resources, it emphasizes the effective use of nuclear fuels and minimizing HLW disposal. Then the nuclear fuel is regarded as domestic resources

- Fuel cycle closure with Fast Breeder Reactor **was** the long held dream of nuclear self-sufficiency and the mainline thrust in the past in Japan

- However, the Japan's breeder program has slowed down

- LWRs are the main stream of Japan's NE. The fuel cycle with MOX-LWRs is in pursuit of sustainable nuclear energy (NE) in Japan

METI Sixth Strategic Energy Plan, Oct 2021

Ambitious efforts toward innovation

Ambitious efforts toward innovation

Sixth Strategic Energy Plan by METI, October 22, 2021

Achieve the government's goal of a 46% reduction in GHG emissions over 2013 by FY2030:

- Renewable Energy share 36%-38%
- Nuclear share 20-22% (about 30GWe estimate)

R&Ds promoted in the plan

1. Hydrogen and ammonia
2. Technological development for reducing CO2
3. Practical application of innovation

METI: Ministry of Economy, Trade and Industry

ANRE: Agency for Narural Resources and Energy

H_2 as fuel …

NH_3 H_2 carrier as well as fuel

H_2 -- No brainer. Ex. TOYOTA's FCVs on the market

How do you produce H_2? Clean hydrogen or dirty hydrogen?

NH_3

- can efficiently transport and store hydrogen
- directly utilize ammonia as a fuel for thermal power generation facilities; demonstrated that co-firing with ammonia reduces CO_2 emissions.

Unlike H_2, the use of Ammonia allows the existing infrastructure as it is, for NH_3 production and transport, and is achieved at cheaper costs

METI Sixth Strategic Energy Plan, Oct 2021
Technological development in Japan for reducing CO_2

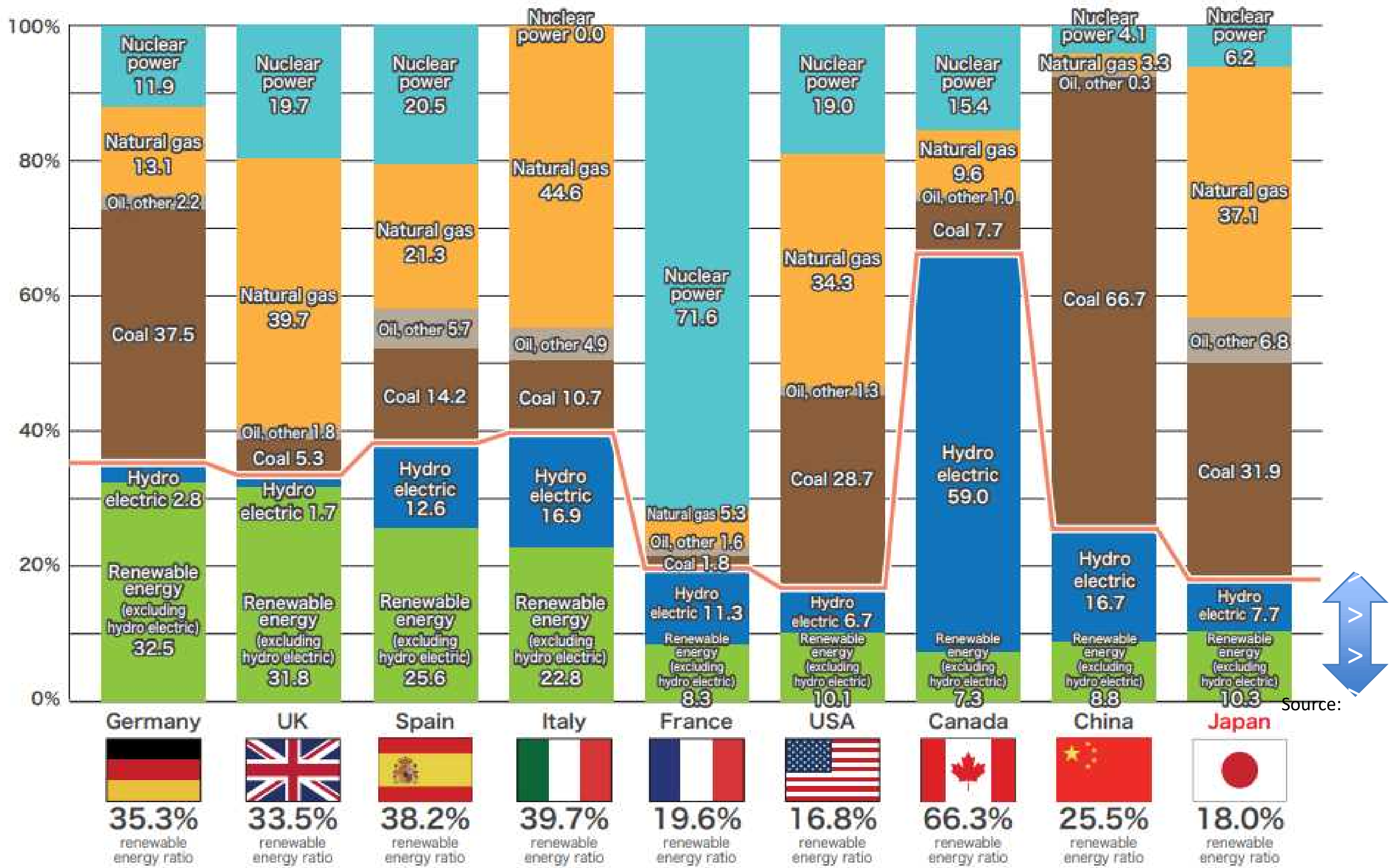
R&Ds to reduce CO_2 include:

- Carbon Recycling: separating and capturing CO_2 and utilizing it as a raw material resource in concrete, chemicals and fuels

- Photosynthesis technology R&Ds: with CO_2, attempts to produce chemical products by utilizing solar energy and CO_2

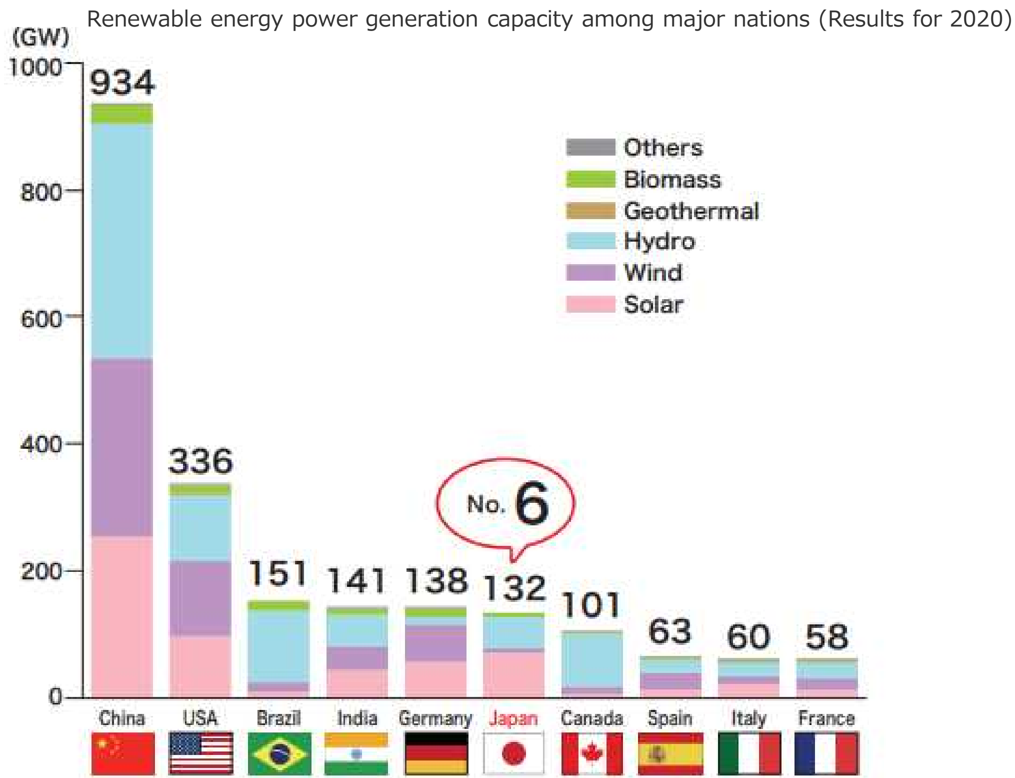
Expanding the use of renewable energy

Comparison of fractions of renewable energy in total power generation in major nations (Percentage of total generated power, 2021)



2021 – Understanding the Current Energy Situation in Japan (Part 2) METI/ANRE 2022.08.19

METI Sixth Strategic Energy Plan, Oct 2021
Renewable energy power generation capacity among major nations (2020)

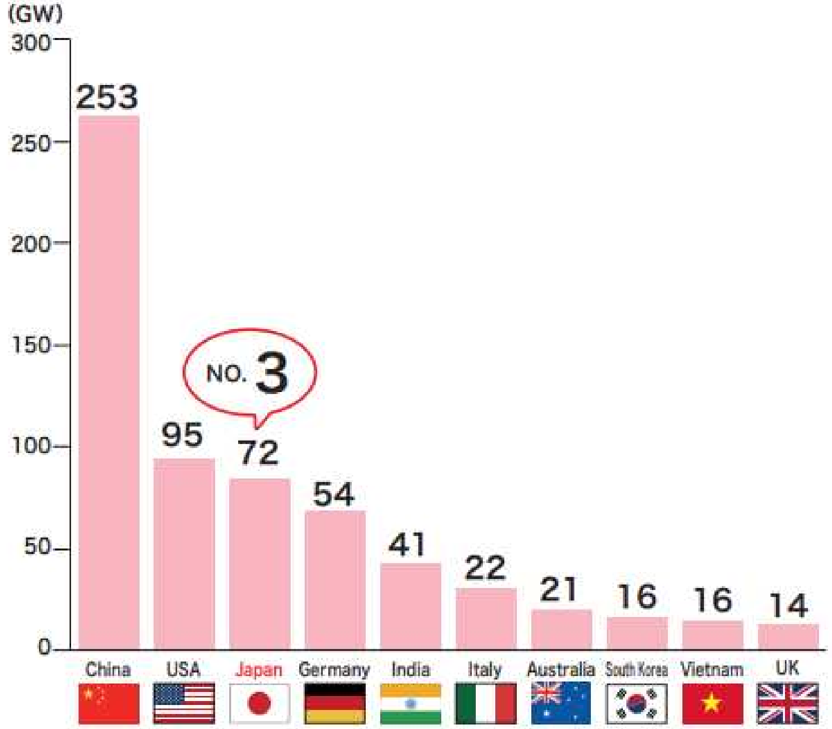


Source: Created by the Agency for Natural Resources and Energy based on the IEA "Renewables 2021"

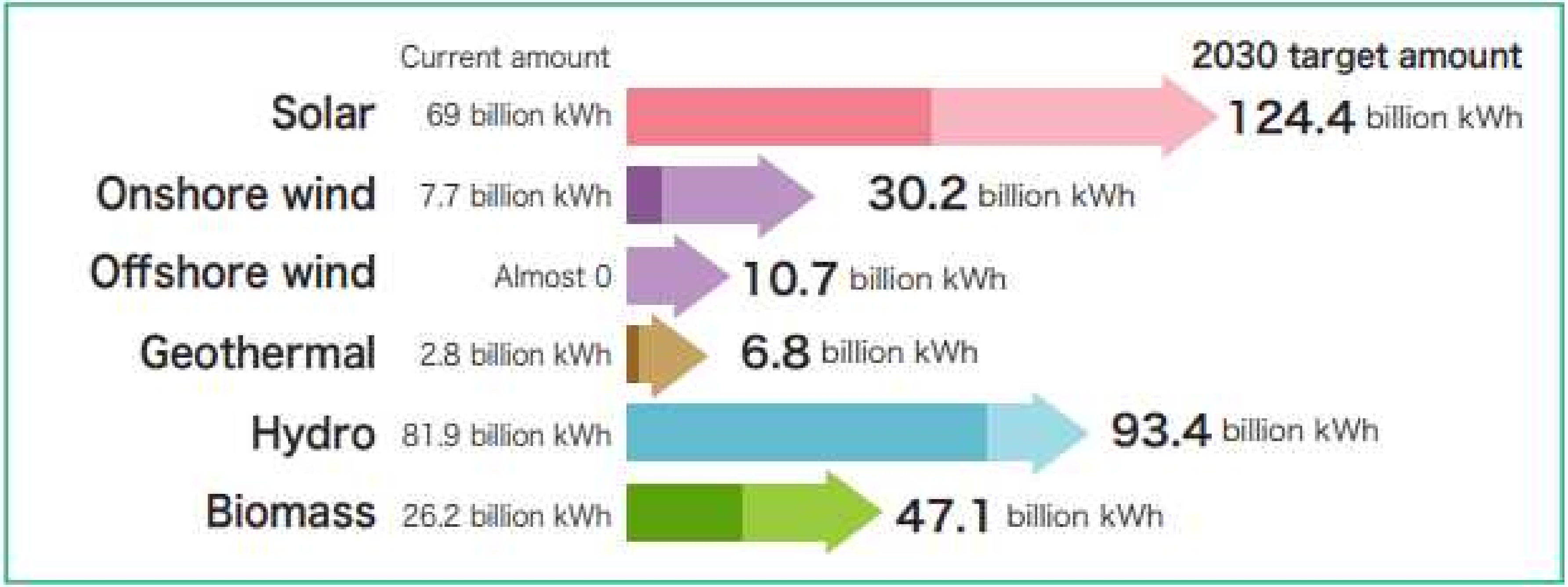
METI Sixth Strategic Energy Plan, Oct 2021

Solar power generation capacity among major nations (2020)

Solar power generation capacity among major nations (Results for 2020)



The target for the introduction of renewable energy in the Japanese energy mix for FY2020 to FY2030



Nuclear Enegy in Japan

History, current status and future

Benefits of nuclear to Japan since inception

Expansion and support of broad industry area

Reduction in GHG emission

Increase in energy self-sufficiency rate

(Ratio of the energy supplied by domestic natural resources to the total consumption)

- in 1960, 58.1% supplied by coal, hydropower, .. etc
- by 1970, decreased to 15.3% due to the fuel transition from coal to oil
- by 2010, increased to 20% due to the introduction of nuclear power generation
- however, since 2011 to 2020, decreased to 11.2% due to 1F NPS accident

Brief History and Current Status of nuclear Enegy in Japan

- Atoms for Peace 1953
- Starting from appropriation of the first national nuclear budget, 1954
- Atomic Energy Basic Act enacted 1955
- JAEC inaugurated 1956, first Long-Term Plan in 1956 provided the direction of nuclear development and deployment
  - R&D priority given to development of Breeder and Fuel cycle technology
  - Power generation by LWR technology, first imported from USA to start building NPPs in the nuclear inception era

1953 Atoms for Peace (Dec 8; Dwight Eisenhower at UN Gen Assembly)
1954 National Nuclear Budget passed in Japan
1955 Atomic Energy Basic Law; JAEC (**Japan Atomic Energy Commission**) established

General

■1956 1st Long term plan by JAEC
- ❖ Development of FBR (commercialization 1970~) and closed fuel cycle technology as national project
- ❖LWR technology, Import first from USA
- ❖1956 JAERI established
  - ❖ Fundamental R&Ds in universities, national institutes and JAERI
- ❖1963.10.26 JPDR (GE, nat circulation BWR, 12.5MWe) first electricity output (~1967); JPDR-II (~1976) SCC
- ❖1965 JAPC's **Calder Hall (Magnox Rx)** critical and March 1967,166MWe onto the commercial grid (~1997)

10 years later

- ❖1966 JAEC's decision on the rescheduling FBR deployment and introduction of **ATR**

■**1967 Long Term Plan (JAEC) Revised due to ATR introduction**

FBR-related

Fast Reactor Development Program

■1963 R&D Committee in JAERI on FBR development

■1964 Ad hoc committee in AEC

■1967.10 Established Power Reactor and Nuclear Fuel Development Corporation (PNC) aiming at development of LMFBR and fuel cycle technology from upstream to downstream

Revisions of 1956 1st Long term plan (JAEC)

- ❖ 1970's FBR commercialization target (according to 56 plan)
- 1967 Long Term Plan Revised: ATR introduction based on the 1966 decision
  - ❖ Late '70s Prototype FBR on criticality target
  - ❖ 80s Construct a first commercial FBR
- 1987 Long Term Plan Revised: LWR is selected as the main source of power for the foreseeable future
- 2000 Long Term Plan: maintain the technological option of FBR and its associated fuel cycle ......
- 2006 Framework of Nuclear Policy
  - ❖ **2030 40% by LWRs (2006 plan; expected)**
- 2010 More than 30% of electricity by nuclear power in Japan; 54 LWRs (30 BWRs and 24 PWRs)

Fast Reactor Development Policy Changes

- Before 1967 FBR R&Ds at JAERI
- 1967.10 PNC established (~1995); FBR R&Ds transferred from JAERI; Joyo design (1964-1967); Monju design (1967 – 1977)
- 1970 BWR (JAPC), PWR (KEPCO), BWR (TEPCO) followed by continuous growth of nuclear power by LWRs
- Exp Fast Rx Joyo on criticality achieved in 1977:
- Prototype FBR **Monju** on criticality achieved 1994
- 2020~2030 Commercialization (1987 JAEC plan)
  - 1995.12.08 Monju sodium leak event
  - JNC from 1998~
  - JAEA from 2005~
- 2030 or later Breeder Rx may be one of the future options (2000 JAEC plan)
- 2050 or later Commercialization (2006 JAEC)

Revisions of 1956 1st Long term plan (JAEC)

■2010 More than 30% of electricity by nuclear power in Japan; 54 LWRs (30 BWRs and 24 PWRs) + 2 under construction

■**2011.3.11 Tsunami attack on the TEPCO 1F NPS (Fukushima Dai-ichi Nuclear Power Station)**

■……… Arms of the clock have stopped since 2011.3.11 in Japan

■As of June 2018, 14 units approved for restart (9 units restarted); 12 units awaiting review by NRA; 11 units not filed;19 units to be decommissioned out of 54+2

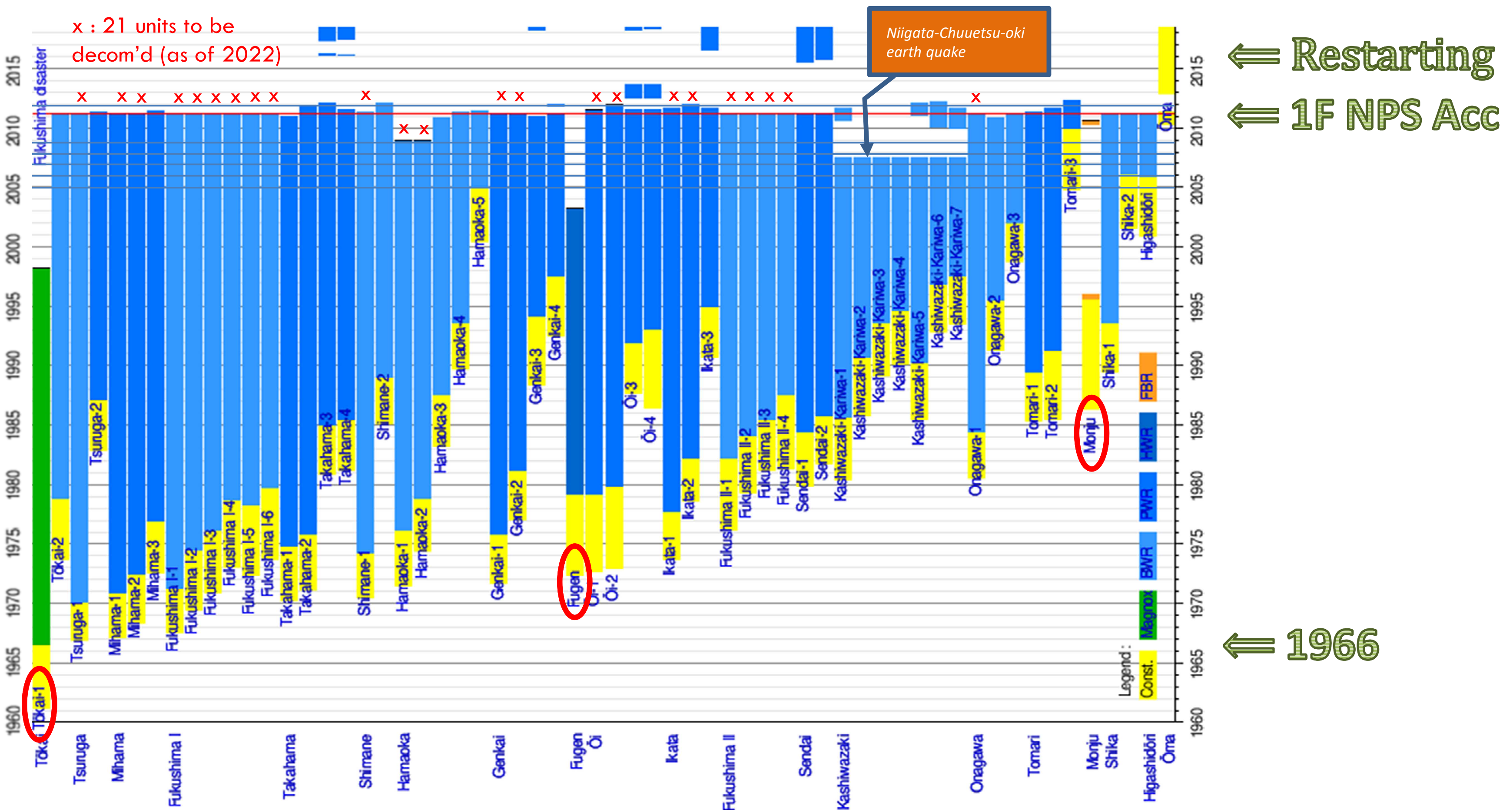
Fast Reactor Development Policy Changes

■2050 or later Commercialization (2006 JAEC)

■2016.12 Monju to be decommissioned

■2030 20~22 % by LWRs (Best Mix –)

■Arms of the clock have stopped since 2011.3.11 in Japan



In total, 57 power reactors were constructed in Japan:

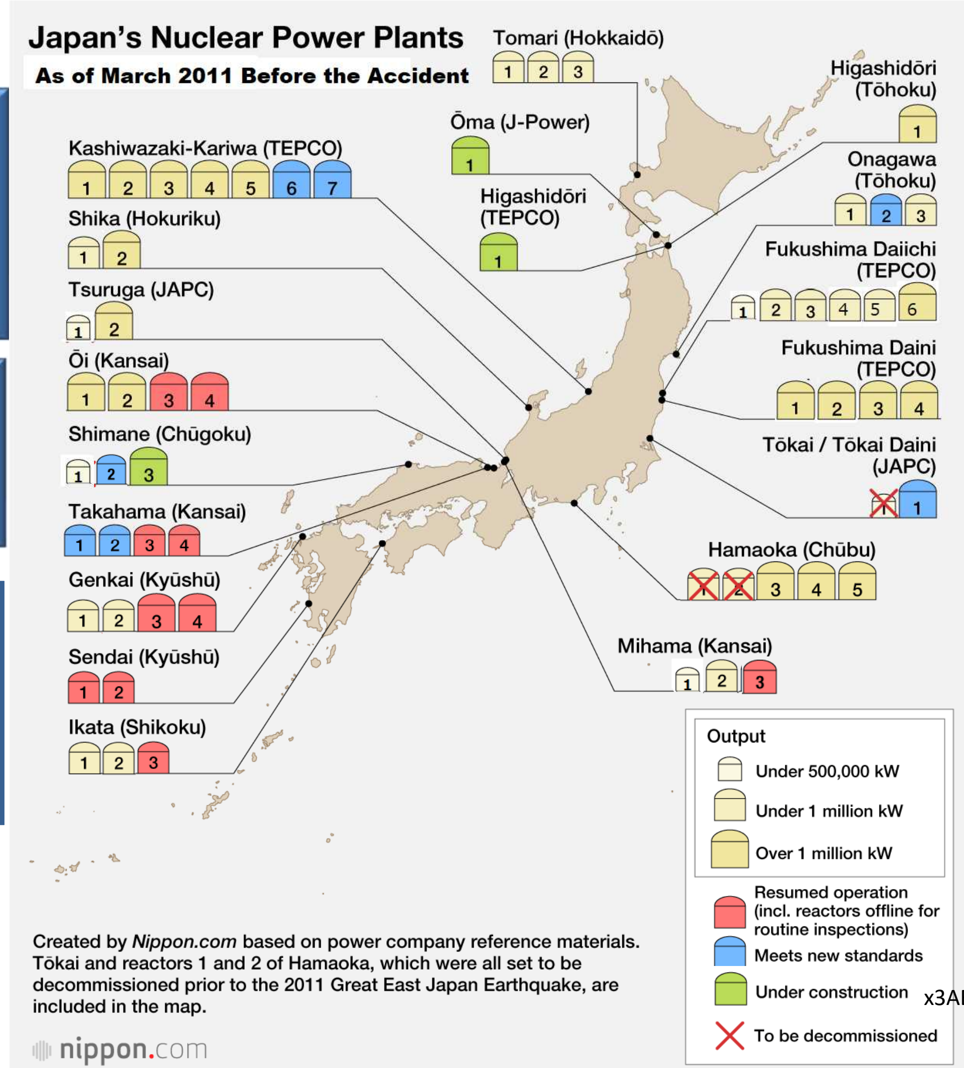
- 24 PWRs
- 32 BWRs (incl. Hamaoka 1 and 2)
- 1 GCR (Magnox)

In addition,

- ATR Fugen,
- LMFR: Experimental Fast Reactor JOYO and Prototype LMFBR Monju

Prior to the Great East Japan Earthquake of March/11/2011,

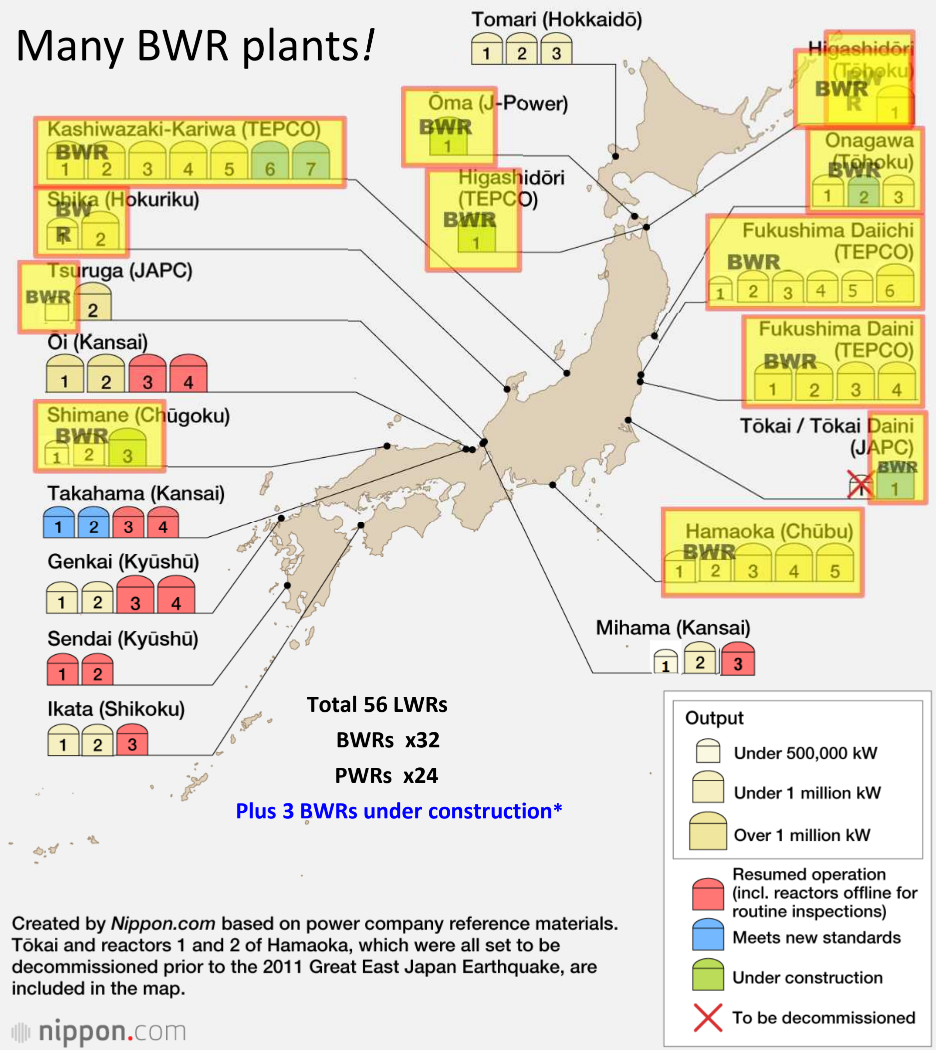
- 54 LWRs were under operation:
- 1/3 of electricity was nuclear origin in Japan



x3ABWRs

3 BWRs are under construction

Many BWR plants!



Total 56 LWRs

BWRs x32

PWRs x24

Plus 3 BWRs under construction*

***Plus 3 ABWRs**

1. **Shiimane #3 construction almost completed as of March 11, 2011**
2. **TEPCO Higashi Dohri #1 construction progress 10% (currently suspended)**
3. **Ohma #1 J-Power Full Mox ABWR 1 construction progress 37% (currently suspended)**

21 LWRs to decommission after the TEPCO Fukushima Daiichi NPS Accident (1F Accident)

+2 Hamaoka BWRs before the 1F Accident;

Experiences in decommissioning in Japan incl. JPDR, Tokai #1GCR, ATR Fugen

LWRs available for Power Generation after Fukushima Daiichi accident

PWRs available x16 units

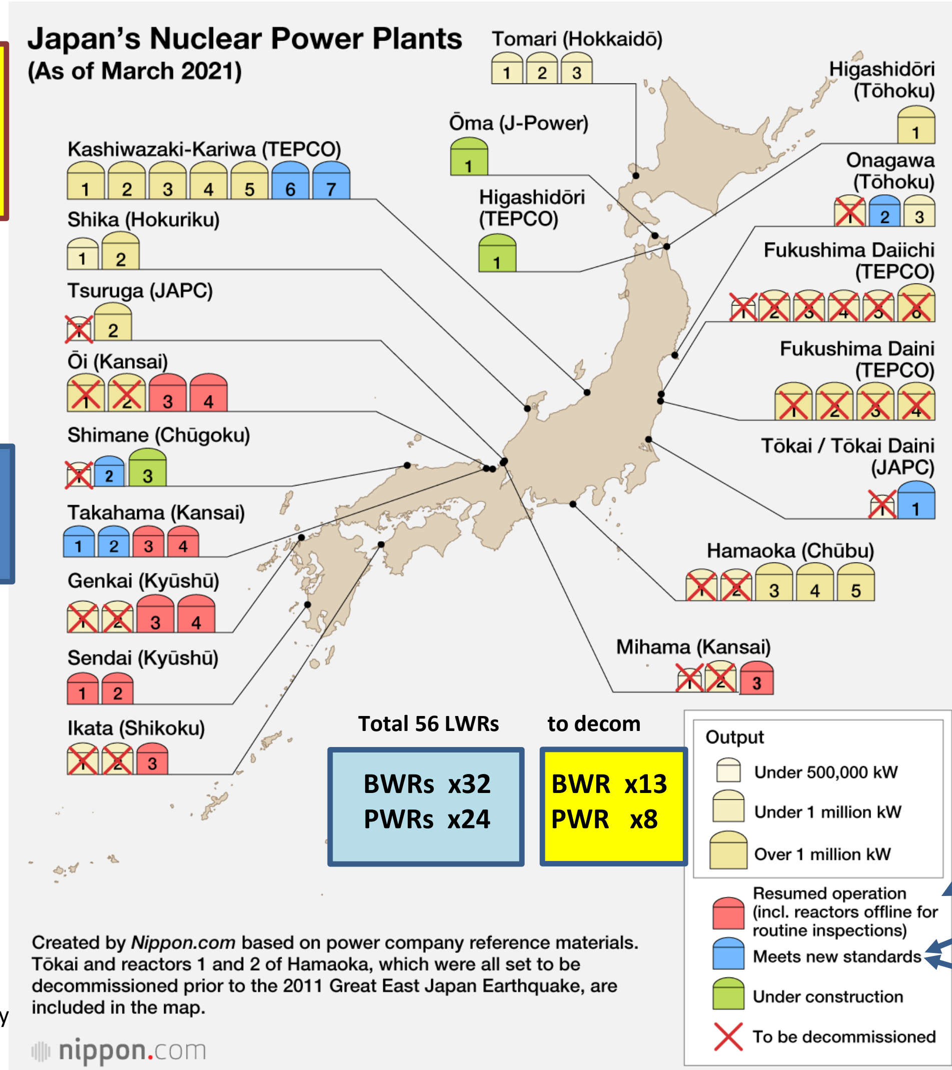
(**Operated x10** incl x1 life extension)

- Approved for installment license amendment (Life ext to 60yrs) x2
- Under review for new regulatory requirements x4

BWRs available x17 units (+ 3 units)

(32-2-13=17)

- Approved for installment license amendment x5
- Under review for new regulatory requirements X4
- To apply for license x8
- (2 ABWRs under construction +1 to apply for construction permit)



March/11 disaster at the TEPCO Fukushima Daiichi Nuclear Power Station (1F NPS):

- caused increased distrust and unease toward nuclear reactors and
- led to a drastic change in how nuclear energy (NE) is regarded.

X10 PWRs

X5 BWRs approved for restart

X6 PWRs to restart (incl. x2 PWRs Life Extension)

METI Nuclear Policy after the 1F NPS Accident - 1

Apr 2014 The Fourth Basic Energy Plan

- Published first from METI after the 1F NPS Accident:
- Nuclear power plants should be restarted as an important baseload power source
- The ratio of nuclear power in the energy mix in 2030 was set at **20% to 22%,** and this target has been maintained up to today

METI Nuclear Policy after the 1F NPS Accident -2

Oct 2021 the Sixth Strategic Energy Plan (METI)

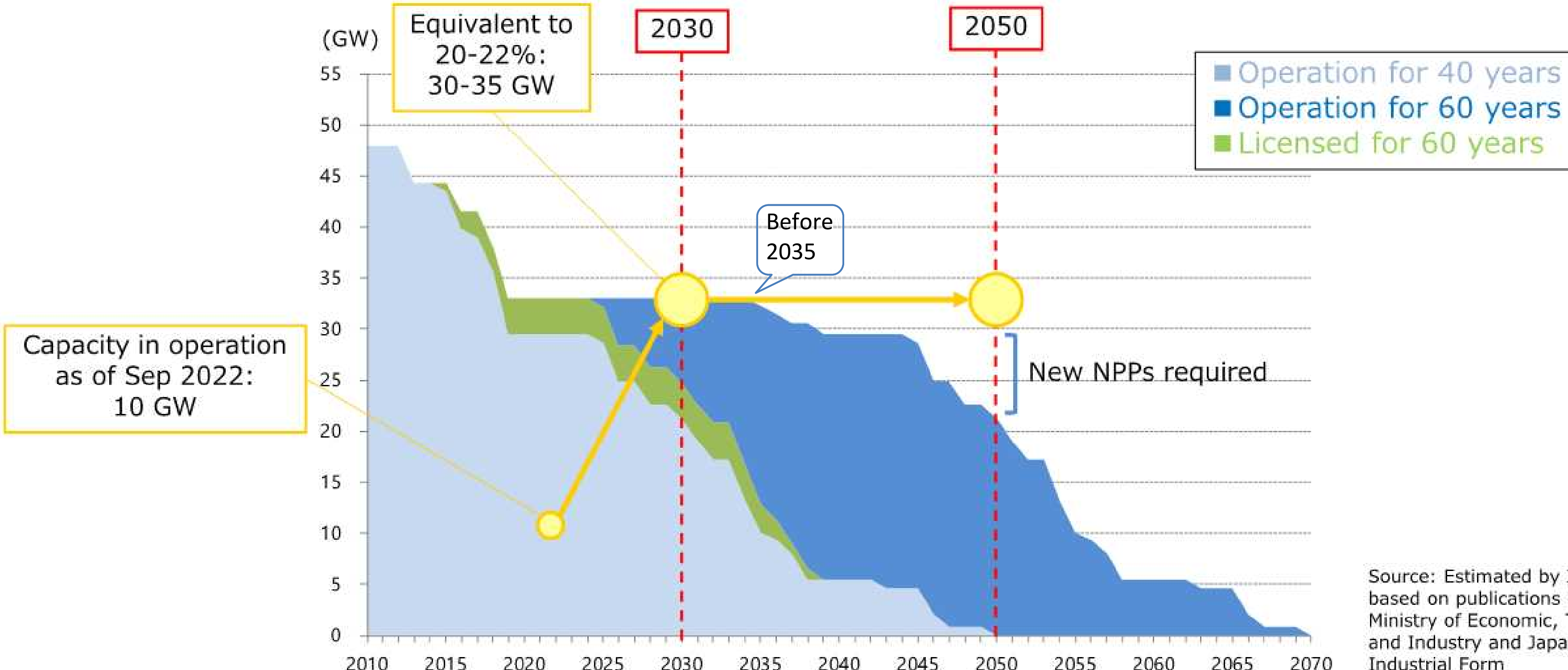
- the basic guideline for the government's medium- to long-term policy on energy supply and demand.
- The power generation mix in FY2030:
    - Nuclear share 20-22% (about 30GWe estimate),
    - Renewal Energy 36-38%,
    - Fossil fuels 41%, and
    - Hydrogen and ammonia 1%

Remarked "Put safety first, respect the judgment of the Nuclear Regulation Authority, and promote the restart of nuclear power plants"

Life extension is the key as well as restart

Presented by Kei Shimogori (The Institute of Energy Economics, Japan), Challenges and Prospects of Restart and Advanced Reactors in Japan, Innovation for Cool Earth Forum, 6 October 2022.

- Existing reactors: 33 units (Restarted: 10 units, Expected to restart after next summer: 7 units)
- 30 GW would be necessary to achieve 20-22% in 2030. Lifetime extension to 60 years is crucial, and new reactors are also necessary to keep the same capacity level in 2050.



Source: Estimated by IEEJ based on publications by Ministry of Economic, Trade and Industry and Japan Atomic Industrial Form

- Needs not only the life extension (40 years to 60 years) but also new build necessary to meet the 30GWe requirement after 2035 -
- R&Ds and build New adv LWRs from MHI, GE-HITACHI, Toshiba, IHI, ..

- SMRs (Vendors)

Also non-LWRs

- FRs (PNC to JAEA)
- HTR HTTR (JAERI to JAEA) to demonstration

New Designs

MHI SRZ-1200

- R&D/Dessin/Build by mid-2030 – aiming at renewal of old NPPs
- Design featured - based on Japanese regulatory safety standards (after 1F accident)
    - ***Natural disaster resistance***
    - ***Security against terrorism and unforeseen events***
        - advanced accumulator design;
        - effectively reduce the probability of radioactive release in the event of an accident

GE-Hitachi BWRX-300 SMR

- the Darlington SMR Project (~2028)
- Scaled from the licensed ESBWR design •
- Mitigates large LOCAs •
- 7 days of passive standby cooling

PRISM

NATRIUM w. TerraPower 345MWe

Toshiba iB1350

- An innovative, large capacity and safety reactor: iB1350

Small Fast Rx: **4S**
Very Small Rx: **MoveluX**
High temp Gas Rx: **HTGR**

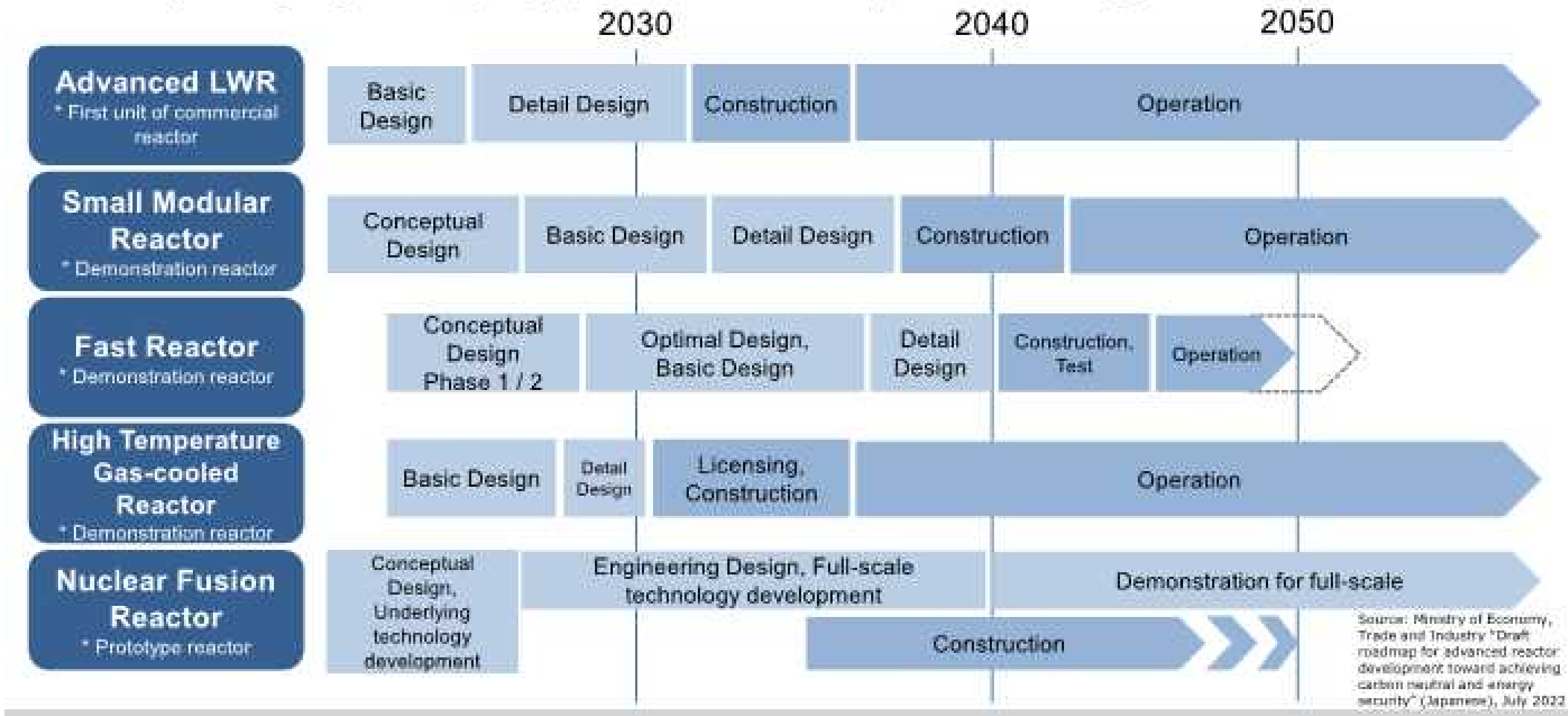
IHI with **Nuscale,**

Pictures

Roadmap for Advanced Reactor Development (METI, Draft outline, Julay 2022)

Source: Presentation at ICEF, 6 Oct. 2022, Kei Shimogori, IEE

- Identified the timeline and milestones toward 2050 based on technology readiness, corresponding regulations, supply chain, marketability, and non-energy utilization.



Nuclear fuel cycle

Nuclear Fuel Cycle System

The establishment of nuclear fuel cycle system from LWR-LMFBR to FBR-fuel recycling was the main line stream of resource-poor Japan's energy policy:

Essential key components:

LMFBR Monju and

Rokkasho Reprocessing Plant (RPP)

before the Fukushima Daiichi NPS Accident (1F Accident)

However, only a limited number of reactors in Japan have been restarted which can load MOX in the core – PWRs in Kyushu and Shikoku

Pu stockpile in Japan gradually is building up

In addition, the decision was made to terminate the Monju project (Dec 2016)

→ the use of MOX in conventional commercial reactors: a pillar of the nuclear energy policy in Japan

Is pursuit of Fuel Cycle Closure a dream?

Inefficient Pu incineration in LWR is the only way to reduce Pu stock in Japan

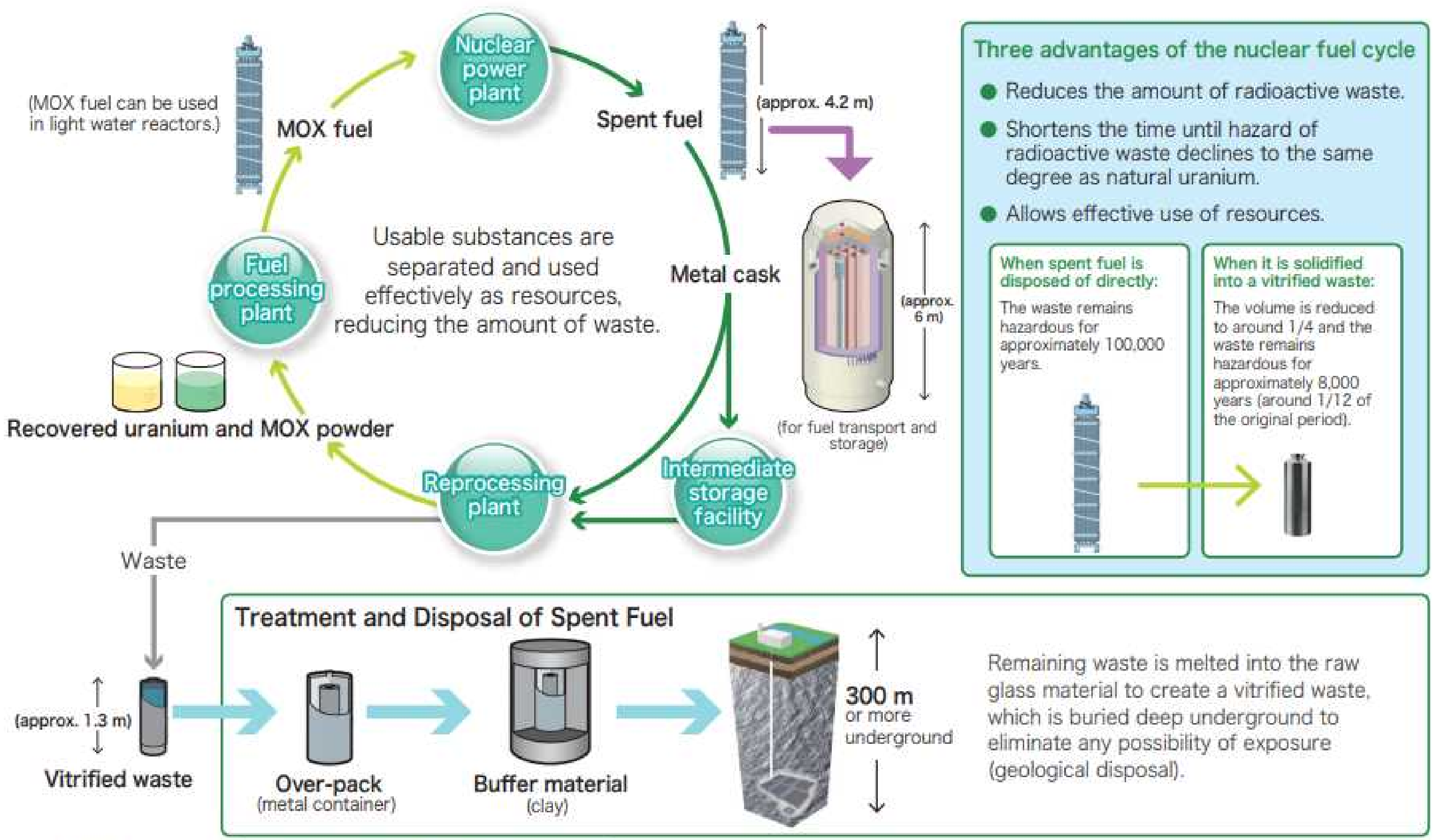
- Partially MOX loaded 16~18 LWR units could burn a total of **5.5 ~ 6.5 ton/y**; Full MOX 1.1 ton/y
- Monju (714 MWth) LMFBR: **0.5 ton/y**; Joyo (125MWth): **0.1 ton/y**

Troublesome Rokkasho Nuclear Fuel Reprocessing Plant:

- Being constructed by Japan Nuclear Fuel Limited (JNFL)
- An annual capacity of 800 tons of U or 8 tons of Pu.
- Not complete yet: the completion expected in 1997, starting its construction 1993, the completion date has been postponed 23 times by 2017 due to technical/socio/political problems

Source: Presentation at ICEF, 6 Oct. 2022, Reiko Fujita, Toshiba

The nuclear fuel cycle and geological disposal

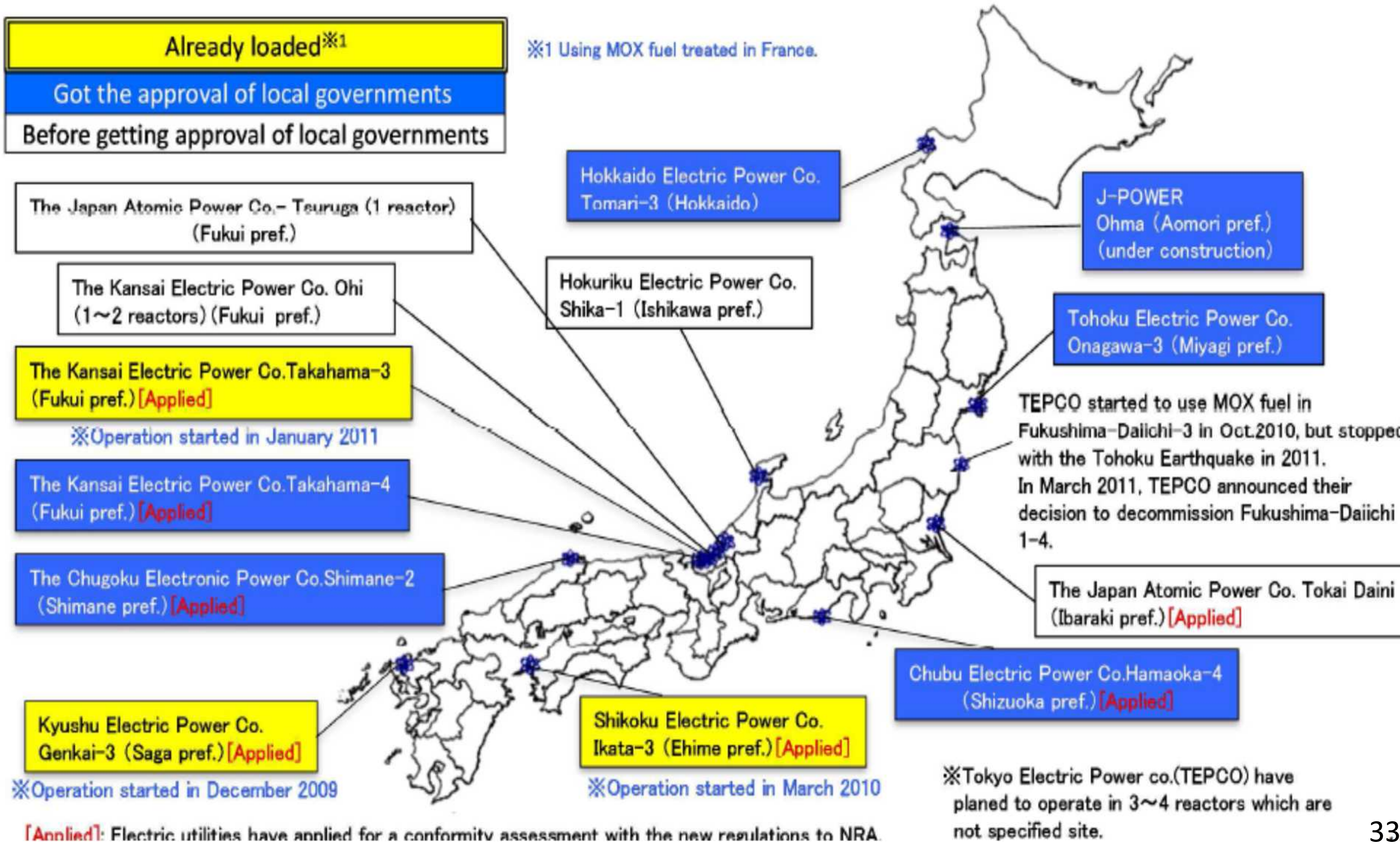


MOX: Mixed Oxide (Mixture of Uranium oxide and Plutonium oxide)

Fuel assembly and metal cask: "Graphical Flip-chart of Nuclear & Energy Related Topics", Japan Atomic Energy Relations Organization

The troublesome Nuclear Fuel Reprocessing Plant in Rokkasho, Aomori Prefecture

MOX fuel loaded NPPs in Japan



Nuclear Regulatory in Japan, Briefly

- Nuclear Safety Commission from 1978 to 2012 within the cabinet, was to plan, deliberate on and determine the matters related to nuclear safety administration, e.g., by reviewing safety inspections conducted by regulatory agencies:
  - NISA Nuclear and Industrial Safety Agency (2001-) oversite branch of Agency for Natural Resource and Energy /METI
  - JNES Japan Nuclear Energy Safety Organization (2003-2014) to strengthen the safety regulation performances for NSC and merged into NRA

Lessons learned from the 1F NPS Accident: Regulations be totally independent and neutral based on the expert knowledge

- Nuclear Regulatory Authority since 2012
- the Nuclear Reactor Regulations Act was revised June 2012 and July 2013 in force:
  - Strengthen the measures against severe accidents caused by
    - SBO
    - Terrorism
    - Missile attacks
  - e.g., Filtered vent system, back ups with multiplicity, diversity and independency
  - Strictly the back-fit system introduced, …

Recent Public Opinions

2010, 77% affirmative/in favor of nuclear power generation.

November 2011, immediately after the accident, 38% affirmative to the need for nuclear power generation, otherwise negative

October 2021, 7.5% of the respondents wanted the immediate close-down of all the NPPs, and 53% wanted a phased-withdrawal from nuclear power generation.

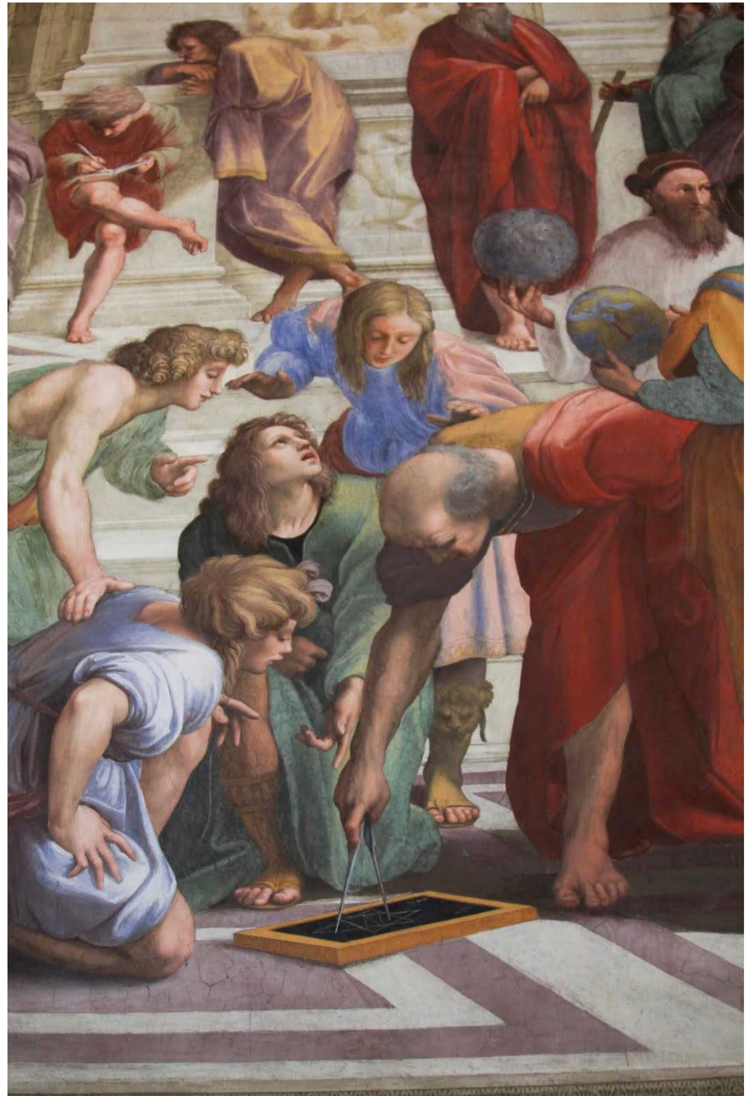
Nikkei opinion poll one year later: in response to the unstable energy situation and to the government policy statement:

Aug. 1, 2022, 70% in favor of NPPs to restart/operate,
22% no nuclear power

Sep. 19, 2022 on construction of new plants,
53% of the respondents in favor and
38% not in favor.

In the summer 2022, reflecting the unstable global energy situation, the government of Japan has started considering development and construction of **the next generation innovative reactors** incorporating new safety mechanisms, as well as maximizing the use of existing nuclear power plants by restarting idled nuclear reactors and extending their life.

Thanks for your attention



Raphael's "School of Athens" fresco