23 December 2019
The 434th Forum on Research Works

Outlook and Challenges for Nuclear Power Generation in 2020

The Institute of Energy Economics, Japan

Nuclear Energy Group, Strategy Research Unit

Tomoko Murakami

Points of the Report

1. Japan

- ✓ Between 2020 - 2021 there is a possibility that the nine restarted nuclear power plants that have received safety approval may have their planned suspension periods extended.
- ✓ This is with the assumption that during FY 2020, a further four plants will be restarted.
- ✓ Costs associated with safety measures exceeded a grand total of 3 trillion yen as of 2018, with 11 to be decommissioned.

→ Improvements to the efficiency of reviews and their predictability are also important

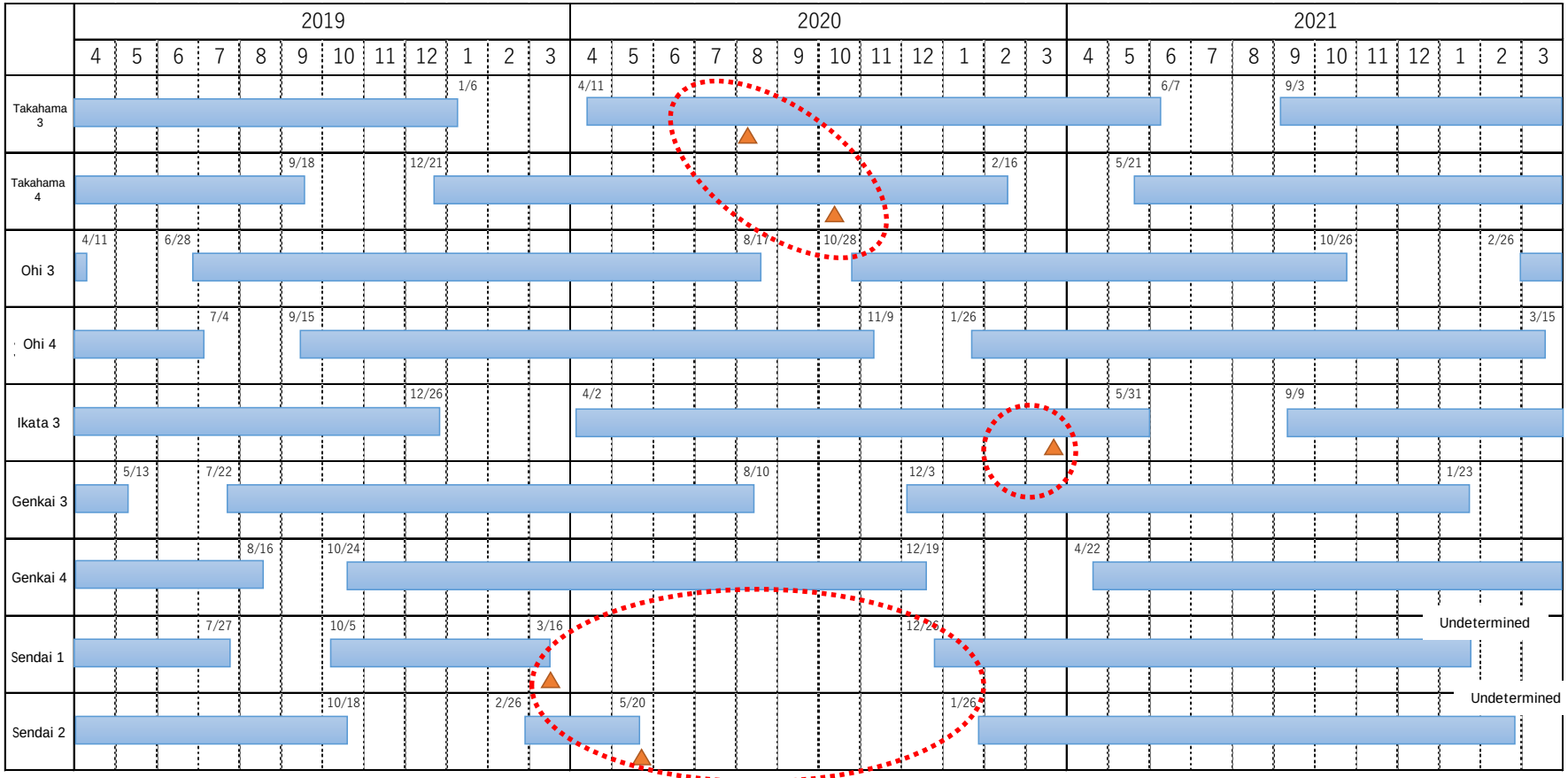
2. World

- ✓ China and Russia, which respectively have the third and fifth highest worldwide capacity, are expected to further expand their presence.
- ✓ All countries that have newly introduced nuclear power since 2000 have been developing nations. Will they be exporters some day?
- ✓ Plans in developed nations are facing an uphill battle. Hitachi was unable to resolve the risks it faced and has abandoned its UK plans.
- ✓ Without determining the causes of cost overruns, vendors in developed nations will not be able to create a market amongst developed nations.

1-1. Outlook for Operations from 2020 (For the Nine Operating Plants)

- The NRA has determined that it will not allow plants to operate that have failed to complete construction relating to Special Safety Facilities* by the extension period of April/May 2019.
- During FY 2020 - 2021, Sendai units 1/2 will see their planned suspension periods being extended

(*) Facilities required to introduce countermeasures for specified major accidents



Source: Produced from business plans provided by electric companies

1-2. Outlook for Reactor Restarts (Safety Design/Lifetime Extension Approval: 6 Plants)

- Units 6/7 at Kashiwazaki-Kariwa received design approval approximately two years ago.
- The four plants which received lifetime extension approval have also received permission for construction, which is now underway.

Unit	Date of Application for Safety Review	Permission to Change Safety Design	Lead Time (Days)	Hearings* from Operators (Apr. 2018 onwards)
Kashiwazaki-Kariwa 6/7	9/27/2013	12/27/2017	1,552	646(0)

Unit	Lifetime Extension Approval Application Date	Lifetime Extension Approval	Lead Time (Days)	Number of Hearings from Operators
Takahama 1/2	3/17/2015	6/20/2016	461	233
Mihama 3	3/17/2015	11/16/2016	610	201
Tokai Daini	11/24/2017	11/7/2018	348	1,322

- For the nine restarted plants, the average lead time between having draft reviews accepted and beginning to generate power was approximately 1 year and 5 months

What about the future?

Period	Average No. of Days for Nine Plants
Draft Review Accepted - Permission to Change Safety Design	67
Permission to Change Safety Design - Construction Plan Accepted	195
Construction Plan Accepted - Generating Power	244
Draft Review Accepted - Generating Power	**505**

*Hearings from Operators
Hearings from operators are meetings between Nuclear Regulation Authority officials and business operators regarding technical matters. These are performed prior to examination meetings, which are held with participation from NRA commissioners.

1-3. Status of Plants Under Review (10 Plants)

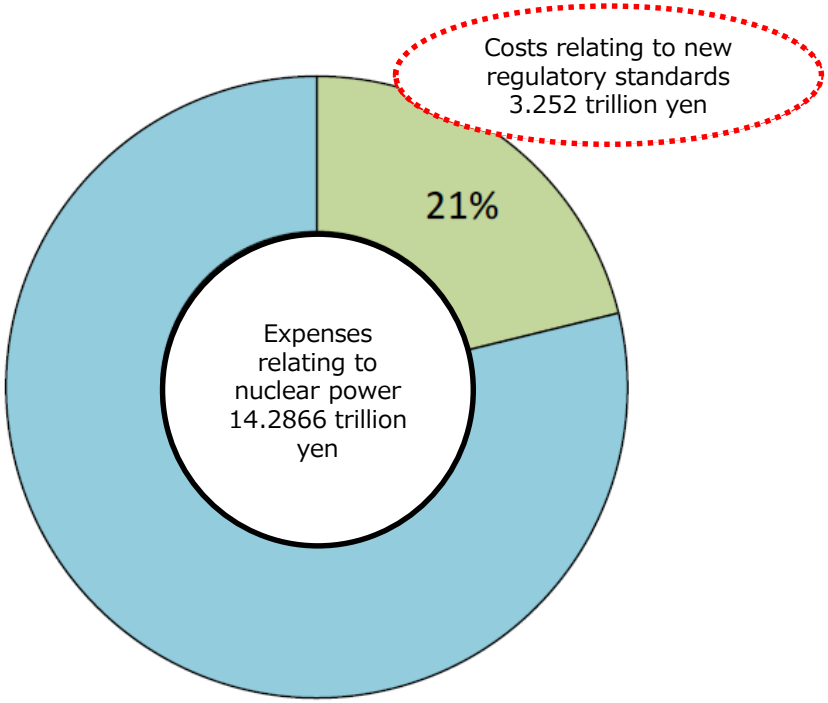
- In the seven years since these reviews began being performed, their efficiency has not improved, so it isn't possible to predict when they will be completed.
- Four years have already passed since the latest applications for review. When will the next one be?

Unit	Application for Safety Review	Number of Hearings from Operators (Sept. 2018 onwards)
Tomari 3	7/8/2013	375(1)
Shimane 2	12/25/2013	267(161)
Onagawa 2*	12/27/2013	476(160)
Hamaoka 4	2/14/2014	191(4)
Higashidori 1	6/10/2014	29(4)
Tomari 1/2	7/8/2013	51(1)
Shika 2	8/12/2014	15(4)
Hamaoka 3	6/16/2015	5(4)
Tsuruga 2	11/5/2015	-
Ohma (new)	12/16/2014	5(4)
Shimane 3 (new)	8/10/2018	4(3)

* Draft review accepted on Nov. 27, 2019

1-4. Costs for Meeting New Standards

- Between FY 2011 - 2018, total expenditure associated with meeting these new regulatory standards totaled 3,025.2 billion yen
- The average cost for the 27 plants which had applied for safety reviews relating to the new regulatory standards was 112 billion yen/plant.
- Final investment figures are still undetermined. Estimates differ depending on conditions.



Source: Japan Atomic Industrial Forum “Nuclear Industry Trends Report 2019 (Fiscal 2018)”

Will plants that are unable to recover this investment be decommissioned?

1-5. Decisions to Decommission: 11 Plants Since March 2015

- Major reasons include uncertainties about recovery of investment in additional equipment over a long term and supply capacity.
- Another reason may be that while one plant is under review for lifetime extension, other plants' review is stalled.

Date	Electric Power Company	Unit	Reasons for Decommissioning (From Company Press Releases)
2015/3/17	Japan Atomic Power	Tsuruga 1	Massive unanticipated additional investment in facilities and long-term construction will be required.
2015/3/17	Kansai	Mihama 1/2	Supply capacity, technological establishment of various safety measures, construction costs, operational periods and other factors were considered.
2015/3/18	Kyushu	Genkai 1	Issues relating to recovering additional investment during the plant's remaining operational period after additional large-scale construction for safety measures.
2015/3/18	Chugoku	Shimane 1	Long-term, massive investment in safety measures required, future electricity demand, supply capacity and other factors were comprehensively considered.
2016/3/25	Shikoku	Ikata 1	Supply capacity, technological establishment of various safety measures, relevant costs and other factors were comprehensively considered.
2017/12/22	Kansai	Ohi 1/2	Additional equipment for the small containment vessel will reduce operationality.
2018/3/27	Shikoku	Ikata 2	Large-scale, long-term seismic retrofitting construction, the operational period after a restart, capacity and other factors were considered.
2018/10/25	Tohoku	Onagawa 1	Capacity, the operational period after a restart and other factors were comprehensively considered.
2019/2/13	Kyushu	Genkai 2	Space restrictions, capacity, remaining operational period after a restart and other factors were comprehensively considered.

2015/3/17
Kansai
Mihama 3/Takahama 1/2
Application for lifetime extension approval

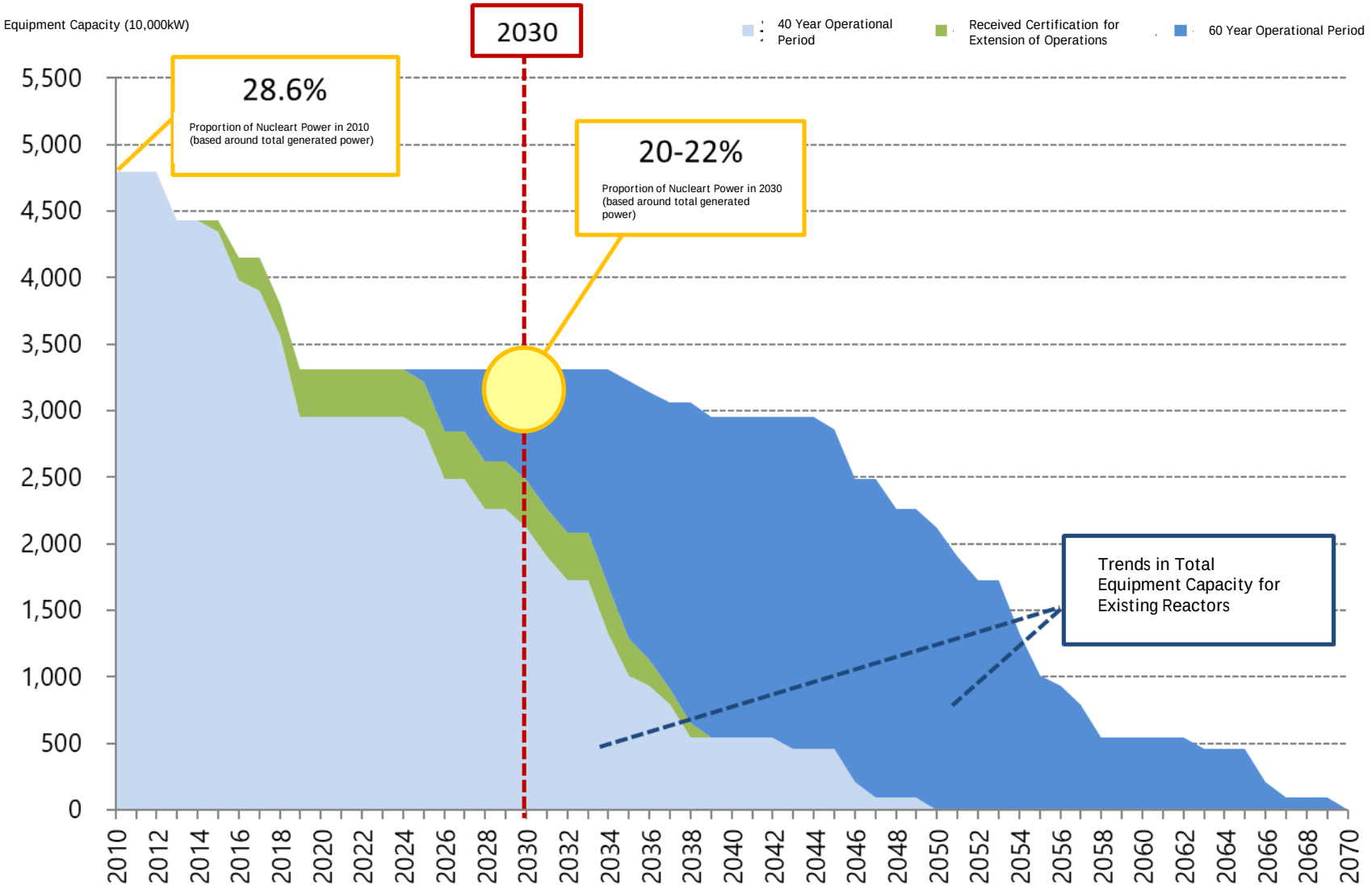
2016/5/20
Kansai Takahama 1/2
Acquired approval for lifetime extension

2016/11/16
Kansai Mihama 3
Acquired approval for lifetime extension

2017/11/24
Japan Atomic Power Tokai Daini
Application for lifetime extension approval

2018/11/7
Japan Atomic Power Tokai Daini
Acquired approval for lifetime extension

1-6. Possibility of Achieving Energy Mix Targets



2-1. Per-Country Worldwide Ranking 2010 → 2019

- Nuclear power generation is being used in 31 countries around the world, with the top three countries providing around half of the world's capacity.
- More than 3/4 of countries have never considered using nuclear power

→ A source of electricity that is different from coal and gas due to its oligopolization.

Jan. 2010 → Jan. 2019

	Country	During Operation Output (10,000 kW)	During Operation No. of Plants	Built Output (10,000 kW)	Built No. of Plants	Planned Output (10,000 kW)	Planned No. of Plants
1	America	10,534	104	Output	1,060		9
2	France	6,602	59		163		1
3	Japan	4,885	54		1,959		15
4	Russia	2,319	27		1,640		17
5	Germany	2,151	17		0		0
6	Korea	1,772	20		960		8
7	Ukraine	1,382	15		200		2
8	Canada	1,328	18		0		0
9	UK	1,195	19		0		0
10	Sweden	938	10		0		0
11	China	912	11		3,847		36
12	Spain	773	8		0		0
	Other	4,124	70		4,146		52
Total		38,916	432		13,974		140

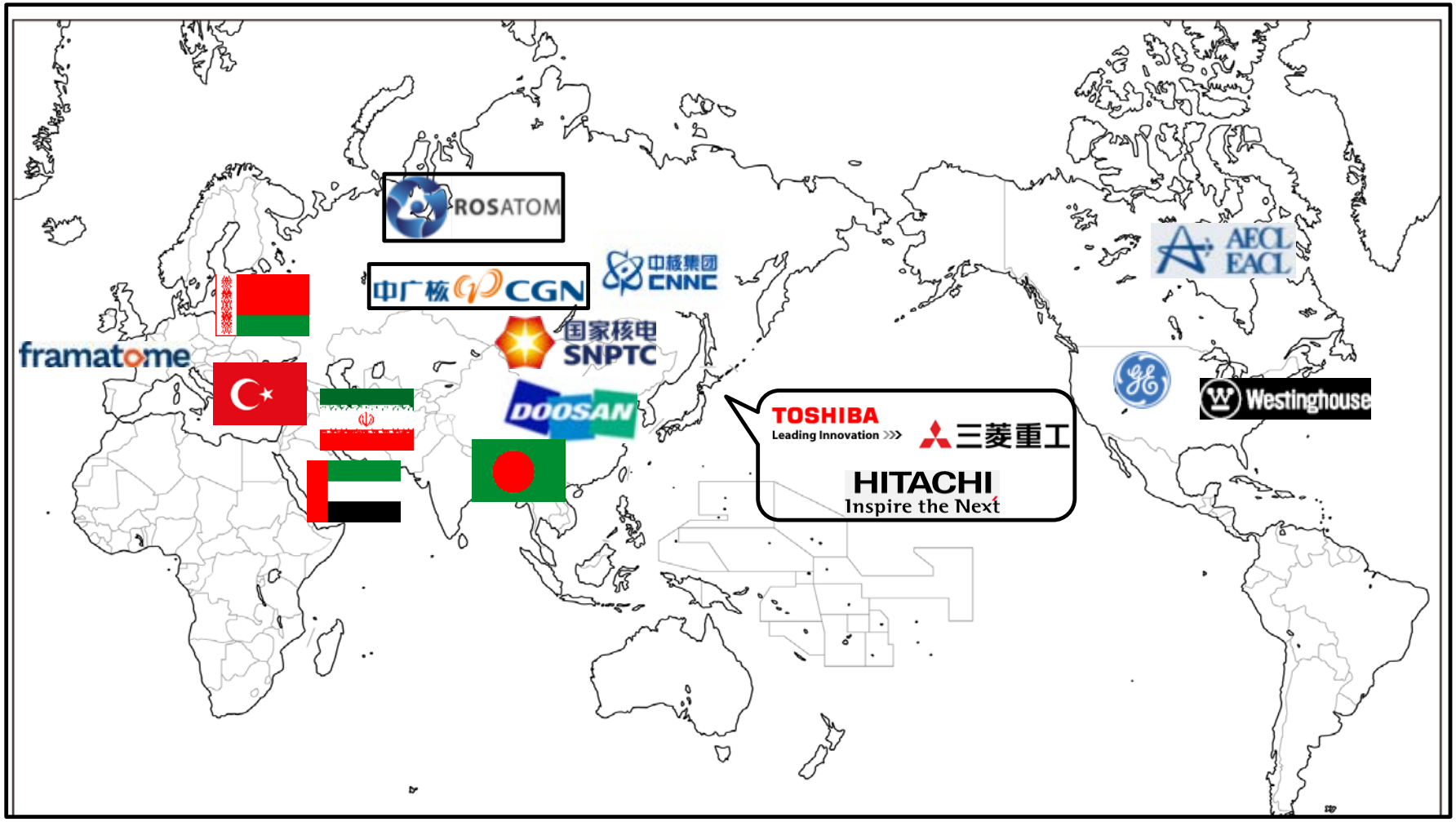
	Country	During Operation Output (10,000 kW)	During Operation No. of Plants	Built Output (10,000 kW)	Built No. of Plants	Planned Output (10,000 kW)	Planned No. of Plants
1	America	▼ 10,306	98		346		3
2	France		6,588	58		163	1
3	China	▲ 4,464	44		3,983		38
4	Japan	▼ 3,804	38		1,572		11
5	Russia	▲ 2,906	32		2,194		22
6	Korea	▲ 2,270	24		700		5
7	Canada	▲ 1,452	19		0		0
8	Ukraine		1,382	15		200	2
9	UK	▼ 1,036	15		344		2
10	Germany	▼ 1,001	7		0		0
11	Sweden	▼ 862	8		0		0
12	Spain	▼ 740	7		0		0
	Other		4,635	78		6,181	59
Total			41,445	443		15,684	143
	▲ Increasing Trend	▼ Decreasing Trend					

Source: "World nuclear power plants 2019", JAIF

WORLDWIDE TRENDS ARE NOT SHOWING A SHIFT AWAY FROM NUCLEAR

2-2. Countries (Businesses) Exporting and Importing Nuclear Power Technologies

- All countries that have newly introduced nuclear reactors since 2000 have been developing nations. Will exporting countries export to non-OECD countries?



2-3. China: International Expansion to Developing Nations and the UK

- China made use of technologies from France, the US, Russia, and Japan before beginning to produce their own power plants. Since 2000, the country has had the world's fastest mass production.
- China began participating in the market for developed nations in 2015, making approaches to both the UK and France. It is now competing with other manufacturers in developed nations.

Date	Event
2017/1/19	The UK Office of Nuclear Regulation (ONR) launches a generic design assessment of the Chinese HPR1000 reactor (same as a Hualong-1)
2017/3/22	The China General Nuclear Power Group (CGN) signs an agreement with Kenya's Nuclear Electricity Board regarding cooperation for human resource development and other areas related to Kenya's introduction of nuclear power generation.
2017/5/17	China National Nuclear Corporation (CNNC) signs a turnkey contract with Argentina's Nucleoelectrica Argentina S.A. (NA-SA) on the construction of a pressurized heavy-water reactor (to be Argentina's fourth nuclear power plant) and its first pressurized-water reactor (to be its fifth).
2017/11/16	The general design assessment of the Chinese Hualong-1 (HPR1000) reactor in the United Kingdom enters the second phase.
2018/8/9	The State Council announces a policy of establishing China's own nuclear reactor standards as international standards, seeking to make China a nuclear power plant standards power by 2027.
2019/5/8	The Romanian state-owned nuclear power company Nuclearelectrica (SNN) and CGN enter into a provisional investment agreement regarding suspended construction work on Cernavoda units 3/4.
2019/6/18	Containment vessel dome roof installed at Karachi unit 2 which is under construction in Pakistan. The installation consists of the first ever exported Hualong-1 unit.
2019/8/20	CNNC bids for the new power plant construction project in Belene, Bulgaria.

Nuclear plant exports are a key component of China's Belt & Road international expansion initiative.

2-4. Russia's international expansion: Eying regions that developed nations will not expand into

- Russia is one of the global leaders in nuclear power reactor and nuclear fuel cycle technologies. In particular, Russia accounts for half the global uranium enrichment capacity. Additionally, it owns and operates the International Uranium Enrichment Center in Angarsk (an IAEA certified international uranium storage bank).
- Russia's primary nuclear technology export destinations are Commonwealth of Independent States members and Eastern Europe. In recent years, Russia has expanded into the Middle East, Africa and South America as well.

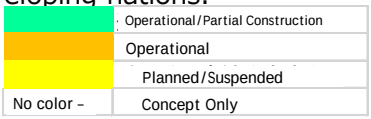
Date	Event
2017/11/30	Construction begins on the Rooppur 1 reactor in Bangladesh.
2017/12/11	Rosatom signs a contract with the Egyptian government to construct the El Dabbaa nuclear power station, the first of its kind in the country.
2018/4/3	Construction is launched for the first reactor of Turkey's Akkuyub nuclear power station in the presence of Presidents Recep Tayyip Erdogan of Turkey and Vladimir Putin of Russia.
2018/6/22	Russia and Rwanda agree on a memorandum of cooperation regarding the peaceful use of nuclear technology.
2018/7/17	Construction begins on the Rooppur 2 reactor in Bangladesh.
2019/5/17	An agreement is entered into with the Uzbekistan government for construction surveys at a planned nuclear construction site in the southwestern part of the country.
2019/6/11	Rosatom Overseas Branch established in Riyadh, Saudi Arabia.
2019/8/20	Rosatom bids for the new power plant construction project in Belene, Bulgaria.
2019/9/7	Rosatom receives permission from the regulatory body to begin full-scale construction of Akkuyu unit 2 in Turkey.
2019/10/24	Discussions on nuclear cooperation with African countries such as Ethiopia are held at the Russia-Africa Economic Forum & Summit.

Comparing Russia's "Graded Approach" and BOO approach (which are easily accepted by developing nations) to Japan's "world-leading safety levels"

*Graded Approach: A method of introducing technology in stages, depending on the status of the country in question.
*BOO: "Build, Own, Operate"

2-5. Plant Vendor Competition/Cooperation Map

- There is currently competition for large-scale reactors in developed nations, and medium-scale reactors in developing nations.
- Except for Korea, almost all of the countries that have begun operations since 2010 have been non-OECD.



	China (CNNC/CGN)	EDF/Framatome	Mitsubishi Heavy Industries	Westing house	Toshiba	GE	Hitachi	Canada	Russia	Doosan Heavy Industries (South Korea)
Over 1.4 GW	Agreement on cooperation June 2015	EPR Commissioning in Finland, France and China	Japanese 3.5+ PWR EU-APWR US-APWR	Brookfield acquired	Japanese 3.5+ BWR	ESBWR Planned in the US	JV in US and in Japan since April 2008			APR-1400 Under construction in UAE
1-1.3 GW	Hualong-1 Under construction in Pakistan	Hold 19.5% of stake December 2017 ATMEA1 Proposing to Czech, Turkey etc KERENA		AP-1000 Commissioning in the US, China	ABWR	ABWR Construction suspended in Taiwan/UK ACR-1000			VVER-1200 AES-2006 Commissioning in Belarus, Turkey, Bangladesh etc	
	PWR	PWR	PWR		ABWR/BWR			CANDU		OPR-1000

Do markets exist only in developing nations?

2-6. Suspension of Hitachi's UK Project (Horizon)

- On January 17, 2019, Hitachi announced that it would suspend work on its new nuclear power facility in the UK known as Horizon. Hitachi's President Toshiaki Higashihara made the following comments at a press conference.
- We've reached our limits for investment as a private company. It took time to negotiate a financing scheme with the UK government, and the scheme that resulted was not economically viable.
- In 2013, Hinckley Point C had a strike price (SP) of 91.5 pounds/MWh, which indicated a viable business. In 2017, a comprehensive review on the design was passed.
  At the time the SP of wind power was 70 pounds a unit, revealing severe environmental changes.
- Our preconditions for recommencing development include a structure that allows for profit, the ability for off-balancing, and the prospect of economic viability relating to site permission costs. Until then, we will focus on projects in Japan.
- Nuclear power is extremely expensive. The biggest challenge is procuring funding.

Nuclear power is not always expensive!
A detailed investigation needs to be performed on causes of cost overruns.

Belarus
Bangladesh
Turkey
…

*See P14 for an example of analyzing factors related to cost overruns.

Thank you for your attention.

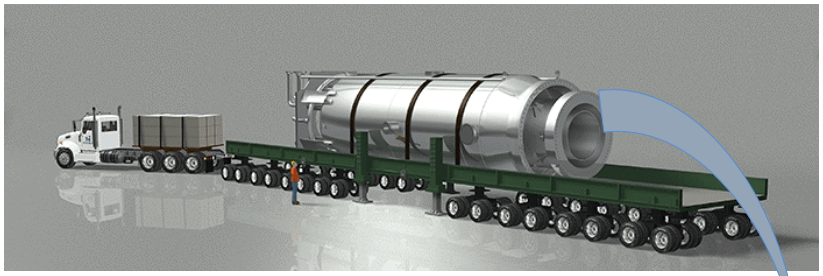
<Reference> Example of Analyzing Factors Related to Project Cost Overruns in Developed Nations

- The design had still not been completed when construction began, so there were constant changes during construction.
- Financing costs were high.
- Difficulties relating to project management - including part procurement - caused delays in processes. There were also increased management costs.
- There was a lack of information exchange/discussion with regulatory institutes, which led to unpredictable regulatory risks.

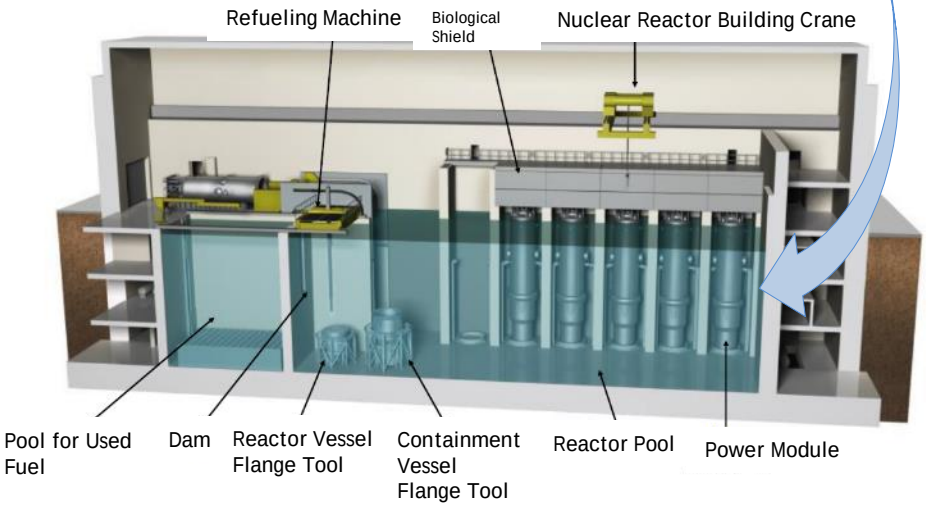
(Reference) SMRs: Low Cost, High Safety, Reduced Construction Time

… More than 40 Years of Hoping

Country	Current Situation
Canada	• Canadian Nuclear Laboratories selected four candidates for SMR development support initiatives, including Terrestrial Energy. • Construction of a demonstration reactor is planned for completion by 2026.
United States	• Nuscale is working on development at the DOE's Idaho National Laboratory. Operations are expected to begin in 2026. • Holtec is cooperating with companies such as Hitachi-GE on development of the SMR-160.
United Kingdom	• A consortium centered around Rolls Royce is currently working on development. • The government is also working on selecting projects for an advanced modular reactor (AMR).



Able to be transported by truck, rail, or boat



Source: Materials produced by NuScale

→ Numerous other countries are also considering SMRs

"Long-term plan for nuclear research, development and utilization" (1982)
4. Multipurpose uses for heat from nuclear reactors
… Multipurpose usage of heat from light water reactors, including the use of small and medium-sized light water reactors, may be realized relatively early depending on conditions…

There are social issues, such as the public's understanding of the economic viability of developing usage systems and the choice of site locations. The government will provide support for these issues to be overcome.

Contact :report@tky.ieej.or.jp