IEEJ-SNEPC Joint Study on Nuclear Policy

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Introduction: Recent nuclear energy policy developments in the Republic of Korea and in Japan

This report is a summary of major findings of the joint study between Nuclear Energy Policy Center of Seoul National University (SNEPC) and The Institute of Energy Economics Japan (IEEJ) which was conducted from June 2017 to March 2018. SNEPC and IEEJ conducted an intensive research on the role of nuclear in the power portfolio, strength/weakness/opportunity/threat of nuclear, stakeholder involvement and regional cooperation in Asia, based on the nuclear policy trends in both countries. The purpose of the joint study is to share the common issues and challenges for development of nuclear energy and to provide practical proposals for sustainable use of nuclear energy in Asia.

1-1 Republic of Korea

1-1-1 Revision of the Basic Plan for Long-term Electricity Supply and Demand in South Korea

South Korea revises its Basic Plan for Long-term Electricity Supply and Demand (BPE) every two years, with each new edition of the plan covering the 15 years that follow the year of publication. The 7th BPE was issued in July 2015, and government-appointed experts are still discussing the revision of the 8th BPE for 2017. The BPE is reviewed and released by the Electricity Policy Review Board pursuant to Article 15 of the Electricity Business Decree after consultation among executive ministries, a report to the National Assembly Standing Committee, and a public hearing. The revised and reviewed contents provide the basic orientation and long-term outlook for electricity supply and demand; plans for facilities for generation, transmission, and transformation; notes on electricity demand management; and evaluation of the previous BPE.

Originally, the policy of the 7th BPE to utilize nuclear power for 28.2% of electricity generation as of 2029 (see Table 2) was expected to be continued in the 8th BPE.

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Table 2　Target of electricity generation in Korea (by sources) in 2029 year

Classification	Nuclear	Coal	LNG	Renewable	RCS	Oil,pumped
6th (2027)	27.4%	34.7%	24.3%	4.5%	4.6%	4.5%
7th (2029)	28.2%	32.3%	24.8%	4.6%	5.8%	4.3%

(Source: MOTIE NOTICE #2015-4-3 dated July 24, 2015)

However, after the new presidential administration took office in early 2017, it announced it would phase out coal and nuclear energy, mainly due to the public's growing concerns about air pollution and nuclear safety, respectively. Instead, South Korea would increase its share of renewable energy to 20% of total electricity generation by 2030. The government also believes the achievement status of the 7th BPE should be newly reviewed once the 8th BPE is revised according to the new energy policy. The new policy makes large-scale expansion of facilities for renewable energy virtually indispensable; the 47.2 GW of new renewable capacity now slated to come online by 2030 is the equivalent of bringing online 30 APR-1400 class nuclear power plants online in 13 years, a capacity increase that has never been achieved in 40-year history of South Korea's nuclear program.

When the contents of the draft 8th BPE were publicized on mass media, the government proposed the following ideas on the energy mix:

- Period: 2017-2031 (15 years)
- Basic Direction
  - Gradually reduce nuclear and coal power plants and expand renewable energy
  - In addition to continuing the past practice of ensuring demand and supply stability as well as economic efficiency, greatly supplement environmental and safety aspects
  - Set reasonable goals through demand management instead of power-plant construction: prioritize eco-friendly distributed renewable energy and LNG generation
- Demand Forecast by 2030 – Maximum Electricity Demand: 100.5 GW
  - This total equals basic demand (113.4 GW) minus demand-management savings (13.2 GW) plus expansion of electric cars (0.3 GW)
  - Projected annual average growth rate of GDP is one percentage point lower than 3.4%, the annual average value in the 7th BPE
- Supply Management – Maintain the Reserve Rate over 22% via 5 GW of Additional Facilities
  - No new nuclear power plant construction: cancel Shin Hanul 3 & 4 and Cheonji 1 & 2
  - No extension of nuclear power plant lifetimes: do not extend Wolsung 1 through 4, Kori 2 through 4, Hanbit 1 & 2, or Hanul 1 & 2 through 2030

Table 3 Target of electricity generation in Korea (by sources) up to 2030 year

Plant Type	2017	2022	2030
Nuclear	24 units (22.5 GW)	27 units (27.5 GW)	18 units (20.4 GW)
Coal	61 units (36.8 GW)	61 units (42.0 GW)	57 units (39.9 GW)
LNG	37.4 GW	42.0 GW	47.5 GW
Renewable	11.3 GW		58.5 GW

(Source: 8th Basic Plan of Electricity [Draft as addressed on December 17th of 2017])

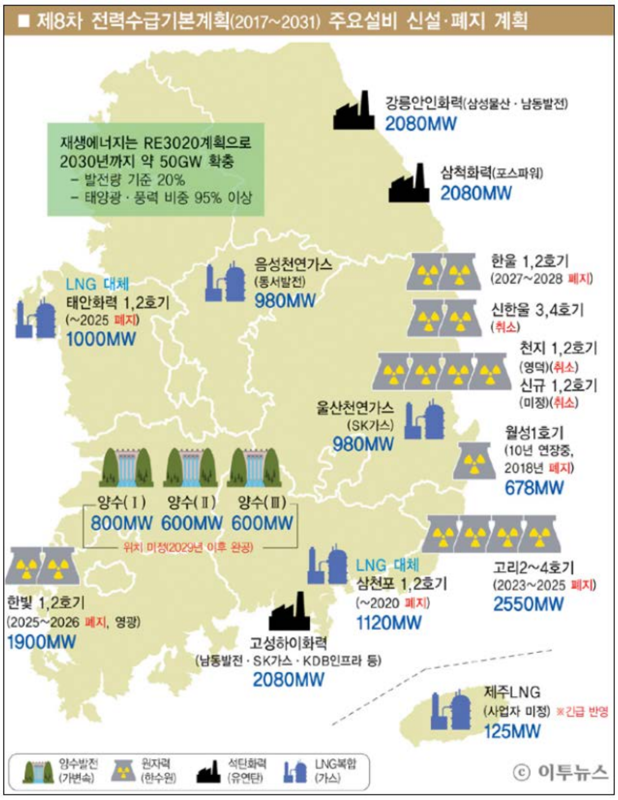


Figure 2 The 8th Basic Plan of the Electricity – New Installation and Permanent Shutdown

(Source: Energy & Environment News Plus dated December 13th of 2017)

If the 8th BPE is finalized according to the principles described above, the nuclear power ratio will decrease rapidly in the future. The remaining procedural steps for the BPE are the report to the National Assembly Standing Committee and the public hearing.

Opposition to the nuclear phase-out has been expressed by many parties. The Korean Nuclear Society (KNS), for example, expressed its position on the draft of the 8th BPE as follows:

The National Energy Policy should be determined after comprehensive consideration of various concerns, such as people's energy welfare, the economy, safety, the environment, stability of supply and demand, and so forth. However, the draft of the 8th BPE is an artificial result reflecting the government policy of energy transition that excludes nuclear power generation.

Nuclear power has supplied good-quality electricity in a safe and economic manner for 40 years. The low generation cost of nuclear power enables people and small businesses to utilize electricity without bearing a large financial burden. The nuclear phase-out policy reflected in the draft of the 8th BPE is supported by neither scientific verification nor a public consensus. Under the proposed policy, the government would deprive our society of benefits of nuclear power such as the economic and stable supply of electricity and the reduction of greenhouse gas emissions and particulate matter pollution.

Although the government mentions assisting the export of nuclear power plants, export would be impossible if there were a moratorium on domestic construction under a nuclear phase-out policy. Construction for an export project requires at minimum 5 years following a contractual agreement. Without real activity in the domestic industry over this time, the supply chain would fail. Permanent shutdown without continuation operations after the first termination of the operation license of a nuclear power plant would ignore nuclear safety and lower Korea's international status.

Instead of a nuclear phase-out, a carbon phase-out should be the goal of the energy transition policy.

Without nuclear power generation, the price of electricity must significantly increase.

As mentioned above, the draft of the 8th BPE contains unrealistic goals set for the purpose of implementing the president's campaign promise, not for serving the national agenda.

Accordingly, we urge the government to reset its energy policy, including its nuclear policy, after considering the will of the people expressed in the public debate on nuclear power generation.

Currently, major newspapers such as Chosun, Donga, Joongang Daily prefers KNS's position, while the KBS (which is effectively controlled by the government) and South Korean environmentalists support the government's position. The new administration has thus far held steadfast to its position on this issue.

1-2 Japan

1-2-1 Revision of the Strategic Energy Plan in Japan

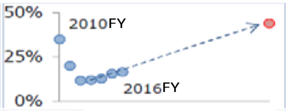
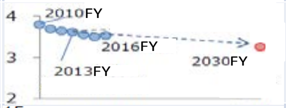
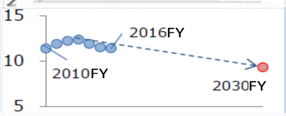
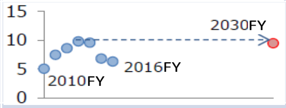
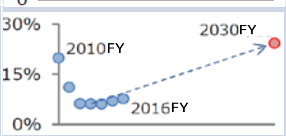
The Government of Japan (GOJ) revises the Strategic Energy Plan, a long-term energy strategy, roughly every three years. The current Strategic Energy Plan was approved by the Cabinet in 2014, and currently government-appointed experts in the Strategic Policy Committee (hereafter "the Committee") are discussing revision of the Strategic Energy Plan in 2018. Prior to the discussions by the Committee, the Minister of Economy, Trade and Industry stated that the key policy direction of the current Strategic Energy Plan should not be changed in this review.

The majority of the Committee members also reportedly argue that it is unnecessary to change the key policy direction of the current Strategic Energy Plan at present. The Strategic Energy Plan of 2014 was established after a long, in-depth discussion based on the reality Japan faces: namely, a low self-sufficiency ratio, increased greenhouse gas emissions, and high energy costs. Hence, the policy of the current Best Energy Mix target to utilize nuclear power for 20-22% of electricity generation in FY 2030 is expected not to be affected by the revision of the Strategic Energy Plan.

1-2-2 Progress status and issues of the current Strategic Energy Plan

The goals set for FY 2030 in the Best Energy Mix Target decided 2015 currently face challenges for achievement, in particular for achieving targeted share of nuclear energy due to the prolonged shutdown of nuclear power plants, as shown in the table below.

Table 4 Progress status and issues of the current Strategic Energy Plan

	Before the Great Earthquake (2010FY)	After the Great Earthquake (2013FY)	2016FY (Estimation)	Targets of Energy Mix (2030FY)	Progress Status
Zero Emission Power Generation	35%	12%	17%	44%	
Final Energy Consumption (Crude Oil Equivalent)	380 Billion liter	360 Billion liter	350 Billion liter	330 Billion liter	
CO2 Emission	1,140 million ton	1,240 million ton	1,140 million ton	930 million ton	
Electricity Cost	5.0 trillion	9.8 trillion	6.3 trillion	9.2 ~ 9.5 trillion	
Self-sufficiency Ratio in the Primary Energy Supply	20%	6%	8%	24%	

(Source: Agency for Natural Resources and Energy, Strategic Energy Plan, 9 August 2017)

1-2-3 Overview of the discussion for the new Strategic Energy Plan of 2018

(1) The draft outline suggested by GOJ

The GOJ presented the following three major points on nuclear power when it disclosed it basic idea for revision of Strategic Energy Plan of 2018:

(a) Continuously reduce reliance on nuclear power generation

(b) Nuclear power is an important power source

(c) Operate existing, safe nuclear power plants

The GOJ also indicated that the biggest challenge in nuclear policy is to recover social trust in nuclear power, and showed a pathway to steadily address this via the following four issues:

- Reconstruction of Fukushima
- Improvement of safety
- Strengthening of disaster resilience
- Decision-making procedures for the intermediate storage and final disposal of radioactive waste

Whether the target nuclear share in FY 2030 is achieved or not depends on: re-start of existing nuclear reactors; life-time extension of the existing reactors; and the possibility of new nuclear construction, which is really challenging at present. The GOJ has taken a very cautious stance toward this issue with regard to the revision of Strategic Energy Plan of 2018, in a bid to avoid inflaming strong opposition against nuclear power. Nuclear energy's share of electricity generation would rapidly decrease in the absence of new construction, as shown in Figure 3.

The GOJ in particular METI also stated that in order to steadily carry out safe restarts and decommissioning of reactors, it is necessary to secure highly specialized human resources and to promote technological development and investment. It would be very challenging to do this, however, if no new nuclear construction is planned for the next several years.

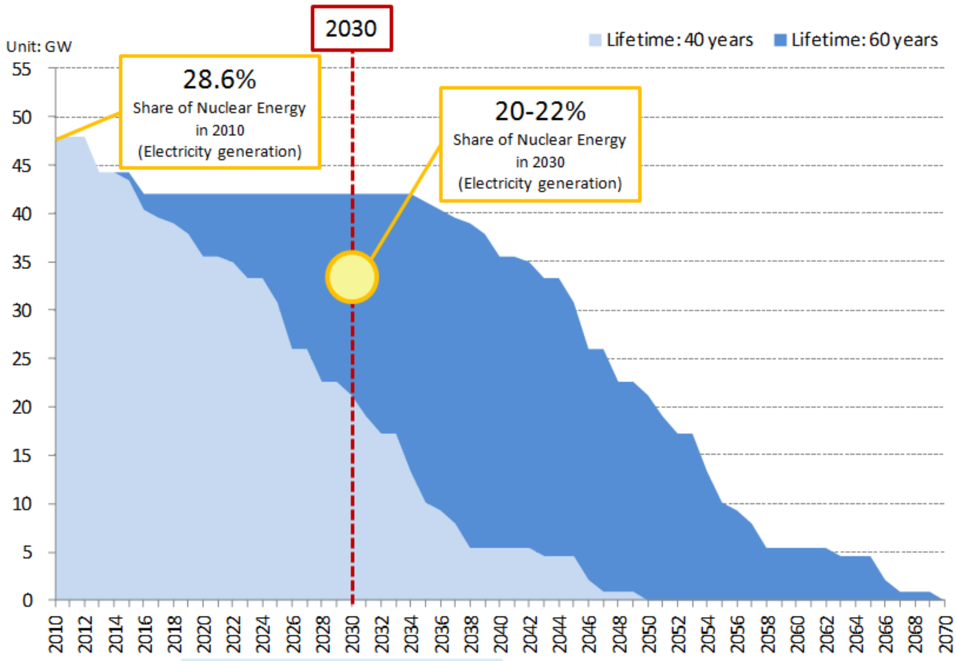


Figure 3 Total Capacity of Nuclear Power Plants in Japan

(Source: IEEJ)

(2) Discussion in Strategic Policy Committee

Many Committee members have stated that promoting the restart of existing reactors should be crucial. In addition, some members of the Committee emphasized that though opposition is strong, the GOJ should not avoid discussion of new nuclear construction. On the other hand, the anti-nuclear members of the Committee argue that phasing out nuclear power is in accordance with public opinion. However, the questions to be asked are: the definition of "the public"; objective analysis of the alternative options for nuclear phase-out; and economic, energy and environmental risk analysis of nuclear phase-out.

There is no common basis between pro- and anti-nuclear members of the Committee for further discussion of future nuclear construction. In this context, it is difficult to expect fruitful output and agreement to be reached.

[Examples of opinions by the Committee members][3]

- "It is difficult to secure the necessary energy only by renewables." (Mr. Sakane, Senior Advisor, Komatsu Ltd.)
- "The energy price should be kept reasonable. If the energy price is not at a reasonable level, industries may leak out of the country." (Ms. Yamamoto, Managing Executive Officer, IHI Corporation)

[3] http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/021/pdf/021_008.pdf (Japanese only, translated by IEEJ)

- "We should proceed with discussion of new construction from the viewpoint of technology inheritance and the need to address growing geopolitical risks." (Mr. Toyoda, Chairman & CEO, The Institute of Energy Economics, Japan)
- "Discussion of new nuclear construction is inevitable if we keep the option of nuclear power in Japan." (Professor Kikkawa, Tokyo University of Science)
- "People should be correctly informed of the safety enhancement activities by JANSI and other voluntary initiatives." (Ms. Sakita, Journalist)
- "As a Committee member, I am full of embarrassment that nuclear power was positioned as an important baseload power source in the current Strategic Energy Plan of 2014 despite the strong opposition to nuclear power among the public (…) There have been no problems under the status quo without nuclear. Public surveys show that a majority is strongly opposed to the restart of nuclear power plants, hoping that nuclear power will disappear in the near future (…) The nuclear fuel cycle should also be reconsidered. Is there really anyone who thinks the nuclear fuel cycle can be realized?" (Ms. Tatsumi, Permanent Advisor, Nippon Association of Consumer Specialists)

(3) Media reports

Each press and news service company has a different opinion about nuclear power. The Yomiuri Shimbun, known as a media to take relatively "pro-nuclear" stance, said in its one of the editorial that "the use of nuclear power is indispensable, considering energy security. Nuclear power plants also contribute to the achievement of the nation's Paris Agreement pledge because they emit fewer greenhouse gases…We should strengthen our approach to the restart as early as possible."[4]

On the other hand, the Asahi Shimbun, known as the one to take "anti-nuclear" stance, stated the following in its editorial: "It is highly doubtful that nuclear energy will serve as the backbone power while many citizens are opposed to re-operation…Japan should also follow the worldwide trend of abolition of nuclear power…We should convert to a renewable energy-centered supply structure; new possibilities in that regard have been opening up recently."[5]

But again, questions to be asked are: the definitions of "many citizens" or "worldwide"; and objective assessment of alternatives including renewable energy.

There is neither mutual understanding nor trust between the proponents of nuclear power, who argue that nuclear power is necessary, and the opponents. We should promote discussion on this complicated problem based on objective and scientific evidences. We should also continuously observe which part of opinion is based on objective and scientific facts and logic, and then make a judgment. It is also very important to recognize the

[4] The Yomiuri Shimbun, Editorial, August 26th, 2017.
[5] The Asahi Shimbun, Editorial, August 13th, 2017.

statement of of Minister of Economy, Trade and Industry and the majority of the experts in the Committee that the key policy direction of the Strategic Energy Plan should not be changed.

The Strategic Energy Plan of 2014 was determined after a long and in-depth discussion on Japan's contemporary political, economic, and social status. The GOJ defined the "3 E's"—Energy Security, Economic efficiency and Environmental sustainability—as basic principles, and then determined the target portfolio or energy mix in FY 2030. Since Japan's conditions have not changed since then, it seems reasonable to think that the target portfolio can be maintained in the discussion of new Strategic Energy Plan of 2018.

2 Role of nuclear energy in the power portfolio

2-1 Contribution of nuclear power to the "3 E's" in the Republic of Korea

South Korea is a major energy consumer: It imports nearly all of its oil and coal supply and is one of the world's top importers of liquefied natural gas (LNG). Electricity generation is chiefly reliant on conventional thermal power—which is fueled by coal, oil, and LNG—and on nuclear power. South Korea has no proven oil reserves. Exploration until the 1980s in the Yellow Sea and on the continental shelf between the Korean Peninsula and Japan did not find any offshore oil. The country's coal supply is insufficient and of low quality. The potential for hydroelectric power is limited because of high seasonal variation in the weather, with most of the rainfall concentrated in the summer. Accordingly, the energy indices in South Korea are dependent on the international market conditions for imported energy sources. To minimize the impact of the turbulent world energy markets, increasing energy self-sufficiency must be an objective of the national agenda. However, the country's new administration has declared it will end the country's reliance on coal and nuclear energy without careful and proper analyses on the trends of domestic energy indices. It would simply increase the shares of renewable and LNG energy. The reason is based upon the following observations:

- South Korea's electricity sector is not fully privatized, unlike many other countries'.
- The state-owned monopoly controls electricity retail, transmission, and distribution, but power generation is open to the private sector.
- In order to increase electricity production via renewable energy, the government encourages private investment and seeks to make the investment environment more market-friendly.

- However, as long as the electricity consumption market is monopolized and controlled by the government, the entrance of new renewable energy producers may be risky and limited under the political situation.

- Accordingly, without firm commitment from the government, which requires the legislation as agreed with the Congress, the private sector may not decide to become an electric producer.

- Up to this time, that kind of legislation has not been done. In South Korea, the new process of law-making causes time-delay significantly.

In terms of power generation, in 2015 South Korea produced 528,091 GWh total; 38.7% of this generation was from coal, 31.2% from nuclear, 19.1% from LNG, and 11.0% from miscellaneous sources including renewable energy (see Figure 4).

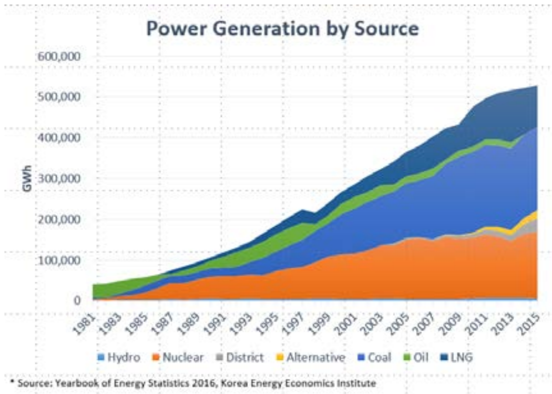


Figure 4　Power Generation by Source during 1981 - 2015

(Source: Yearbook of Energy Statistics 2016, Korea Energy Economics Institute)

This means that nuclear energy represents a major part of power generation in South Korea. Considering that nuclear energy is free of greenhouse gas (GHG) emissions, it is regarded as the most reliable alternative energy to meet South Korea's Paris Agreement pledge to reduce domestic GHG emissions in 2030 to roughly twice the country's 1990 levels. Since emissions are already above the ultimate goal and are growing quickly compared to other OECD states', the new administration has a lot of work to do. It has proposed to increase the share of renewable electricity generation in 2030 to 20% of the total, building on the 10% share by 2024 currently targeted by the renewable portfolio standard. The problem where emissions are concerned is that the administration is also planning considerable new gas-fired generation. Implementing this would risk failing to meet the Nationally Determined Contribution (NDC) target level, since LNG plants, unlike nuclear plants, release considerable GHG emissions. Figure 5 shows the respective contributions of each energy sector to national GHG emissions. Without reducing total emissions significantly, the country will fail to meet its Paris commitment.

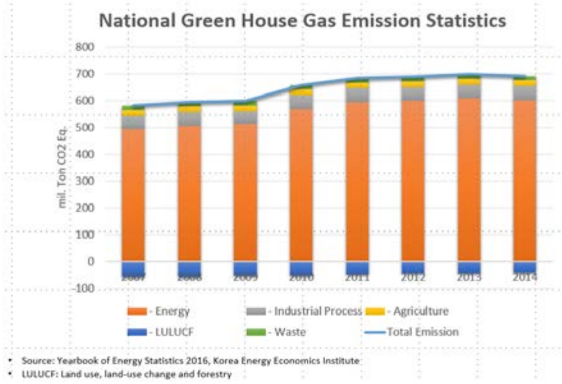


Figure 5　National Green House Emission Statistics

(Source: Yearbook of Energy Statistics 2016, Korea Energy Economics Institute)

In every market, wholesale and consumer pricing significantly impact product costs and consumer behavior. South Korea has a national power grid with a unified electricity pricing structure. The wholesale electricity market operates on a cost-based pool, in which the price of electricity has two components: the marginal price, which represents the variable cost of generating electricity; and the capacity price representing the fixed cost. A unique characteristic of South Korea's electricity market is that the market price is set by actual variable costs, as opposed to the common method of using the bidding price. The single national distributor of electricity (KEPCO), which is majority-owned by the government, has fared well over the years in terms of keeping electricity prices low and power flowing: Blackout time in South Korea is in the ultra-low 12-18 minute range, just 10% that of the reliable North American power grid.

Korea Power Exchange (KPX) and Korea Electric Power Corp. (KEPCO) are in charge of demand-side management programs, including demand response. Load management programs have been around since the 1970s, including major programs such as night rates for thermal power-storage, seasonal tariffs, time-of-use tariffs, and linking an electricity bill to a base rate plus a peak consumption rate. In the 1990s, voluntary load reduction and energy efficiency programs picked up, and in the early 2000s, demand response programs formed. Demand response programs have been an effective tool in curbing power system investments in South Korea, including generation, transmission, and substation networks. Demand response plays a key role in KPX's long-term electricity supply and demand outlook.

The progressive pricing system in residential electricity consumption pricing is the other key tool that reduces peak demand, in turn slowing down the need for capacity and transmission investments. A demand and energy charge is included in the bill, which is based on several pricing levels. The more energy is consumed in a month, the higher the rate for each pricing level. This pricing structure incentivizes low energy consumption, reducing demand growth. Outside the residential pricing system, KEPCO offers many pricing options for respective consumer types. For example, the educational electricity pricing is very low as compared to the residential one. With this kind of pricing scheme, consumers are more energy-aware and can change their behavior to minimize energy consumption. This so-called “Smart Pricing System” has mitigated electricity demand growth, which would otherwise mirror the pace of the nation’s rapid economic growth. Through observation of the Smart Pricing System, one can also plainly conclude that residents—a group of consumers with political power—dislike electricity price hikes.

South Korea’s new administration has directed the country to increase the ratio of domestic power generation based on renewable energy sources, such as solar power and offshore wind power, to at least 20% by 2030. Under these circumstances, South Korea’s renewable energy industry is expected to enjoy substantial growth of facility installation, since that type of generation produced only 3.6% of the country’s total power over 2016. Facility expansion is indispensable for meeting the administration’s goal, which requires expanding renewable-energy facilities by 47,826 MW of capacity, the equivalent of bringing online over 30 APR-1400 class nuclear power plants by 2030—a pace which has not been achieved in the 40-year history of South Korea’s nuclear program. Moreover, a series of alternative power generation projects can be synchronized with the new government’s directive, to cancel new coal-fired power and nuclear power plant construction projects as well as shut down the 10 oldest coal-fired power and single oldest nuclear power plant in the country. The new government is also planning to adopt an increase in the minimum required alternative energy supply in compliance with the Renewable Portfolio Standard (RPS), and to temporarily run a Feed-In Tariff (FIT). The RPS is to compel each power generation company with a certain capacity to supply a certain amount of power by means of new and renewable sources. The FIT, which was canceled six years ago in South Korea, is for the government to make up the difference in price when the price of electricity supplied by alternative means falls below the price announced by the government.

There is skepticism about whether achieving the administration’s goal is possible. Facility expansion requires a long period of time, but policy consistency cannot be guaranteed. In addition, the major market for South Korea’s manufacturing industry is not domestic but overseas, which means a change in South Korea’s energy policy may have very little corresponding effect on these manufacturers’ competitiveness. The new government’s proposal would necessitate a very significant electricity price increase, which is known as a critical concern of the public; the FIT already cost 402.1 billion won (approximately US$365.5 million, US$1=1100won) in 2016 alone.

As shown in the left-hand graph of Figure 6, power unit prices of nuclear and coal energy are relatively cheap (Nuclear – 62.61 won/kWh (approximately US$0.057/kWh); Coal – 71.41 won/kWh (approximately US$0.065/kWh)). Also, the portion of coal and nuclear energy in South Korea’s power generation is about 70%. On the other hand, the power unit prices of LNG and other sources (including renewable energy) are 169.49 won/kWh (approximately US$0.154/kWh) and 121.08 won/kWh (approximately

US$0.110/kWh), respectively. In the case of renewable energy, the unit price is compensated with subsidies, which are depicted in the right-hand graph of Figure 6.

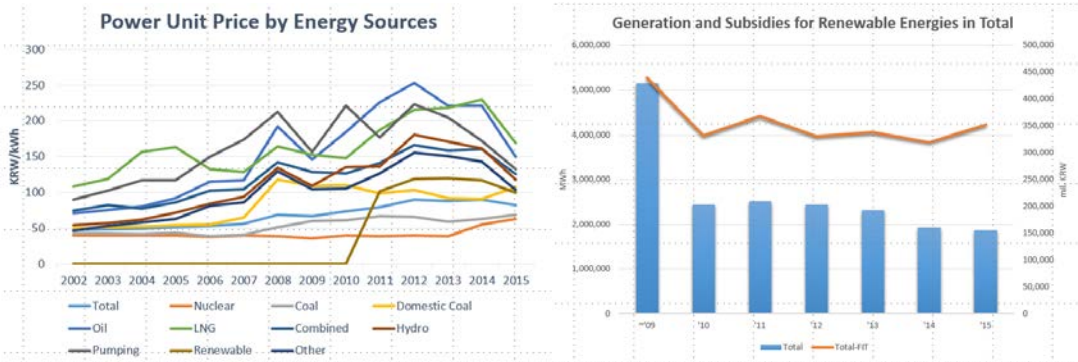


Figure 6 Power Unit Price by Energy Sources / Generation and Subsides for Renewable Energies in Total

(Source: Yearbook of Energy Statistics 2016, Korea Energy Economics Institute)

Based upon the above information, it is apparent that the biggest barrier to replacing coal and nuclear energy with renewable energy and LNG is that doing so would raise energy prices, given that consumers are reluctant to pay more for energy.

As described in the opening paragraphs of this section, South Korea is one of the world's largest energy importers because it lacks domestic energy resources. It relies on imports for about 98% of its oil, coal and LNG consumption, with all oil and LNG shipped overseas because the country lacks international oil or natural gas pipelines. Despite its lack of domestic energy resources, South Korea has some of the largest and most advanced oil refineries in the world. In an effort to improve the nation's energy security, oil and natural gas companies are aggressively seeking overseas exploration and production opportunities. Every effort to increase self-sufficiency requires proper and careful approaches.

As shown in Figure 7, South Korea imported US$80.94 billion of energy in the year 2016. By category, fossil fuel imports consisted of coal (US$9.31 billion, 11.5% of energy imports); crude oil (US$44.30 billion, 54.7%); petroleum products (US$14.58 billion, 18.0%); and LNG (US$12.17 billion, 15.0%). Only US$0.6 billion (0.7%) of imports were of uranium, one reason nuclear energy is considered as "nearly domestic" energy.

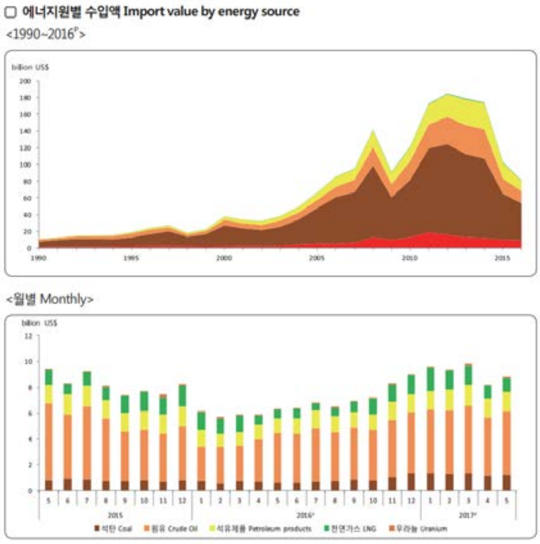


Figure 7 Import value by energy source

(Source: Yearbook of Energy Statistics 2016, Korea Energy Economics Institute)

Following Japan's Fukushima disaster and South Korea's problems with false safety certifications of nuclear equipment in late 2012, the government has reconsidered its long-term reliance on nuclear power in the electricity portfolio. In addition, South Korea is attempting to balance its fuel portfolio to satisfy higher energy consumption, moderate its nuclear power generation while reducing GHG emissions, and offset some fossil fuel imports. As part of this effort, the government is promoting greater demand-side management and energy efficiency measures as well as use of renewable energy. However, prospects in energy saving appear limited because the Smart Pricing System has already wrung inefficiencies out of the system.

2-2 Contribution of nuclear power to the "3 E's" in Japan

2-2-1 Nuclear power developments in Japan

Japan started research and development of nuclear power in the 1950s with support from the United States. From the 1970s to 1990s, Japan constructed many light-water reactors. There were no commercial nuclear reactors in the country in 1965; however, the number of reactors increased dramatically afterward, and Japan operated 20 reactors by the end of the 1970s and 36 by the end of the 1980s. At first, nuclear reactors were constructed based on the technologies of companies in foreign countries including the United States and United Kingdom, but by the 1990s domestic plant makers like Mitsubishi Heavy Industries, Hitachi, and Toshiba successfully caught up with those technologies and achieved domestic manufacturing of almost all equipment at nuclear power plants. Before the Fukushima Daiichi accident in 2011, Japan had 54 reactors, contributing approximately 30% of total electricity generation and contributing to the improvement of Japan's low energy self-sufficiency rate. According to the Framework for Nuclear Energy Policy in 2005 (adopted in October 2005 by the Cabinet), nuclear power was expected to continue to meet at least 30-40% of electricity supply even after 2030. After the Fukushima accident, however, all reactors were shut down from May 2012, and each reactor must now meet a series of new regulatory requirements and receive local government consent to restart. Only 5 reactors are operating at present (as of May 5, 2018); Under the circumstance, the electricity generation of nuclear power in 2016 was only 17TWh, approximately 2% of total power generation.[6]

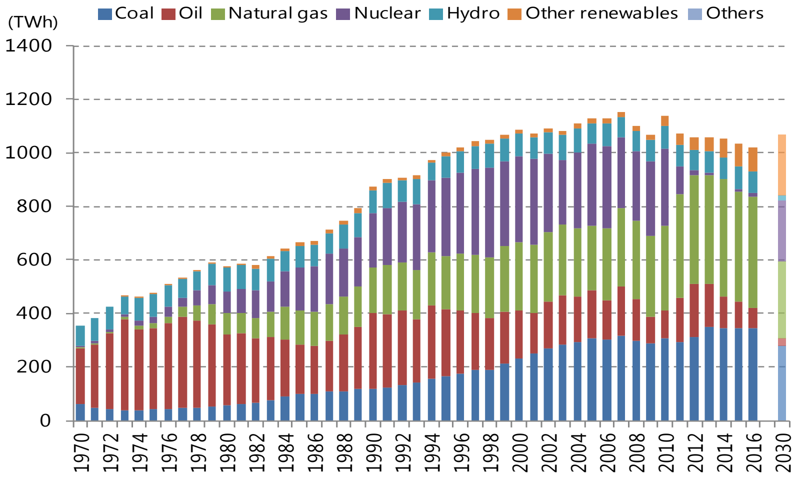


Figure 8　Trend of electricity generation in Japan (by sources) with 2030 target

(Source: IEA, World Energy Balances 2017; author calculated and added the data for 2030)

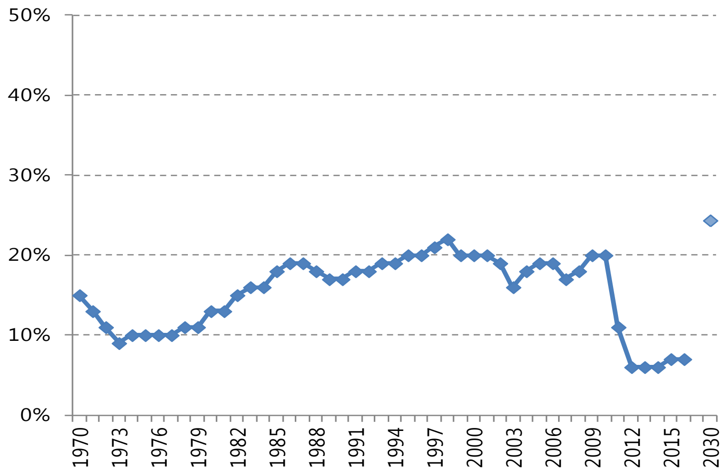


Figure 9　Energy self-sufficiency rate of Japan with 2030 target

(Source: IEA, World Energy Balances 2017; Ministry of Economy, Trade and Industry, Best Energy Mix Goal 2015)

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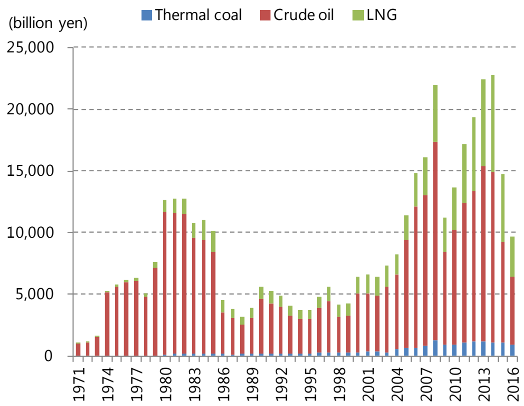
[6] IAEA, Power Reactor Information System.

2-2-2 GHG emissions

Nuclear power has contributed to not only energy security but also GHG emissions reduction in Japan. The loss of nuclear power after the Fukushima accident has been compensated by an increase in fossil fuel power generation which resulted in substantial increase in fuel imports both in terms of value and volume. Japan's GHG emissions in 2013 were the highest level since 1990 due to the lack of nuclear power which was compensated by fossil fuels. Since then, GHG emissions in Japan have decreased mainly because of energy-saving. Meanwhile, the imported cost of fossil fuel has declined thanks to the decline of oil prices in 2014.



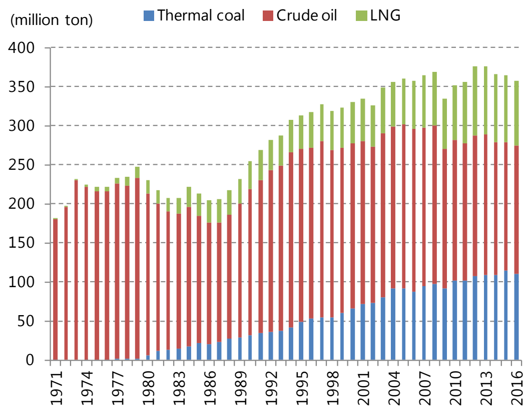


Figure 10 The cost and volume of imported fossil fuels

(Source: Ministry of Finance, Trade Statistics of Japan; IEEJ-EDMC, EDMC Databank)

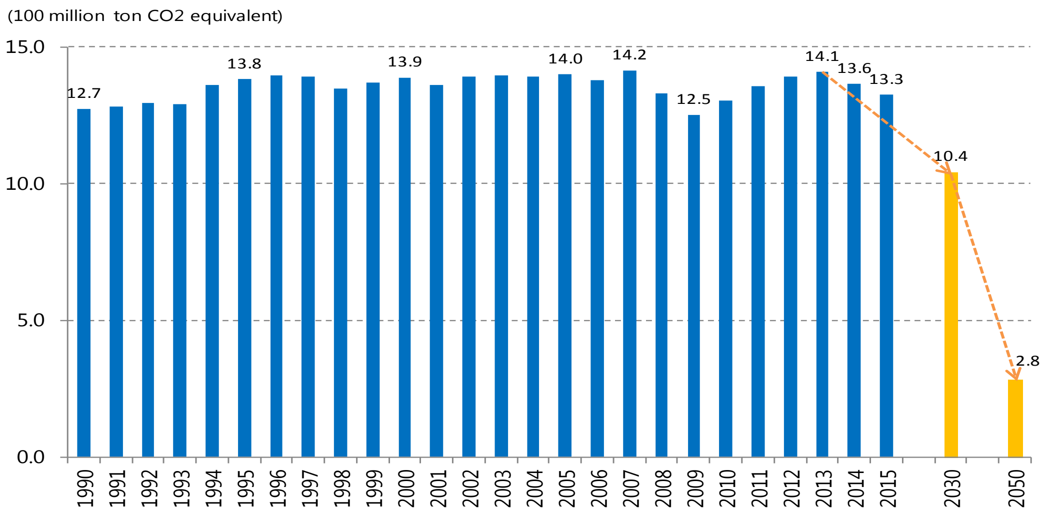


Figure 11 GHG emissions in Japan with 2030 and 2050 targets

(Source: Ministry of Environment, Japan's National Greenhouse Gas Emissions in Fiscal Year 2015; author calculated and added the data in 2030 and 2050)

2-2-3 Generation costs

Before the Ministry of Economy, Trade and Industry (hereafter, "METI") decided the energy mix target for 2030, METI also published the analysis of the levelized costs of electricity (LCOE) for various power-generation technologies, based on thorough review of the latest data and information. The working group for LCOE analysis discussed and finalized the cost analysis, and then called for public opinion with regard to the relevant data, information, opinions, etc. The final results were published on May 26, 2015.[7] The expenses include the respective costs for capital, additional safety investment, O&M, fuel, nuclear fuel cycles (front-end and back-end including reprocessing and final disposal), CO2, accident risk, and policy (R&D, siting for nuclear power, and FIT for renewables). For Solar PV and wind, possible future cost declines have been taken into account.

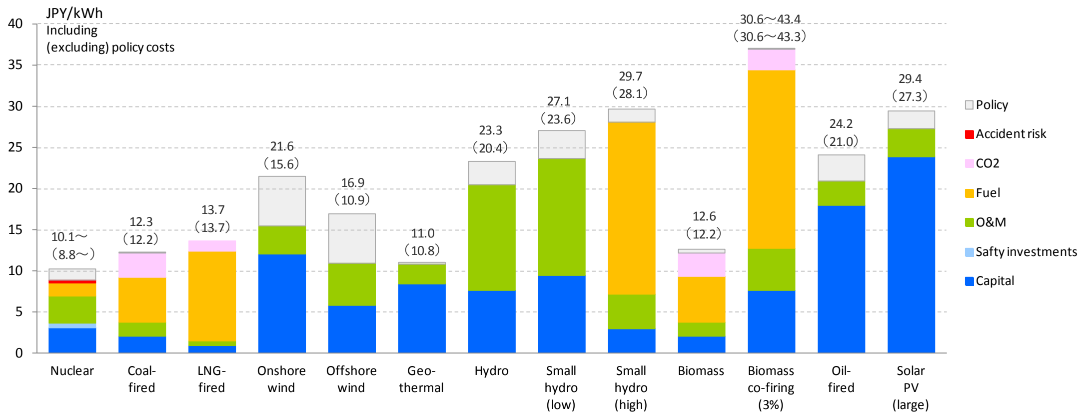


Figure 12 Power generation cost estimate for Japan (2014)

(Source: Power Generation Cost Verification Working Group (2015))

[7] The Japanese government directed the working group to estimate the costs of generating power for various power sources in 2014. The group's estimate serves as a reference in the review of the future energy demand and supply structure by the Subcommittee on Long-term Energy Supply-demand Outlook, under the Strategic Policy Committee of the Advisory Committee for Natural Resources and Energy. The working group used the model plant method, and the data for sample plants is applied to the real value for 2014. You can find the spreadsheet at the URL http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/#cost_wg (Japanese only). [Accessed 16 October 2017]

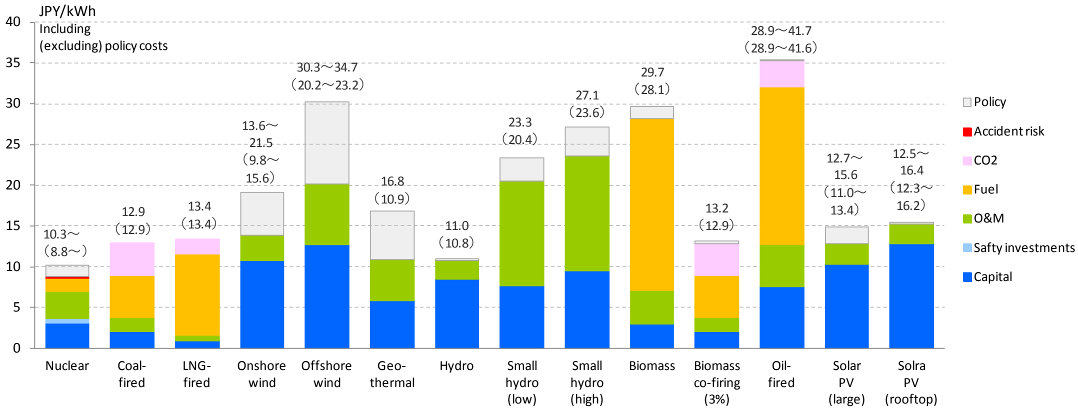


Figure 13　Power generation cost estimate for Japan (2030)

(Source: Power Generation Cost Verification Working Group (2015))

The recent lower levels of oil and gas prices have had an impact on generation costs. For example, the average import CIF price of LNG was ¥87,061/metric ton (approximately US$791.46/metric ton, US$1=¥110) in the fiscal year 2014, and declined to ¥39,331/metric ton (approximately US$357.55/metric ton) in fiscal 2016 due to the lower level of oil prices.[8] According to the government's 2014 estimate, the generation cost of a new LNG-fired plant is ¥13.7/kWh (approximately $0.125/kWh). If the fiscal 2016 cost of LNG import were applied to the calculation and all other costs held unchanged, however, the estimated generation cost would fall to ¥8.2/kWh (approximately $0.075/kWh).[9] This means that new construction of nuclear power plants can be more difficult to economically justify if and when the prevailing lower oil and gas prices at present continue to exist in the long run.

Apart from LCOE analysis, the electric companies' financial report suggested that while actual capital costs of nuclear power generation have been stable since 2000, O&M costs and back-end costs have increased, and the capacity factor has declined because of plant shutdowns caused by accidents, scandal penalties, and earthquakes. This has driven up the average actual power generation cost (Figure 14), which had been in the range of about ¥6-10/kWh (approximately $0.055-0.091/kWh) before 2011 and indicated a declining trend with the decrease of capital costs during the period. But the cost surged from fiscal 2011 onward as capacity factor dramatically declined.

[8] EDMC, EDMC Energy Trend Aug. 2017.

[9] This generation cost comparison is an estimation, not the exact cost of current generation. The LNG price used in this calculation is not fixed; it is just a snapshot of the current trend.

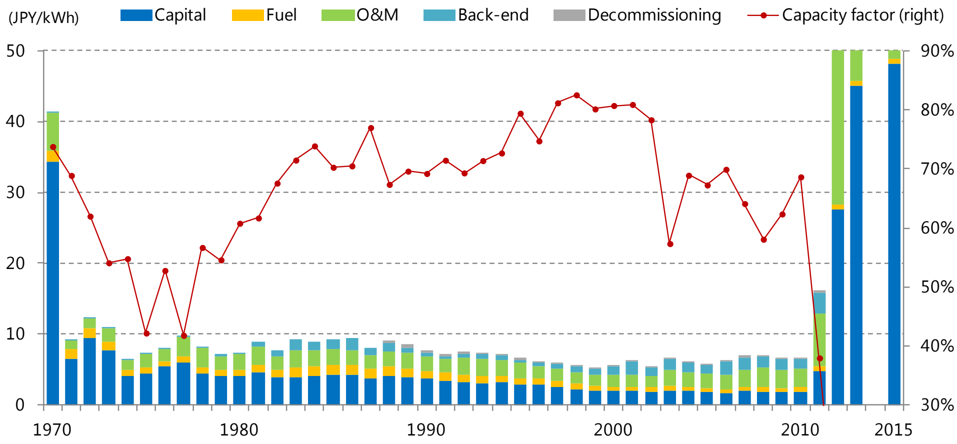


Figure 14 Generation cost comparison between nuclear power and other fossil fuel -fired plants and other fossil fuel -fired plants

(Source: Calculated using Annual financial reports of electric power companies)

With the liberalization of the wholesale and retail electricity markets in Japan, nuclear power must face severe competition in the market place for its survival. The GOJ is contemplating some relevant mechanism to address the issue of nuclear power in competitive electricity market, but at the same time, electric utilities using nuclear power should continue their efforts to lower generation costs under the ongoing liberalization of electricity markets. The details of above mentioned mechanisms are discussed in Chapter 3-4.

3 Strength, weakness, opportunity, threat

Generally, strength of nuclear energy is defined as 3E. The government and nuclear power industry jointly have worked together in developing advanced reactors both in Japan and Republic of Korea in order to improve those strength of nuclear energy. As an example of advanced reactors, Chapter 3-1 overviews the characteristics of South Korean Advanced Power Reactor Plus which has already been commercialized in the country. Nuclear energy has excellent characteristics in 3E, however, safety is regarded as weakness. Chapter 3-2 discusses safety regulatory scheme which mitigates safety related risks of nuclear power in both countries. In addition, projects for the new construction and planning of nuclear power plants are great opportunities for nuclear power industries in both countries. Chapter 3-3 globally reviews some emerging markets which expects to introduce or expand nuclear power capacities. Lastly, liberalization of electricity markets put some threats to nuclear energy. Chapter 3-4 reviews measures for nuclear energy to survive under competitive electricity markets in Japan.

3-1 Development of advanced reactors

The nuclear power industry has been developing and improving reactor technology for more than five decades and is starting to build the next generation of nuclear power reactors to fill new orders. One of them, the Advanced Power Reactor Plus (APR+), is described below.

The Advanced Power Reactor Plus (APR+) is a successor of the Advanced Power Reactor 1400 (APR1400) and features improved reactor concepts. It has been developed as a two-loop evolutionary pressurized water reactor by adopting several advanced design features to further enhance economic efficiency, safety, and reliability.

Regarding the economic enhancement, it has been decided to raise the APR+ reactor core power to 4,290 MWth. This corresponds to a 1500MWe class nuclear power plant. Also, study on the plant design has been performed to shorten the construction period.

As for safety and reliability improvements, several advanced design features are introduced in the APR+ design, such as an improved direct vessel injection (DVI+), advanced fluidic device (FD+), passive auxiliary feedwater system (PAFS), and four mechanically and electrically independent trains of safety systems based on the N+2 design concept. With respect to severe accident mitigation design features, the emergency reactor depressurization system (ERDS) for rapid depressurization during high pressure severe accident scenarios and the enhanced in-vessel retention through external reactor vessel cooling (IVR-ERVC) system have been newly incorporated.

The major design requirements for the safety and performance goals for APR+ are listed in Table 5. Reflecting the name APR+, the configuration Reactor Coolant System for APR+ is the same as that of the APR1400, as shown in Figure 15.

Regarding licensing progress, the Standard Design Approval of APR+ was issued by the South Korean nuclear regulatory body in 2014.

Table 5 APR+ DESIGN REQUIREMENTS FOR SAFETY AND PERFORMANCE GOALS

General Requirements	Performance requirements and economic goals
Type and capacity: PWR, 1500 Mwe Plant lifetime: 60 years Seismic design: SSE 0.3g Safety goals: Core damage frequency < 1.0E-6/RY Containment failure frequency < 1.0E-7/RY Occup. radiation exposure < 1 mSv / RY	Plant availability: greater than 92% Unplanned trips: under 0.2 times per year Unplanned trips: under 0.2 times per year Refueling interval: 18 months or longer Construction period: 36 months (Nth plant) from first concrete (F/C) to fuel loading (F/L) Economic goal: ≥ 20% cost advantage over fossil-fueled power plants

(Source: Standard Safety Analysis Report (SSAR) for the APR+)

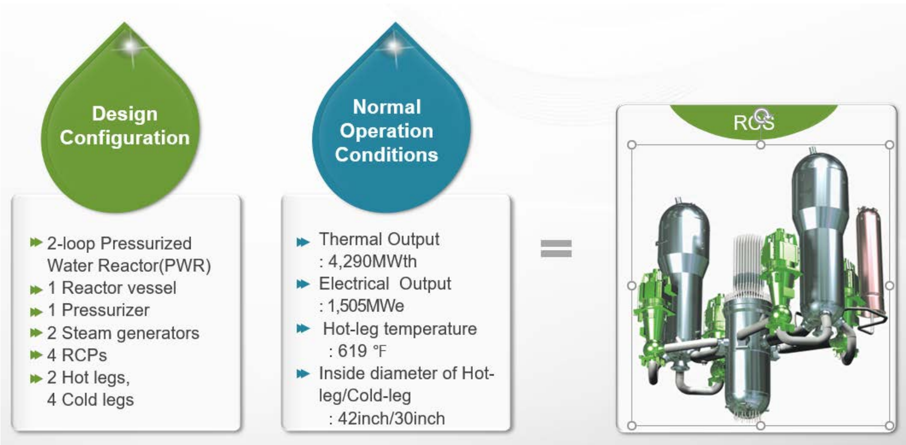


Figure 15 Overview of the Reactor Coolant System for the APR+

(Source: Standard Safety Analysis Report (SSAR) for the APR+)

3-1-1 Economical Aspects

The APR+ core thermal power is uprated to 4,290 MWth, which corresponds to a 1,500 MWe class nuclear power plant. This power rating is 108% of the APR1400 core power and is considered the maximum power output for a two-loop reactor coolant system (RCS) configuration with minimized component size change. The full-power hot leg temperature of APR+ was increased from the 323.9°C (615°F) of the APR1400 to 326.1°C (619°F) to optimize the RCS design parameters. The total RCS flowrate is increased to about 103% of the APR1400's, and is optimized through primary component sizing. The reactor core of the APR+ is designed to generate 4,290 MW of thermal power with an average volumetric power density of 101.9W/cm^3. The core is designed for an operating cycle of 18 months or longer with a maximum rod burnup as high as approximately 60,000 MWD/MTU, and has an increased thermal margin of more than 10% to enhance safety and operational performance.

The possibility of utilizing mixed oxide (MOX) fuel as high as up to one-third of the core is also considered in the core design.

In addition, the APR+ reactor core is designed to be capable of daily load following operations. A standard 100-50-100% daily load following operation and frequency control operation have been considered in the reactor core design as well as in the plant control systems. Besides, various load maneuvering capabilities are considered in the design such as up to 10% step change in load, +/- 5%/min ramp load changes. Also, it has a house load operation capability during a sudden loss of load up to 100% (full load rejection), in which plant control systems automatically control the plant at a 3-5% power level without causing any reactor trips or safety system actuations.

The HIPER16TM fuel which will be used for the APR+ has the capability of a batch average discharge burn-up as high as 65,000 MWD/MTU and has an increased overpower margin as compared to the previous fuel design (PLUS7TM). The fuel handling system is designed for a safe and rapid handling and storage of fuel assemblies from the receipt of fresh fuel to the shipment of spent fuel.

The lifetime of the reactor pressure vessel is extended to 60 years by using low carbon steel, which has lower contents of copper, nickel, phosphorus, and sulfur, resulting in an increase of brittle fracture toughness. The inner surface of the reactor vessel is cladded with austenitic stainless steel or nickel-chromium-iron alloy. The reactor vessel is designed to have an end-of-life RTNDT of 21.1°C (70°F).

The general arrangement of the APR+ was designed based on the twin-unit concept and slide-along arrangement with common facilities such as compound building, which includes rad-waste building and access control building. The construction period of a nuclear power plant should generally be minimized for economic reasons. The target of construction period for the APR+ Nth plant is 36 months from first concrete to fuel loading. To meet the target construction period, several new engineering methods are adopted and applied, such as modularization, new construction methods, construction process improvements from the reference plant, etc. Modularization is widely known as a methodology to reduce construction duration, and is one of the most effective methods to make a nuclear power plant more economical. The SC (Steel-plate Concrete) module and integrated composite module will be mainly applied to the RCB, AB, and CPB designs. Also, the new construction methods such as the over-the-top method, RVI (Reactor Vessel Internal) module, and RCL (Reactor Coolant Loop) & RVI parallel construction method are adopted and applied to reduce the construction period. Thus, the Nth unit of the APR+ will be constructed within 36 months with the help of experience and know-how from the APR+'s first and second construction projects.

3-1-2　Safety and Reliability Aspects

The quantitative safety goals for the APR+ are as follows:

- The total Core Damage Frequency (CDF) shall not exceed 10-6/RY for internal initiating events and 10-7/RY for a single event
- The containment failure frequency shall be less than 10-7/RY
- The whole-body dose at the site boundary shall not exceed 0.01 Sv (1 rem) for 24 hours after initiation of core damage with a containment failure

To achieve the above quantitative goals, the defense-in-depth concept remains a fundamental principle of safety requiring a balance between accident prevention and mitigation. One design requirement for the APR+ is that a small break loss-of-coolant-accident (LOCA) with a break size smaller than 150 mm in diameter should allow the continued use of the reactor with its fuel inventory after the repair of the ruptured pipe and/or other damages in the reactor coolant system. Also, the APR+ safety-related systems are designed to perform their functions even if an individual component in any system fails to operate (single failure concern) and any component affecting the safety function is simultaneously inoperable due to repair or maintenance, hence the name “N+2 design”.

The major design characteristics of the APR+ safety systems are as follows;

- Improved reliability of the safety injection system (SIS) through mechanically and electrically independent four (4) train design [N+2 design]
    - ➢ Each train has one active safety injection pump (SIP) and one passive SIT equipped with the fluidic device; the safety injection pumps and electrically actuated valves are capable of being powered from the plant's normal power sources as well as the emergency power sources such as Emergency Diesel Generators (EDGs)

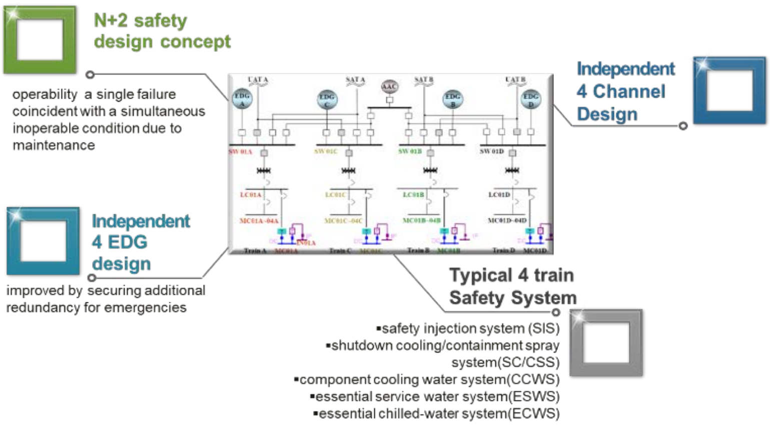


Figure 16　N+2 Design Application to the APR+

(Source: Standard Safety Analysis Report (SSAR) for the APR+)

- Simplified operation of the SIS by merging the high-pressure injection, low-pressure injection, and re-circulation modes into one injection mode
- Lowered susceptibility of in-containment refueling water storage tank (IRWST) to external hazards by locating the refueling water storage tank (RWST) inside the containment
  - The IRWST is located inside the containment, and the arrangement is made in such a way that the break flow as well as the injected core cooling water can return to the IRWST, which consists of an annular cylindrical tank along the containment wall at low elevation, a holdup volume tank (HVT), and four inside-sumps
- Enhanced plant safety by adopting advanced features such as the FD+ in the safety injection tank (SIT) and the DVI+ in the SIS
  - FD+ to reduce the possibility of nitrogen (N2) gas ingestion during water discharge and to effectively utilize water volume occupied below the FD.

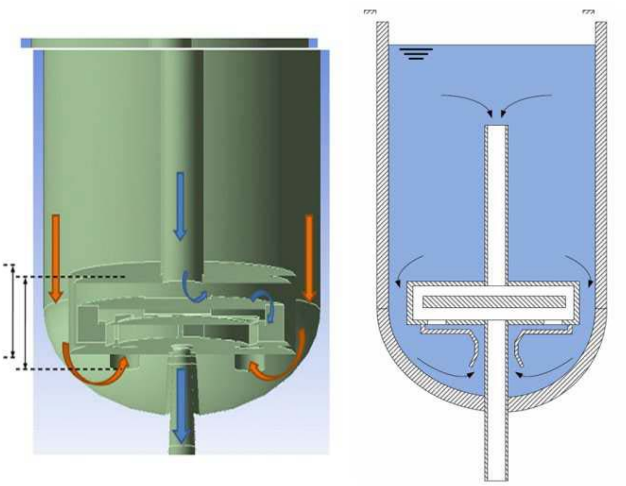


Figure 17 Fluidic Device plus for APR+

(Source: Standard Safety Analysis Report (SSAR) for the APR+)

  - To minimize the bypass of emergency core cooling (ECC) injection water in the RV down-comer during the LOCA, four ECC Core Barrel Ducts (ECBDs) are installed vertically on the outer surface of the core support barrel at the corresponding position for each DVI nozzle (DVI+ design concept)

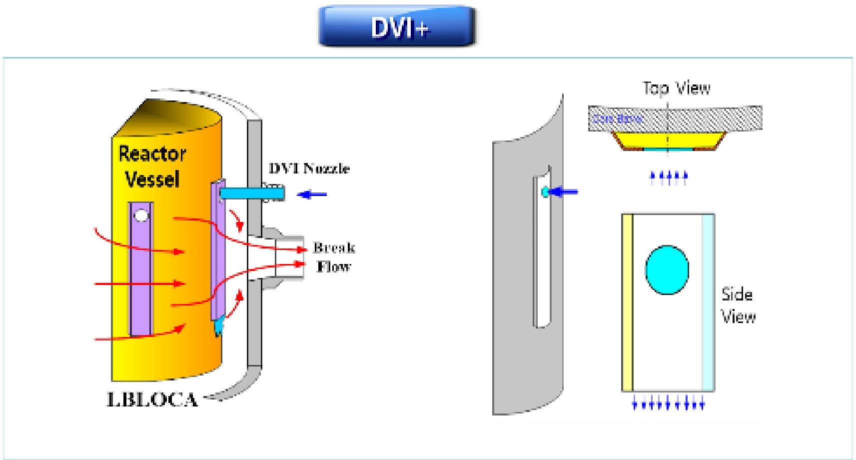


Figure 18　Direct Vessel Injection plus for APR+

(Source: Standard Safety Analysis Report (SSAR) for the APR+)

- Improved reliability of the containment spray system (CSS) through designing the CSS and shutdown cooling system (SCS) in common
- Passive decay heat removal capability using PAFS, which completely replaces the conventional active auxiliary feedwater system
  - ➢ The PAFS is composed of four independent trains to satisfy the single-failure criterion; two Passive Condensation Heat Exchanger (PCHX) bundles are installed inside the Passive Condensation Cooling-water Tank (PCCT); the PAFS is designed to be capable of operating without AC power for a minimum of 8 hours to ensure a subsequent RCS cooldown for 8 hours to the shutdown cooling entry condition, even if the cooldown starts within 5 minutes of the reactor shutdown

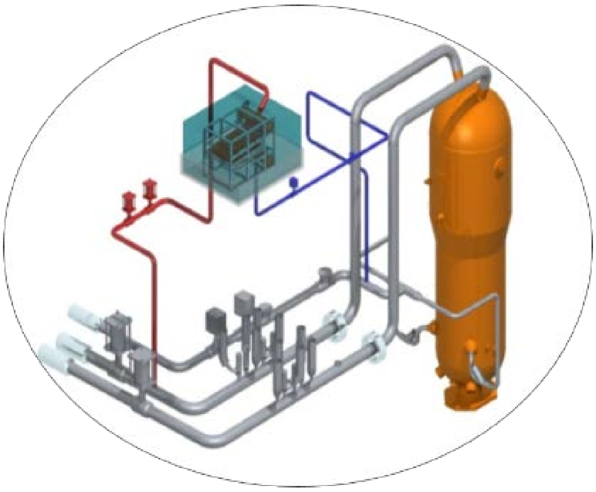


Figure 19　Passive Aux. Feedwater System for APR+

(Source: Standard Safety Analysis Report (SSAR) for the APR+)

The buildings and the structures are designed applying the Safe Shutdown Earthquake

(SSE) of 0.3g as a Design Basis Earthquake (DBE). Since seismic evaluation is performed to include the effect of the soil-structure interaction on the soil sites, the APR+ plant can be constructed not only on rocky sites but also on soil.

In the APR+ design, severe accidents are addressed as follows:

- For phenomena likely to cause early containment failure, for instance, within 24 hours after accidents, mitigation systems shall be provided, or the design should address the phenomena although the probability for such accidents is low
- For phenomena which potentially lead to late containment failure if not properly mitigated, the mitigation system or design measures should be considered in conjunction with the probabilistic safety goal and cost for incorporating such features to address the phenomena

The severe accident management systems designed in the APR+ consist of the following: (1) large dry pre-stressed concrete containment, (2) cavity flooding system (CFS), (3) Hydrogen Mitigation System (HMS) to prevent containment hydrogen concentrations from reaching detonation levels, (4) emergency reactor depressurization system (ERDS), (5) large reactor cavity designed for retention and cooling of core debris, (6) emergency containment spray backup system (ECSBS), and (7) containment filtered vent system (CFVS)

In summary, the APR+ shall be constructed and operated with many advanced design features to enhance economic efficiency, safety and reliability, a part of which has already adapted to APR-1400 in operation in South Korea. Due to the powerful strength of the APR+, it will be one of the most outstanding reactors among the Gen-III+ reactors in the world such as EPR by Framatome, AP1000 by Westinghouse and ATMEA1 by ATMEA.

3-2 Safety regulatory scheme in Japan and in the Republic of Korea

A comprehensive safety regulatory scheme is indispensable to sustainable use of nuclear power. Both Japan and the Republic of Korea originally introduced the safety regulatory scheme developed in the US and have revised it several times reflecting lessons learned from various incidents in the world, including the Three Mile Island accident, Chernobyl accident and the Fukushima accident. The process of the upgrading the safety regulatory scheme after the Fukushima Daiichi accident in Japan and the process of the reinforcement of the safety regulatory authority in the Republic of Korea are described in this section below.

3-2-1 Safety regulatory scheme in Japan

The Fukushima Daiichi accident gave us a few lessons. One is regarding the structure of governmental bodies of promotion and regulation of nuclear power in Japan. Another is regarding the definition or understanding of the "risk" in relation to nuclear power technologies, especially related to the external disasters, which had been beyond the scope of the original regulation.

(1) Background of NRA establishment[10]

Before the Fukushima Daiichi accident, the Nuclear and Industrial Safety Agency was responsible for "Regulation" of nuclear safety under the METI, which itself was responsible for nuclear power "Utilization and Promotion." To ensure a transparent separation of these two sectors, nuclear safety regulation was decoupled from the METI, and a new Nuclear Regulation Authority (NRA) was established in September 2012. The Authority is a highly independent external organization of the Ministry of the Environment. But some stakeholders question about the nature of the "independence" of the NRA. Some point out that the operators should comply with anything requested by the NRA in the current review process and the dialogue is limited. Some opinion leaders and academic experts have remarked[11] that: "This is not an 'independent' authority, but an 'isolated' authority,"

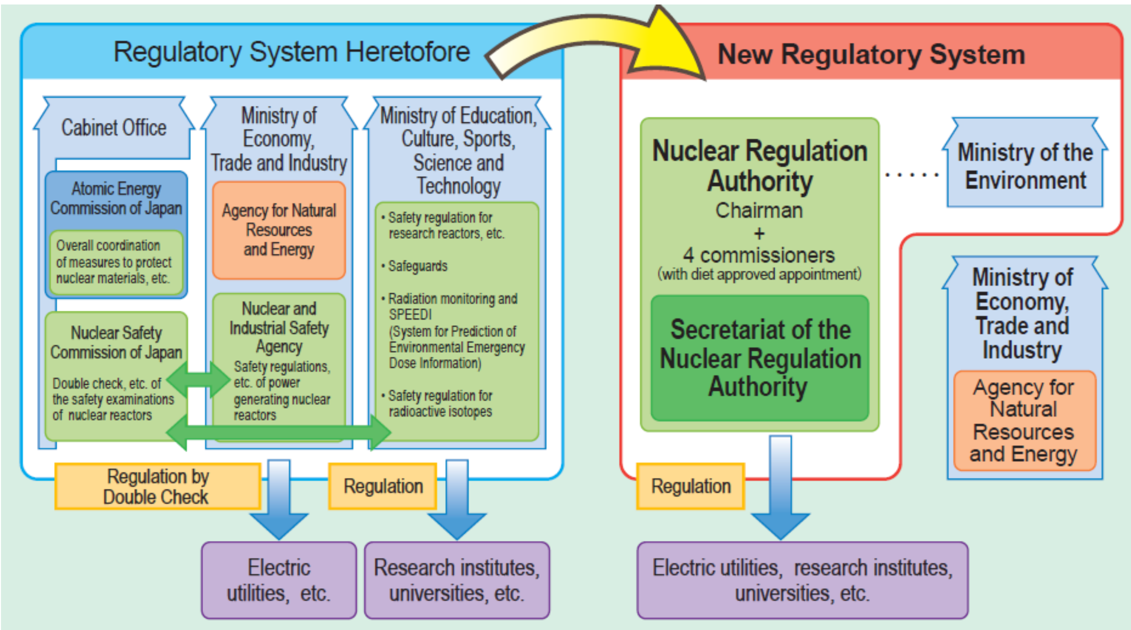


Figure 20 Regulatory system reformation

(Source: Nuclear Regulation Authority)

[10] NRA website, URL https://www.nsr.go.jp/english/e_nra/nsr_leaflet_English.pdf [Accessed 16 October 2017]

[11] (example) "Solitary Nuclear Regulation Authority", Kensaku Amano, 2015 (Japanese only), URL: http://www.energy-forum.co.jp/eccube/html/products/detail.php?product_id=338 [Accessed 16 October 2017]

(2) Revision of Nuclear Regulations[12]

The scope of the safety regulation in Japan before Fukushima Daiichi accident was much narrower than that of today. For example, the previous regulation did not include necessary measures to maintain the resilience against external disasters such like tsunami nor comprehensive diversity of the safety equipment. Taking into account the lessons learned from the Fukushima Daiichi accident as well as current scientific and technological knowledge, the NRA revised nuclear regulations. The major issues are listed below:

(a) Development of countermeasures against severe accidents

- Development of further preventive measures against release of radioactive materials into the environment is needed
- Preventive measures shall be included in licensees' Operational Safety Programs

(b) Introduction of back-fit systems

- All nuclear reactor facilities, including existing plants, shall meet all new regulatory requirements

(c) Introduction of a 40-year operational time limit* for nuclear reactor facilities

- The operational time for 40 years will begin on the day the operation started

* The operation of a nuclear reactor for more than 40 years will be permitted by the NRA only in cases where the nuclear reactor meets the regulatory requirements.

On July 8, 2013, the Nuclear Reactor Regulation Law was amended to revise regulatory requirements based on a concept of "defense-in-depth". In addition to reinforcement of the previous requirements, new requirements have been introduced to prevent or moderate severe accidents as well as external hazards including terrorist attacks.

Operators have been required to install specific facilities designated by the NRA in preparation against severe accidents. Additional reviews required for these facilities have made the review procedure more complex, and this is exactly why the lead time for the reviewing process has been so long so far.

[12] Nuclear Regulation Authority (2013), "Enforcement of the New Regulatory Requirements for Commercial Nuclear Power Reactors", URL: https://www.nsr.go.jp/data/000067212.pdf [Accessed 16 October 2017]

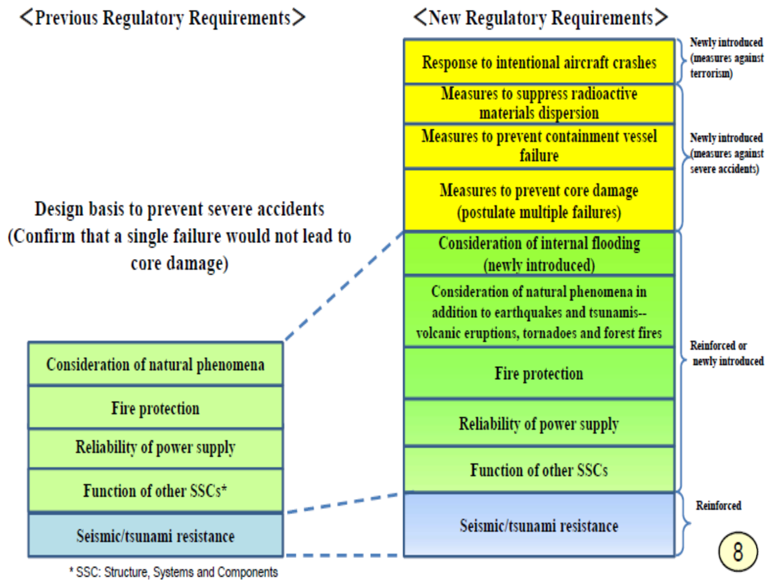


Figure 21　Comparison between previous and new regulatory requirements

(Source: Nuclear Regulation Authority)

(3)　The flow of review and inspection[13]

Application reviews for the “reactor installment license (general safety review)”, “plan for construction works”, and “operational safety programs” are conducted to check if the technical specifications fit with the regulatory requirements. Reviews for these three plans proceed in parallel to confirm the effectiveness of both the hardware and software in an integrated manner.

[13] NRA website, URL: https://www.nsr.go.jp/english/regulatory/20150826.html [Accessed 16 October 2017]

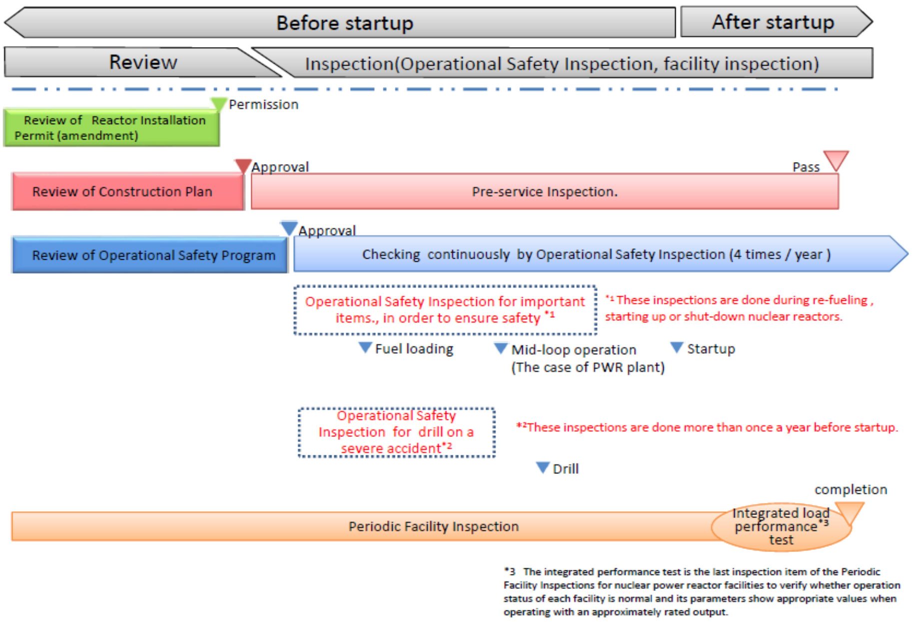


Figure 22 The flow of review and inspection

(Source: Nuclear Regulation Authority)

(4) Current status

As of April 2018 (six and a half years after the Fukushima Daiichi accident), only five nuclear power plants had restarted operation after the safety review. One of the reasons for this limited numbers of restart is suggested by some experts that the NRA review process takes far longer time than expected because of limitation in numbers of NRA staff, more stringent safety requirements than originally expected, etc.

Table 6　NRA review status

As of Apr.2018

Units	Application to NRA	Restart	Duration(days)	No. of hearings
Sendai 1	7/8/2013	8/14/2015	767	802
Sendai 2	7/8/2013	10/21/2015	835	
Takahama 3	7/8/2013	2/1/2016	938	553
Takahama 4	7/8/2013	2/27/2016	964	
Ikata 3	7/8/2013	8/15/2016	1,134	498
Ohi 3	7/8/2013	4/10/2018	1,737	466
Genkai 3	7/12/2013	4/18/2018	1,741	428
Units	**Application to NRA**	**Permission for Changes in Reactor Installation**	**Duration(days)**	**No. of hearings**
Genkai 4	7/12/2013	1/18/2017	1,286	428
Ohi 4	7/8/2013	5/24/2017	1,416	466
KK 6/7	9/27/2013	12/27/2017	1,552	646
Tomari 3	7/8/2013	-	-	374
Shimane 2	12/25/2013	-	-	190
Onagawa 2	12/27/2013	-	-	265
Hamaoka 4	2/14/2014	-	-	187
Tokai Daini	5/20/2014	-	-	892
Higashidori 1	6/10/2014	-	-	-
Tomari 1/2	7/8/2013	-	-	50?
Shika 2	8/12/2014	-	-	-
Hamaoka 3	6/16/2015	-	-	-
Tsuruga 2	11/5/2015	-	-	-

(Source: Nuclear Regulation Authority)

(5) Issues to be considered

After the Fukushima accident, nuclear restart progressed in a very modest and slow pace under NRA's review process. Given the critically important role of NRA, the following issues are to be considered for further improvement of effective safety regulation:

(a) Number of qualified staff of the NRA is limited in order to perform its assigned responsibilities. The number of full-time staff at the NRA is currently 920, some 330 of whom are part-time employees.[14] In contrast, the US-NRC has some 4,000 staff for 99 existing reactors. Due partly to the limitation of NRA's staff number, some nuclear power plants have not yet been reviewed even though they have already applied for review. It is necessary for NRA to reinforce its personnel.

(b) The regulatory activity should be conducted in an effective and predictable manner. Integrated Regulatory Review Service (IRRS) conducted by the International Atomic Energy Agency (IAEA) recommends the "NRA should consider developing a hierarchical structure for the management system which supports effective and consistent implementation of regulatory activities".

(c) The NRA should be independent, but not be isolated. The NRA should promote and enhance sufficient dialogue with external experts and the operators. Since the Three Mile Island accident in the US, the NRC and industry have worked cooperatively to make nuclear regulations more efficient and valid. The NRA will benefit by learning from the experiences of the US case.

(d) Current regulatory activities sometimes seem to require operators prove "zero risk" for the nuclear power plants. Instead, regulations should define tolerable risk based on the fact that there is no such thing as "zero risk" in nature, while operators should make an effort to keep risk as low as possible.

(e) Meetings for the safety review are disclosed on YouTube, and the minutes of the meetings on the NRA's website. However, both the videos and minutes are very long, and have many technical terms that are hard to be understood by non-specialists or ordinary citizens. While this is conducted to promote "transparency", according to NRA, other measures may be necessary for the purpose of the real "transparency" and better understanding.

(f) The NRA's duty is to pursue nuclear safety, not to consider economic efficiency. But the fact is that the public will have to pay the additional cost in a form of increased electricity bill or tax if the safety regulation is too strict or the review process takes longer than necessary.

The role of NRA is critical for the future safe usage of nuclear power in Japan. It is recommended that NRA should further promote effective nuclear safety regulation and

[14] NRA website, URL: https://www.nsr.go.jp/data/000148261.pdf [Accessed 16 October 2017]

licensing activities in a predictable manner, by optimum use of dialogue with relevant stakeholders, lessons learned from advanced experiences, etc.

3-2-2 Safety regulatory scheme in the Republic of Korea

(1) Overview of the NSSC

The Nuclear Safety and Security Commission (NSSC) is an independent central government agency responsible for managing nuclear safety. It was established to protect people and the environment from the risk of radiation and to supervise radiation-users' implementation of safety management responsibilities. After being established under the President of the Republic of Korea pursuant to the Act on Establishment and Operation of the NSSC in 2011, the NSSC was moved to the Prime Minister's Office following a cabinet reshuffle. The NSSC independently regulates overall nuclear safety as a government body and cooperates with ministries such as the Ministry of Science, ICT and Future Planning (MSIP); the Ministry of Trade, Industry and Energy (MOTIE); and the Ministry of Environment (ME).

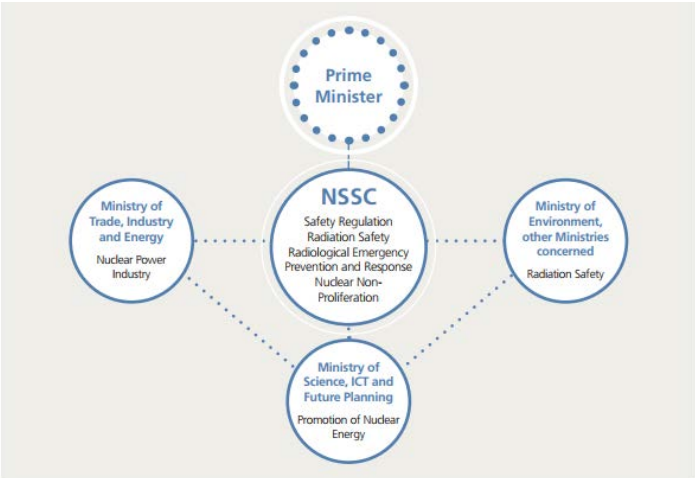


Figure 23 Administration System for the Nuclear Safety and Security Commission

(Source: Nuclear Safety and Security Commission)

(a) Organization

As a consensual administrative organization that makes independent decisions on nuclear issues, the NSSC is headed by two standing commissioners (the Chairman and Secretary General) and seven non-standing commissioners (external professionals recommended by the Government and the National Assembly).

Regarding the competence of the commissioners of the NSSC, the Act on the Establishment and Operation of the NSSC (AEON) requires that "Commissioners shall be appointed or recommended from among those people with superior insight and experiences in the fields and of various fields, such as nuclear energy, environment, health and medicine, science and technology, public safety, law, liberal arts, and sociology, to contribute to nuclear safety." This ensures the needed nuclear safety competence. Also, the AEON sets out requirements that disqualify from acting as Commissioners any persons who belong to a political party or who have been involved with nuclear energy user groups within the previous three years. In addition, the AEON requires the exclusion of Commissioners from matters in which they may have a personal conflict of interest.

The NSSC has a head office, which consists of the Planning and Coordination Office, Nuclear Regulatory Bureau and Radiation Emergency Bureau, as well as four regional offices nationwide. It is responsible for safety regulation on R&D, production, and utilization of nuclear energy. The Korea Institute of Nuclear Safety (KINS), Korea Institute of Nuclear Non-proliferation and Control (KINAC), and Korea Foundation of Nuclear Safety (KOFONS) provide the NSSC with expertise and technical support for nuclear safety and security.

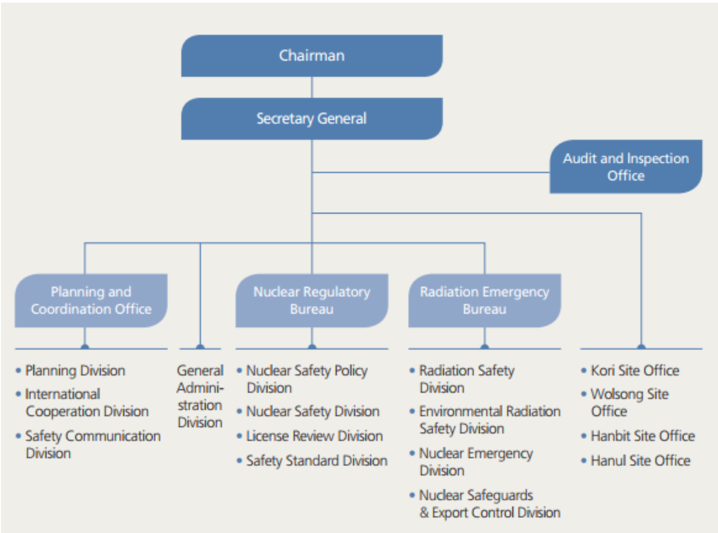


Figure 24　Organization Structure of the NSSC

(Source: Nuclear Safety and Security Commission)

(b) Staffing and Budget

To strengthen regulation of nuclear safety and security and to ensure regulatory transparency, the nuclear safety regulation fund was increased in 2016 and has been allocated 178.2 billion won (US$158 million). A total of 764 employees (140 from the NSSC, 501 from the KINS, 82 from the KINAC, and 41 from the KOFONS) are working full-time to enhance nuclear safety regulations as of the end of 2016.

(c) Regulation on Nuclear Safety

To prepare for unexpected natural disasters, the NSSC has improved the safety of nuclear power plants by enhancing the anti-seismic design basis, installing automatic shutdown facilities and flood gates, and extending flooding barriers. In the case of loss of power or flooding into nuclear power plants, the NSSC would prevent the situation from degenerating into a severe accident by providing mobile EDGs (Emergency Diesel Generators) and extra storage batteries, and installing outside injection channels for emergency cooling water. In the case of damage to nuclear fuel, the NSSC would prevent massive release of radioactive materials by installing an extra hydrogen elimination device, building exhaust ventilation systems in containment buildings, and upgrading guidelines on serious accident management. To improve emergency response capability and minimize damage in the case of a large release of radioactive materials, the NSSC carries out radiological emergency response exercises and enhances response capability for simultaneous accidents at multiple reactors.

(2) Licensing Process

(a) Safety Regulation Process for the Nuclear Power Plant

The national policies and strategies to ensure the safe use of nuclear energy are prescribed in the Nuclear Safety Act, based on which the NSSC's responsibilities cover nuclear reactors; fuel cycle facilities; uses of nuclear materials; and transport, storage and disposal of radioactive materials and waste.

The NSSC conducts site approval, issuance of construction permits, pre-operational inspection, issuance of operation licenses, QA inspections, and periodic safety reviews for regulation of nuclear facilities.

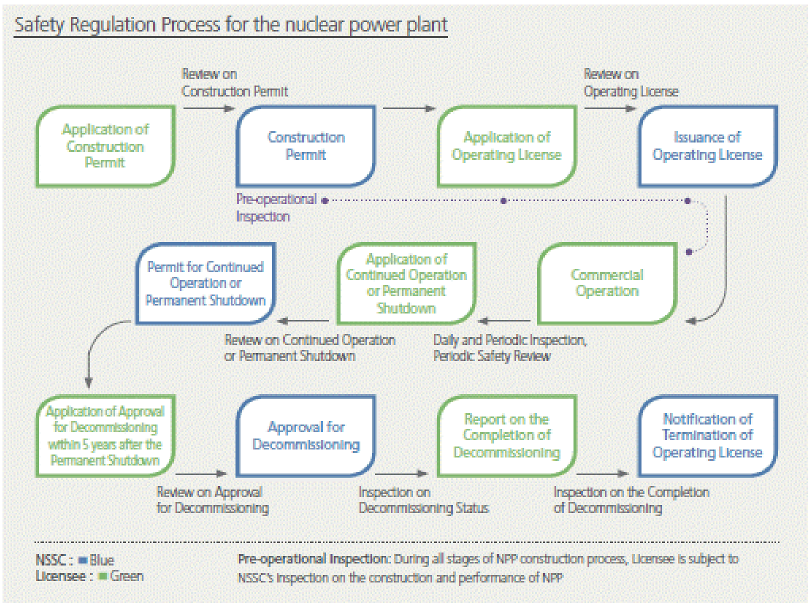


Figure 25 Safety Regulation Process for the Nuclear Power Plant

(Source: Nuclear Safety and Security Commission)

(b) Inspection on the Treatment of the Radioactive Materials

The NSSC is responsible for overall safety of packaging, transport, storage, and disposal of radioactive isotopes; nuclear and radioactive materials; and radiation levels.

For regulation of radiation-utilizing facilities and institutions, the NSSC reviews and assesses applications of their products, distributions, and uses. The NSSC also conducts pre-service inspection, periodic inspection, quality assessment, and other regulatory inspections to check whether the facilities and institutions comply with the standards and regulations imposed on their licenses.

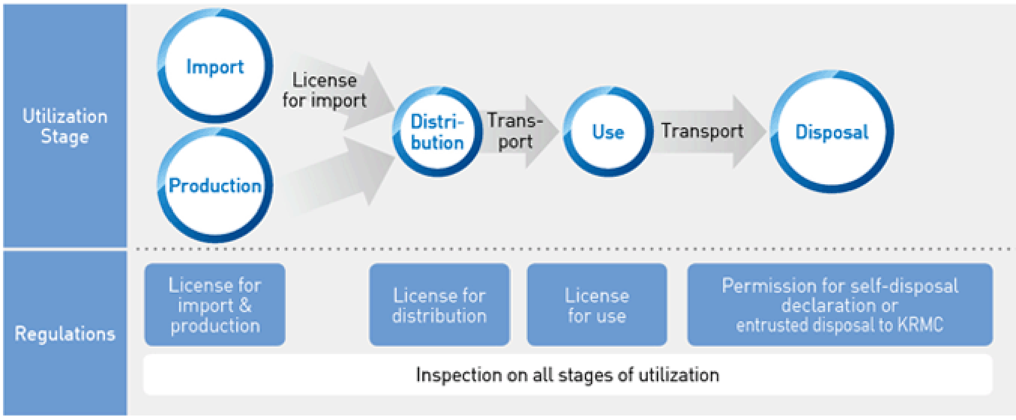


Figure 26 Inspection Process on the Treatment of the Radioactive Materials

(Source: Nuclear Safety and Security Commission)

(c) Managing Emergency Preparedness

The NSSC oversees all affairs related to radiological emergency preparedness and response according to the Act on Physical Protection and Radiological Emergency.

The national emergency preparedness network includes the Central Radiological Emergency Response Headquarters (a main center operated by the NSSC), the Off-site Radiological Emergency Management Center, and the Regional Radiological Response Headquarters led by regional governments. The Korea Institute of Nuclear Safety established the Radiological Emergency Technical Advisory Center to provide technical support, and the Korea Institute of Radiological and Medical Sciences established the Radiological Emergency Medical Support Center to provide medical aid.

The NSSC conducts emergency drills at both the national and regional levels. To enhance capabilities to cope with extreme conditions, it develops and implements new types of scenarios that include the complicated and simultaneous occurrence of accidents at multiple reactors.

The NSSC is expanding its infrastructure to manage radiological emergency by increasing the number of unmanned environmental radiation monitoring posts, regional radiation monitoring stations, and radiological emergency medical centers.

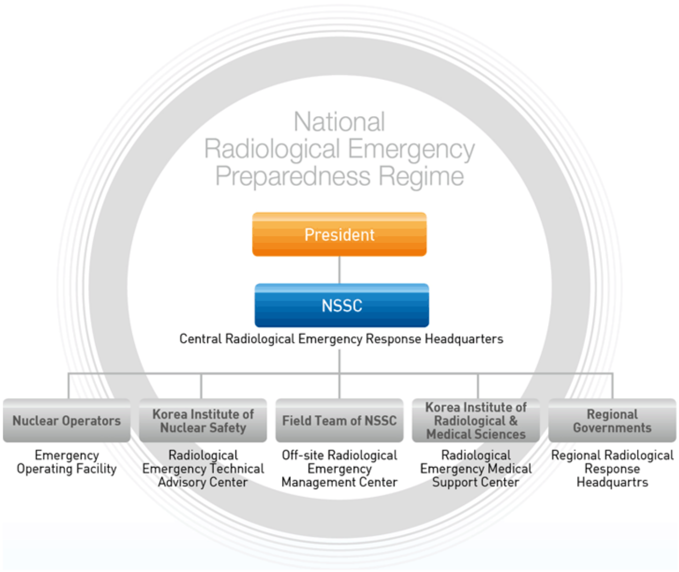


Figure 27 National Radiological Emergency Preparedness Regime

(Source: Nuclear Safety and Security Commission)

(d) Control of Nuclear Security

The NSSC has been actively supporting the efforts of the international community to strengthen physical protection. Based on the Act on Physical Protection and Radiological Emergency, the NSSC assesses threats and determines the Design Basis Threat to prevent internal and external threats and minimize damages. Nuclear operators are asked to build a physical protection system that fits the characteristics of their own facilities and meets the determined Design Basis Threats. The NSSC inspects the facilities to confirm their compliance with the requirements.

3-3 Global market for new nuclear power plants

Projects for the new construction and planning of nuclear power plants are in apparent progress in such countries as China, India, Bangladesh, Pakistan, Russia, Belarus, the Czech Republic, Ukraine, Brazil, Argentina, the UAE, and Turkey. Most of these states are not OECD members; while projects in OECD countries are generally confronting serious difficulties. Plants that have launched commercial operation in the past three years are Kudankulam 1 & 2 in India (VVER, the Russian-type LWR), Bushehr 1 in Iran (VVER), Chashma 3 & 4 in Pakistan (CNP-300, the Chinese-type LWR), Shin-Kori 3 and Shin Wolsong 2 in the Republic of Korea (OPR-1000 and APR-1400), and several plants in China. All of these plants have adopted the reactor design technology of non-OECD countries, which is noteworthy.

Meanwhile, the new construction projects in OECD countries are making slow progress compared to their non-OECD counterparts. With the exception of Vogtle 3 & 4, most of the projects in the US have been suspended, mainly due to the low wholesale price of electricity.

The Vogtle 3 & 4 reactors have adopted the AP-1000 supplied by Westinghouse.

Taishan 1, under construction in China, is the first reactor adopting EPR design technology in China. There are two more EPRs under construction in Europe, Olkiluoto 3 in Finland and Framanville 3 in France. Taishan 1 will start commercial operation in early 2018; therefore, it will be the first EPR in operation in the world. Nevertheless, the construction period of Taishan 1 is much longer than those of other reactors that have recently started commercial operation in China. In general, reactors adopting OECD technology appear to require more time for construction than those adopting non-OECD technology.

A longer construction period demands more human resources, more work units, and most of all, more money. Developing countries suffer from chronic electricity shortages and immature social infrastructure, which may lead them to prefer conventional reactor technologies with a given level of safety to a state-of-the-art reactor design. On the other hand, a shorter construction period resulting in lower construction costs would be one of the most important elements for developing countries.

As of 2017, the construction work for Barakah 1, the first commercial reactor in the UAE, is almost complete and will start test operations in early 2018. The construction period for Barakah 1 is likely to be some 6 years, remarkably short compared to those of Taishan 1 (some 9-10 years) and of Olkiluoto 3 (more than 10 years). The successful completion of Barakah 1 would be a significant boon for the Republic of Korea's consortium developing new construction markets in non-OECD countries, and would be a serious threat to all competitors such as Rosatom, Hitachi-GE Nuclear Energy, Areva, ATMEA, Mitsubishi Heavy Industries, and CGN/CNNC.

In which regions or countries are there promising markets for vendors and suppliers from the Republic of Korea and Japan? This is an interesting issue. The KHNP lists Ukraine, the Czech Republic, Slovakia, and Poland as promising markets overseas.[15] Japanese companies list Turkey, the Czech Republic and the UK as their promising markets. How can the nuclear industry judge the prospects of these potential markets?

Ten years ago, when people called the new construction boom in the US "a nuclear renaissance", the US was considered the most promising market for new construction projects. Major reasons were the relatively low geological risk, stable economic condition, mature social infrastructure, and governmental support system. Nobody anticipated the low wholesale market electricity price due to the shale gas revolution and the rapid penetration of renewables of today. Nevertheless, the US market still has features of the strengths mentioned above, and most importantly, its electricity demand is slowly increasing. It can still be a promising target for new construction projects, as is the UK.

In consideration of the strongest incentive for the necessity of new nuclear power plants,

[15] KHNP website, URL: http://www.khnp.co.kr/eng/content/846/main.do?mnCd=EN03060201 [Accessed 16 October 2017]

namely “demand”, developing countries suffering from a chronic shortage of electricity should be a major promising target to develop. Hence, countries like the Czech Republic, Iran, and India seem to be promising markets for both South Korean and Japanese vendors.

In 2016, India and the US agreed to promote the plan of constructing six AP-1000 plants in India. This was before the fatal losses of the AP-1000 projects in the US were revealed, and today the plan of introducing AP-1000 plants to India seems to have stalled. India has a strong incentive to increase its nuclear share for various reasons, so any proven technology with a short construction period and a given level of safety, such as the APR-1400, would be highly appreciated. ATMEA1 is another prospective technology for India; however, the design concept and the “state-of-the-art” safety philosophy would likely be more accepted by developed countries than by developing countries. The weakness of ATMEA1—if one could call it a weakness—is that it has not yet been used in an operating plant. The debut of ATMEA1 would more likely be in a developed country.

A short construction period, or at least the prevention of a prolonged construction period, is a crucial condition and a fundamental requirement for developing countries. South Korean technology introduced to UAE is the only construction of plants using technology of non-OECD countries which has been successfully completed in the past several years. Why have developing countries accepted these reactor designs and successfully constructed them quickly? The nuclear industries of South Korea and Japan need to consider this question and to restructure their marketing strategies to developing countries, conducting in-depth analyses of their users’ actual requirements.

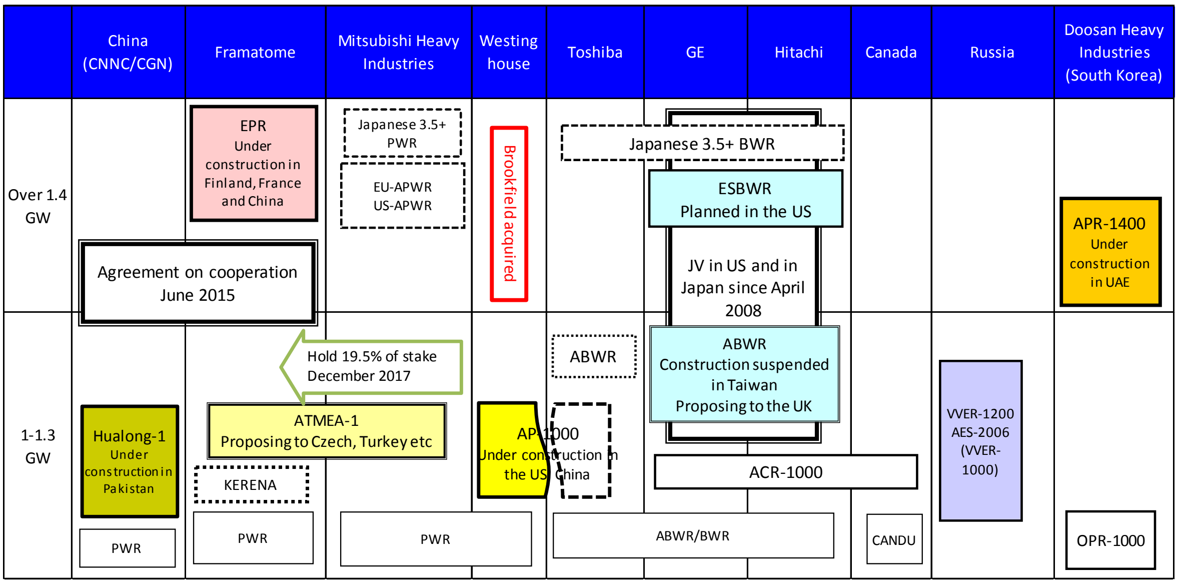


Figure 28　Competition-Cooperation Map of Vendors

(Source: Websites of the vendors)

3-4 Electricity Market reform

In Chapter 2-2-3, the cost of nuclear power generation was discussed. This analysis compared power generation costs only, and important advantages of nuclear power such as zero emissions and the stability of electricity supply as base-load power source were not included in the evaluation axis.

Recently, the GOJ has started to conduct a comprehensive electricity market reform in order to promote competition and market efficiency. But electricity market liberalization sometime creates complicated challenges with regard to energy security and environment protection. In this regard, this section will discuss the background of the establishment of the capacity market and non-fossil fuel market in Japan in a bid to address energy security and environment protection in a liberalized market.

3-4-1 Background of the electricity market reform in Japan

In Japan, regional monopoly electric utilities were traditionally responsible for the stable supply of electricity. These utilities had secured supply capacity based on the stable earnings guaranteed by regulated tariff ("costs pass-on to consumers" approach), and had promoted the development of power sources aligning with the government's energy policies such as energy security and global warming response.

After the accident at Fukushima Daiichi Nuclear Power Station in 2011, comprehensive review of Japan's energy policy started., Although electricity market reform has been taking place in a stepwise manner since 1995, in the context of the before-mentioned comprehensive energy policy review, the Electricity Business Act was amended in 2016 to complete the process and it is considered as one of the center piece of the comprehensive review. All electricity markets (including one for households) were liberalized, and the mechanism for allowing electric utilities' regional monopolies was abolished.

New entrants into the electricity market increased after the liberalization of 2016, and the predictability of the earnings of existing electric utilities declined. Therefore, it has become difficult for existing electric utilities to construct new power plants with large scale initial capital investment even if they can feature high supply reliability and low CO2 emissions that satisfy the government's policy. To achieve the target power portfolio in 2030 under a liberalized, competitive market, Japan requires a new framework to promote power developments that matches policy objectives. In this regard, power market in Japan faces trade-off relation between achieving policy desired best mix and pursuing market liberalization.

3-4-2 Capacity mechanism

In Japan, investment in new power plants has recovered primarily through regulated tariffs under the "costs pass-on to consumers" method, but today under the liberalized market without regulated tariffs, the expected return on investment in power plants can be much less and uncertain. In addition, since the introduction of the FIT system targeting renewable energy in July 2012, the introduction of renewable energy has been rapidly expanding; however, this has caused the decline of other power plants' capacity factors. At the same time, the wholesale power price is expected to decline due to the lower marginal cost of electricity generated from renewable energy. Deterioration of the profitability of the electricity business is highly probable in the future.

If the electric utilities' willingness to invest in power supply declines due to the above factors, new construction or replacement of power plants would be difficult. As a result, the following problems might occur: (1) rapid increase of electricity charges if and when a period of tight supply and demand emerges in the future, and (2) inability to secure the necessary adjustment of the power supply when intermittent supply from renewable energy increases.

These problems are difficult to solve only with the supply power adjustment function of the wholesale electricity market. The government thus decided that measures to secure a certain degree of predictability of recovering investment in power supply developments were necessary. Studies on the introduction of a capacity market are being conducted; the specific scheme is yet to be determined. The capacity mechanism is a "measure to reward the availability of electrical generation capacity in order to ensure that electricity supply can match demand in the medium and long term" (Erbach 2017).[16]

The total required capacity for a few years ahead is decided and is centrally allotted in an auction. Capacity providers bid to receive a capacity payment that reflects the cost of building or maintaining capacity.

The UK held its first capacity market auction in December 2014, the second one in 2015, and the third one in 2016. Successful bids were made for all nuclear and hydro capacity. The winning bid prices were £19.40/kW/year in 2014, £18.00/kW/year in 2015, and £22.50/kW/year in 2016. In the UK and some states in the US, capacity auction compensates for the nuclear operators' losses in spot markets.

3-4-3 Non-fossil fuel market

Japan's energy supply is highly dependent on both fossil fuels and imports, and the country's energy self-sufficiency rate is very low compared to other developed countries'. For this reason, Japan's economy is vulnerable to fluctuations in the import price of energy, and it is difficult to respond to large scale supply disruption in the world energy market that are caused by international circumstances. This is a major challenge for the supply structure.

[16] Gregor Erbach (2017),"Capacity mechanisms for electricity" European Parliamentary Research, Service Members' Research Service PE 603.949, URL: http://www.europarl.europa.eu/RegData/etudes/BRIE/2017/603949/EPRS_BRI(2017)603949_EN.pdf [Accessed 16 October 2017]

To address these issues, the Act on Sophisticated Methods of Energy Supply Structures was enacted in 2009. Under this act, in order to expand the introduction of non-fossil fuel energy sources, the government sets a target to be achieved by companies and provides administrative guidance to any companies that fall short of their goals without sufficient reason. Based on the law, the government sets the target for the entire electric power business, according to which the ratio of non-fossil fuel power sources should be 44% or more in 2030.

Although the target ratio for non-fossil fuel power sources for electric utilities has been set, there is no market for trading non-fossil fuel credits in Japan. For this reason, one of the practical challenges for electric utilities is their insufficient means of achieving the goal for non-fossil fuel power sources. Based on these circumstances, the creation of a new market for such credits is currently under consideration.

According to the plan currently under consideration, power producers who generate electricity with non-fossil fuel power sources could receive credit certificates from a public agency based on the amount of power generated, and sell these credits in a market. When the system is implemented, non-fossil fuel power sources, including nuclear power, could gain revenue from these sales of the credits as well as from the sale of the electricity itself. Non-fossil fuel power sources' competitiveness would thus improve.

4 Stakeholder involvement and regional cooperation in Asia

4-1 Public debate on Shin-Kori 5 & 6

On October 22, 2017, the new administration of South Korea announced that the construction of two nuclear power plants named Shin Kori 5 & 6, which had been temporarily halted since mid-July, would be resumed. The announcement followed the administration officially receiving the outcome of the public debate on the issue: a deliberative poll result in favor of the resumption.

South Korea is the fifth-largest producer of nuclear energy in the world, with its 24 reactors generating about a third of its electricity. After the new administration took office in early 2017, it announced it would phase out coal and nuclear energy, mainly due to the public's growing concerns about air pollution and nuclear safety respectively. Instead, it would increase the share of renewable energy to 20% of all electricity generation by 2030. The new policy created concern about whether the two ongoing construction projects named Shin Kori 5 & 6 would be halted, sparking heated debates between pro- and anti-nuclear advocates in South Korea. As of May 2017, Shin Kori 5 & 6 were about 30% complete, with roughly US$1.4 billion already spent and estimated total losses (sunk costs) of US$2.3 billion if scrapped. Campaigners favoring resumption of the construction assured that the Shin Kori 5 & 6 would be "the most safety upgraded version of the generation III type, equipped with intensive safety features," while those for cancelling it expressed their concerns about the location of these nuclear reactors in a highly populated area, no matter how advanced the safety measures would be. To resolve the gaping discrepancy between both parties, the administration temporarily suspended the construction and proposed establishing an independent, ad hoc committee on managing public debate and a deliberative opinion poll on whether the Shin Kori 5 & 6 should proceed or not. South Korea's public debate on nuclear energy policy proceeded in a similar way to what Stanford professor James Fishkin defined and explained in his work on deliberative democracy. The committee conducted four rounds of surveys in total, including initial phone interviews of about 20,000 people, which allowed the committee to follow up on changes of opinion. Based on a German format used in selecting nuclear waste disposal sites, the committee randomly selected 500 people, considering demographics in South Korea, and invited them for deliberation. The participants were provided with briefing materials prepared by both pro- and anti-nuclear groups. Lectures were also offered by competing experts followed by Q&A sessions, and then the participants were given opportunities to discuss the issue face-to-face in small groups.

After one month of actual deliberation—three months for the committee's activity in total—59.2% of the 471 participants in the final survey responded that they were in favor of resuming the construction work on Shin Kori 5 & 6, while 40.5% supported cancelling it. Other noteworthy details were as follows:

1. In the regions where all nuclear facilities were located in South Korea, the resumption was preferred
2. Males were more likely than females to prefer resumption

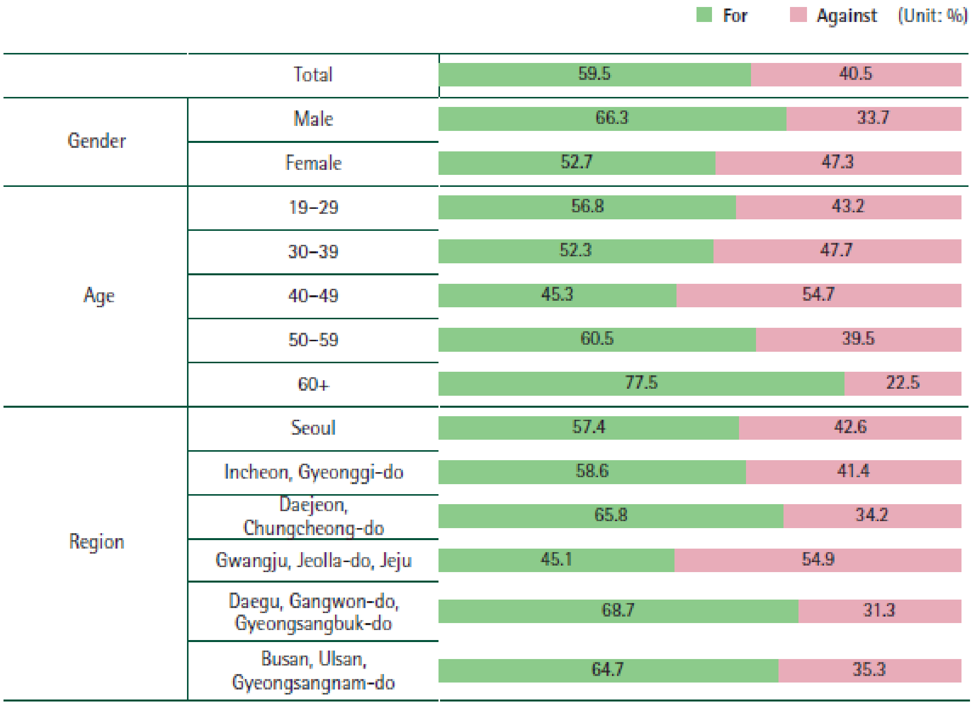


Figure 29 Respondent Opinions on Whether to Resume Construction by Gender, Age, and Geographical Location

(Source: Results of Participatory Surveys for Public Deliberation on Shin-Gori Nuclear Reactors No. 5 & 6)

As secondary measures in the above poll, the participants also responded that, among four choices of immediate government actions necessary after resuming the construction, respondents' preferences were ranked as follows: (1) strengthen nuclear safety measures (first choice of 33.1% of respondents); (2) expand investment in increasing the share of renewable energy in the energy mix (27.6%); (3) promptly prepare a plan to resolve the spent fuel issue (25.3%); and (4) maintain the nuclear phase-out policy (13.3%). It was recognized at that time that, since only four options were given, the "last-place" finish of the phase-out could be interpreted as a sign the phase-out was not considered necessary. However, the survey also found that 53.2% supported the policy of gradual reduction of nuclear facilities, with 35.5% in favor of maintaining the status quo and 9.7% calling for nuclear expansion.

Although the new regime promptly accepted the committee's recommendation of resuming Shin Kori 5 & 6 construction, it has stood by its nuclear phase-out policy based on its interpretation of the poll to consider the gradual reduction of nuclear facilities equivalent to a nuclear phase-out. Anti-nuclear groups expressed their dissatisfaction with the resumption of construction, but added that they would respect the government's final decision based on this deliberative polling. Meanwhile, pro-nuclear advocates immediately welcomed the resumption of construction, but expressed concerns about government's adhering to its nuclear phase-out policy otherwise.

Following the public debate, the controversy over Shin Kori 5 & 6 has persisted because the government is pursuing the nuclear phase-out policy without additional confirmation from the people. The country is still divided on how to plan and prepare for its energy future. Pro-nuclear campaigners warn that the new nuclear phase-out policy could lead to a sharp rise of electricity bills, a potential energy shortage, and the downturn of South Korea's nuclear export capacity. They also point out that increasing the share of LNG in South Korea's energy mix would create other problems, while renewable energy technology is still in a rudimentary stage. In contrast, anti-nuclear advocates assert that safety and environmental concerns should be given priority over economic gains, and argue that LNG, which they consider less dangerous than nuclear energy, could be used as a bridge energy source until renewables become more competitive. They also insist that even if nuclear safety measures were sufficiently advanced, the impact of any nuclear accident caused by human mistakes or misjudgment would be far more critical than any accidents involving other sources of electricity generation.

On the one hand, many South Koreans say that they do not know what's going on in nuclear energy issues. One of the essential questions from the public is the lack of transparency in planning and implementing nuclear energy policy, which has been heavily dominated by key stakeholders for several decades, a trend that has continued under the current administration. Although the knowledge and opinion of experts on nuclear technology should be respected in any case, and the authority to make nuclear energy policy decisions is the government's, the recent Shin Kori public debate experience could be followed up with a wider public debate and deep discussion of the future of nuclear energy in South Korea. The deliberative polling with regard to the resumption of construction on Shin Kori 5 & 6 had its own limits, such as insufficient time assigned for deliberation and a lack of consideration for the voices of local residents around the plant. Nevertheless, this experiment, with proper and agreeable adjustment between the concerned parties, is expected to serve as an important model for decision-making to peacefully resolve or manage conflicts over other highly divisive issues.

4-2 Publication of "Nationwide Map of Scientific Features" for geological disposal

4-2-1 Outline

The GOJ published the "Nationwide Map of Scientific Features for Geological Disposal" (hereafter, "the Map") in July 2017. The Map classifies all areas of Japan into four categories with respect to their potential for disposal of nuclear waste, namely: "area with unfavorable geological features", "area endowed with natural resources", "area with good chance to be confirmed as having favorable characteristics", and "area within the former area where it is favorable from the viewpoint of waste transportation". The Map does not indicate any specific location as a disposal site. It is instead intended to be the first step on the long road toward the decision of such a site.

The process of decision-making toward a final high-level radioactive waste depository contains implications for stakeholder involvement, since various stakeholders have played relevant roles for several decades. It is important to learn lessons from the decision-making process and to put them into practice for better risk communication regarding nuclear energy and radioactivity.

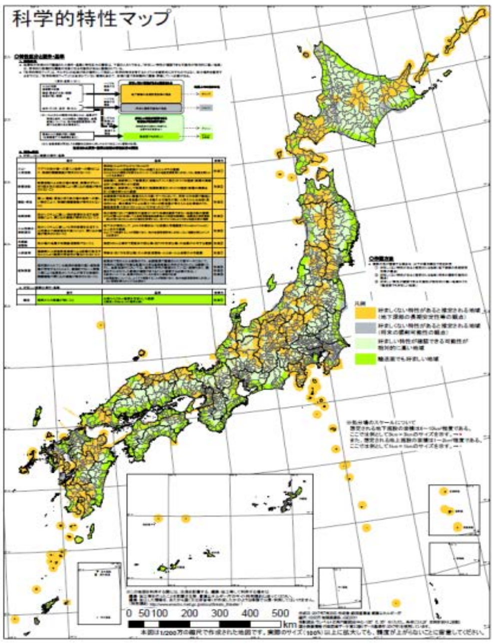


Figure 30　Nationwide map of scientific features for geological disposal

(Source: Ministry of Economic, Trade and Industry)

4-2-2　Chronology

R&D related to the final disposal of high-level radioactive waste (HLW) started in the late 1970s in Japan. The major concern was the safe management of vitrified HLW generated from fuel reprocessing.

The Second Progress Report on R&D for the geological disposal of HLW was published in 2000, and it showed that disposal of HLW in Japan is technically feasible and can be practically implemented at sites which meet certain requirements for geological stability. Based on the report, the Act on Final Disposal of Specified Radioactive Waste (hereafter "Final Disposal Act") came into force in 2000. The act stipulates the deep geological disposal of HLW at depths greater than 300 meters, together with a stepwise site selection process in three stages, in the Basic Policy on the Final Disposal of Designated Radioactive Wastes (hereafter "Basic Policy").

The Nuclear Waste Management Organization of Japan (NUMO) was established in October 2000, as a corporation authorized by the Final Disposal Act, to implement a project for the geological disposal. The NUMO initiated the siting process with open solicitation of volunteer host municipalities for exploring the feasibility of constructing a final repository.

This open solicitation approach was announced in December 2002. Nine municipalities expressed their interest, but six withdrew their positive statements because local newspapers exposed these municipalities' plan for hosting a HLW repository before the plan's official announcement which resulted in strong local opposition. In two other municipalities, the mayors consulted with the town councils, but could not get their consent and gave up. Only Toyo town in Kochi Prefecture formally applied for the literature survey to NUMO, but the mayor who applied then lost re-election, and the new mayor withdrew the application. Since then, nothing has happened on this front for over 10 years.

4-2-3 Chronology: Revision of the Basic Policy[17]

On May 22, 2015, the Cabinet decided to approve a revision of the Basic Policy based on the Final Disposal Act. Major points are:

- While making efforts based on the responsibility of the present generation to alleviate the burden of future generations, the GOJ will ensure reversibility and retrievability and promote technological development for alternative options
- The GOJ will ensure that the wider population demonstrates gratitude and respect to areas contributing to the projects
- The GOJ will select scientifically suitable areas and invite local governments to cooperate in the investigation
- The GOJ will support consensus building and sustainable development in local communities
- The Japan Atomic Energy Commission will regularly evaluate progress in technological development, etc.

Major purpose of the revision is to give more significant responsibility and role to the GOJ, rather than to local municipalities or electric utilities, since the problem of HLW is a national issue.

4-2-4 Basic concept of geological disposal in Japan[18]

The high-level safety features of the Japanese disposal concept can be summarized as follows:

- Multiple engineered barriers (e.g. glass matrix, overpack, bentonite) are used to ensure that the failure of one barrier does not jeopardize the containment of radionuclides

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[17] METI website, URL: http://www.meti.go.jp/english/press/2015/0522_01.html [Accessed 16 October 2017]

[18] OECD-NEA (2016), "Japan's Siting Process for the Geological Disposal of High-level Radioactive Waste", URL: http://www.meti.go.jp/press/2016/08/20160809002/20160809002-1.pdf [Accessed 16 October 2017]

- The host rock will provide a favorable geothermal, chemical, mechanical and hydrological environment to maintain the stability and performance of the disposal system for over tens of thousands of years; the characteristics of the host rock will safely protect the emplaced high-level radioactive waste (HLW) from disturbances caused by natural events
- The repository will be located away from valuable resources (e.g. gas and coal mines) and at a depth such that future inadvertent human intrusion into the closed repository will be very unlikely

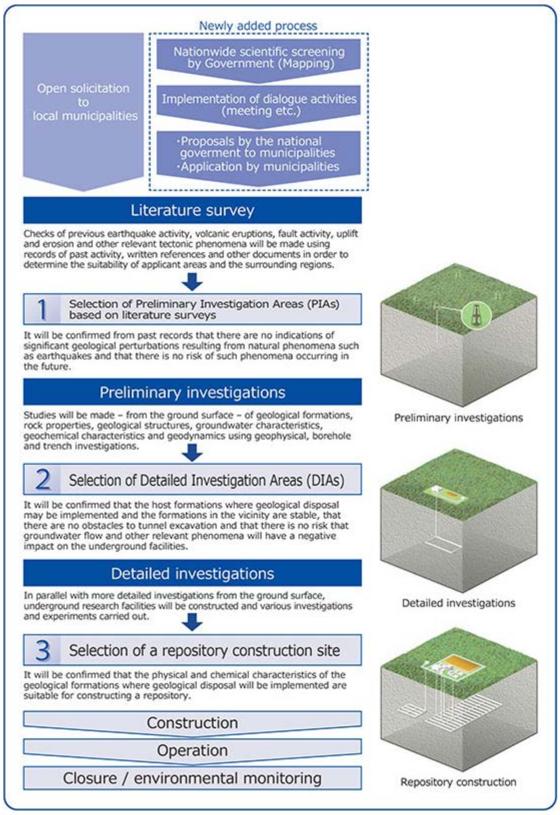

Figure 31 Geological disposal program

(Source: Nuclear Waste Management Organization of Japan)

4-2-5 Criteria for nationwide scientific screening

The Map defines the criteria for the nationwide scientific screening with the conditions below:

- Area to be avoided: “an area in which the required engineering is very difficult and/or a geological disposal facility is very likely to be significantly affected by events and characteristics directly associated with loss of safety functions”
- Area to be preferably avoided: “an area in which the required engineering may be very difficult and/or a geological disposal facility might be significantly affected by events and characteristics directly associated with loss of safety functions”

- Preferable area: “an area in which there is reasonable confidence (high likelihood) that the site features and characteristics would provide a good margin of safety of geological disposal”
- Preferable area from the viewpoint of project feasibility: “an area in which there is reasonable confidence in the engineering feasibility of implementation”

4-2-6 Process for selecting the repository site[19]

The site selection procedure specified in the Final Disposal Act consists of three steps, namely the literature survey, preliminary investigation, and detailed investigation.

The NUMO will compile reports on the investigation results at each stage of the process and will hold explanatory meetings. The opinions of the residents expressed at these meetings will be made known to the relevant prefectures and municipalities together with the NUMO’s views, and the selection will proceed on the basis of respecting local opinions, obtaining stakeholder agreement, and securing government approval.

The GOJ has stipulated that when approving each stage of the site selection process, the opinions of the municipality mayors and the governors of the prefectures concerned must be considered and respected. If the mayor or the governor does not agree with the process, then further steps will not take place.

Following the selection of a repository construction site, the disposal facilities will be designed, and a safety evaluation will be undertaken; construction will begin after the safety review by government experts has been completed and authorized.

The critical issue in this selection process is “an agreement between the GOJ, the hosting municipalities, and the operator”. Without a full agreement by the hosting municipalities, a plan could be suspended at any time during the procedure.

4-2-7 Lessons learned from dialogue with the public[20]

Lessons learned from the long activities so far are as follows.

First, it should be admitted that it is a little optimistic to believe that technological development might solve the problem of HLW while storage is still above ground. To continue storage at ground level would narrow the choices and increase the risk for future generations, indicating partiality for one’s own generation. The new Basic Policy explains the responsibility of the current generation to leave options for future generations.

Second, the prolonged struggle between the stakeholders shows the difficulty of explaining the scientific fact that the deep underground is extremely stable in the long term.

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[19] NUMO website, URL: https://www.numo.or.jp/en/jigyou/new_eng_tab03.html
[20] METI website, URL: http://www.meti.go.jp/committee/sougouenergy/denryoku_gas/genshiryoku/houshasei_haikibutsu_wg/pdf/031_03_00.pdf (Japanese)

This is widely known among scientists, but some laymen believe the underground is more unstable. After explaining the general characteristics of the deep underground, specific characteristics such as volcanoes or active faults should be carefully explained. Promoting better understanding is one of the major purposes of the Map.

Third, it has become apparent that the relationship between the Map and the selection process was misunderstood. Any disposal site cannot be determined without detailed investigation; however, some people seems to have thought that an "area with a good chance to be confirmed as having favorable characteristics" is going to be soon determined as a final disposal site. Continuous communication between the stakeholders, especially people living in the areas with scientifically favorable characteristics, should be carried out in depth.

Not only industry aspects but also social aspects are crucial to proceed with the final repository project. The consideration of business image and social aspects is important. The principal objective has been to inform the public of the technical issues regarding geological disposal. Today, however, it is important to deepen the argument and investigation while focusing on how society can accept geological disposal. The NUMO, as the major implementing body, should improve its presentation of information regarding businesses' image during construction and operation of the plant. The information shows environmental impacts, the future vision of the hosting municipality, and a long-term symbiotic image helps the residents in the hosting municipality to think about coexistence with the disposal facility.

The publication of the Map is, first of all, expected to attract interest in geological disposal and to bring about constructive discussions on how we should deal with the risk. The NUMO is improving its materials and supporting systems for learning day by day. Expanding the range of learning would call for sharing the results of future learning activities with many stakeholders. The decision-making process on the final repository of HLW has been difficult, but the lessons could be turned into good practices for better risk communication regarding nuclear energy and radioactivity.

4-3 Toward a practical regional cooperation in East Asia

More than 100 commercial nuclear power plants are in operation in East Asia, namely in Japan, the Republic of Korea, Taiwan, and China. It has been over 40 years since the first commercial plants went online in Japan, the Republic of Korea, and Taiwan. The nuclear industry in these three countries is mature, but it is gradually declining, especially in Japan and Taiwan. "How can we preserve technological capability while the domestic market is shrinking?" is a common issue for these three countries.

Table 7, 8 and 9 show the types of reactors by country. Japan, the Republic of Korea, and Taiwan introduced reactor technology mainly from the US, while China has introduced it mainly from Russia and France. Japan, the republic of Korea, and Taiwan have established the safety design and regulation based on that of US. On the other hand, China independently established their safety regulation. The foundation of developing nuclear energy has led to a significant difference in the safety philosophy between China and the other three countries.

Table 7　Types of reactors in Republic of Korea

Reactor	Output (MW)	Type	vendor	Commercial operation
Kori 1-4	587(1), 650(2), 950(3/4)	WH-PWR	WH	1978-1986
Shin-Kori 1-2	1000	OPR-1000	Doosan	2011-2012
Shin-Kori 3-4	1400	APR-1400	Doosan	2016-2017
Hanbit 1-2	950	WH-PWR	WH	1986-1987
Hanbit 3-6	1000	OPR-1000	Doosan	1995-2002
Hanul 1-2	950	FR-PWR	Framatome	1988-1989
Hanul 3-6	1000	OPR-1000	Doosan	1998-2005
Wolsong 1-4	679(1), 700(2/3/4)	CANDU-6	AECL	1983-1999
Shin-Wolsong 1-2	1000	OPR-1000	Doosan	2012-2015

Table 8　Types of reactors in Taiwan

Reactor	Output (MW)	Type	vendor	Commercial operation
Chinshan 1-2	666	BWR-4	GE	1978-1979
Kuosheng 1-2	985	BWR-6	GE	1981-1983
Maanshan 1-2	963	WH-PWR	WH	1984-1985

Table 9 Types of reactors in China

Reactor	Output (MW)	Type	Vendor	Commercial operation
Daya Bay 1-2	984	French M310	Framatome	1994
Qinshan Phase I	310	CNP-300	-	1994
Qinshan Phase II, 1-2	650	CNP-600	-	2002, 2004
Qinshan Phase II, 3-4	650	CNP-600	-	2010, 2012
Qinshan Phase III, 1-2	720	CANDU-6	AECL	2002, 2003
Fangjiashan 1-2	1087	CPR-1000	CNPC	2014, 2015
Ling Ao Phase I, 1-2	1000	French M310	Framatome	2002, 2003
Ling Ao Phase II, 1-2	1080	CPR-1000	CNEPC	2010, 2011
Tianwan 1-2	1060	VVER-1000	ASE	2007
Ningde 1-4	1080	CPR-1000	CNEPC	2013-2016
Hongyanhe 1-4	1110	CPR-1000	CNEPC	2013-2016
Yangjiang 1-4	1080	CPR-1000	CNEPC	2014-2017
Fuqing 1-4	1087	CPR-1000	CNPE	2014-2017
Fangchenggang 1-2	1080	CPR-1000	CNEPC	2016
Changjiang 1-2	650	CNP-600	-	2015-2016

Since Japan, the Republic of Korea, and Taiwan have several common features with respect to the trend of nuclear power utilization, we propose some potential issues for regional cooperation both in the techno-economical and the political areas.

- Cutting O&M costs for reactors in operation: Most of the existing reactors in Japan, South Korea, and Taiwan are over 20 years old and require some repair works to maintain operation. Since cost competitiveness is more and more crucial to survive in the liberalized wholesale electricity market, rationally saving on O&M costs—including safety investment costs—should be the top priority for operators while sufficiently meeting safety standard.
- Spent fuel management and final disposal of HLW: None of these countries has a final disposal facility for spent fuels, and the challenges for doing so are more likely social arguments than techno-economical challenges. Sociological solutions, including stakeholder involvement, are as highly anticipated as techno-economical solutions.
- Decommissioning: East Asian countries including Japan have less experience in decommissioning of commercial reactors. The regulation for decommissioning has therefore not been well-designed and is still under consideration. Therefore, costs and potential profits of decommissioning work is uncertain for the business sector. In this context, “How should we make the decommissioning business economically workable and profitable?” can be the common and important discussion issue for industry players.

The utilization of nuclear energy has long been a subject of policy debate, and the subject is particularly urgent in the Republic of Korea and in Japan, which have used nuclear energy for several decades and which are now facing a changing business and political environment. Nuclear energy made significant contribution, and is expected to continue to do so, to the 3Es (energy security, environmental protection and economic efficiency) for many countries in the world in particular those in East Asia including Japan and Republic of Korea. Under the circumstance, researchers and academia of the two countries are encouraged to hold more frequent information exchange, peer review, and discussions on nuclear policy of the two countries and the world. Such exchange is expected to contribute to promote better understanding of the importance of sound nuclear policies, not only for their own countries, but also for all the East Asia and the world.

5 Abbreviations List

AB	Auxiliary Building
AEON	Act on the Establishment and Operation of the NSSC
APR	Advanced Power Reactor
BPE	Basic Plan for Long-term Electricity Supply and Demand (Korea)
CDF	Core Damage Frequency
CFS	Cavity Flooding System
CFVS	Containment Filtered Vent System
CNP	Chinese type LWR
CPB	Compound Building
CSS	Containment Spray System
DBE	Design Basis Earthquake
DVI	Direct Vessel Injection
ECC	Emergency Core Cooling
ECBDs	ECC Core Barrel Ducts
ECSBS	Emergency Containment Spray Backup System
EDGs	Emergency Diesel Generators
EPR	Evolutionary Pressurized Reactor
ERDS	Emergency Reactor Depressurization System
FD	Fluidic Device
FIT	Feed-In Tariff
GHG	Greenhouse Gas
GOJ	Government of Japan
HMS	Hydrogen Mitigation System
HLW	High-Level Radioactive Waste
HVT	Holdup Volume Tank
IAEA	International Atomic Energy Agency
IEEJ	Institute of Energy Economics Japan
IRRS	Integrated Regulatory Review Service
IRWST	In-containment Refueling Water Storage Tank
IVR-ERVC	In-Vessel Retention through External Reactor Vessel Cooling
KBS	Korean Broadcasting System
KEPCO	Korea Electric Power Corporation
KHNP	Korea Hydro & Nuclear Power
KINAC	Korea Institute of Nuclear Non-proliferation and Control
KINS	Korea Institute of Nuclear Safety
KNS	Korean Nuclear Society
KOFONS	Korea Foundation of Nuclear Safety

LNG	Liquefied Natural Gas
LOCA	Loss-Of-Coolant-Accident
LWR	Light Water Reactor
KPX	Korea Power Exchange
ME	Ministry of Environment
METI	Ministry of Economy, Trade and Industry (Japan)
MOTIE	Ministry of Trade, Industry and Energy (Korea)
MOX	Mixed Oxide
MSIP	Ministry of Science, ICT and Future Planning (Korea)
NDC	Nationally Determined Contribution
NRA	Nuclear Regulation Authority (Japan)
NRC	Nuclear Regulatory Commission (US)
NSSC	Nuclear Safety and Security Commission (Korea)
NUMO	Nuclear Waste Management Organization of Japan
OECD	Organisation for Economic Co-operation and Development
PAFS	Passive Auxiliary Feedwater System
PCCT	Passive Condensation Cooling-water Tank
PCHX	Passive Condensation Heat Exchanger
RCB	Reactor Containment Building
RCL	Reactor Coolant Loop
RCS	Reactor Coolant System
RPS	Renewable Portfolio Standard
RVI	Reactor Vessel Internal
RWST	Refueling Water Storage Tank
SCS	Shutdown Cooling System
SIP	Safety Injection Pump
SIS	Safety Injection System
SIT	Safety Injection Tank
SNEPC	Seoul National University Nuclear Energy Policy Center
SSAR	Standard Safety Analysis Report
SSE	Safe Shutdown Earthquake
VVER	Russian type LWR

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