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Nuclear Safety: The Republic of Korea's Experience in Eliminating Capacity Deficits

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Summary

South Korea has maintained a consistent national policy to achieve a stable energy supply by fostering a nuclear power program with 25 nuclear power plants in operation. After the Fukushima disaster, public concerns on nuclear safety have grown and significant efforts were made by government and industry to improve nuclear safety. To ensure regulatory independence, the Nuclear Safety and Security Commission was established and the Nuclear Safety Act was separated from Atomic Energy Act. Special inspections of nuclear power plants were carried out immediately and 50 follow-up actions were identified to improve the safety against severe accidents. An IAEA Integrated Regulatory Review Service team and the World Association of Nuclear Operators were invited to review nuclear safety. With Northeast Asia expected to become the most densely nuclear power plant-populated area in the world, effective international cooperation in this region is required in order to entrench strong nuclear safety standards and build a resilient safety culture with effective emergency preparedness.

Introduction

1. In the last half century Northeast Asia has become a central industrial region in the world. The success of the region's economic development is rooted in good human resources and sound energy policies, and in the fact that nuclear energy played a significant role as a base-load energy source in a region of low natural energy resources.

2. The Government of the Republic of Korea (South Korea), faced with insufficient energy resources, maintained a consistent national policy to achieve a stable energy supply by fostering a nuclear power program. In January 2017, a total of 25 nuclear power plants were in operation and an additional five were under construction. According to the 7th Basic Plan for Long-term Electricity Supply and Demand, covering the years 2015 to 2029 and announced in July 2015, nine more units are planned to be constructed by 2029, which will cover up to 28.5 per cent of total electricity generation in South Korea.

3. For the sustainable development of nuclear energy, which ensures efficient energy supply and safe operation, South Korean national civil nuclear programs are generally divided into three: governmental, industrial, and academic programs. There are more than ten university departments and programs related to nuclear engineering. The Korea Atomic Energy Research Institute has played a major role in developing national nuclear research programs with these universities.

4. The Atomic Energy Act of 1958 played an important role in promoting and regulating the nuclear industry in South Korea until 2011. After the Fukushima disaster, that Act was divided into the Nuclear Promotion Act and the Nuclear Safety Act to improve the effectiveness of nuclear development and enhance nuclear safety respectively.

5. Since the Fukushima disaster, public concerns on nuclear safety have grown in South Korea. These concerns were represented in a recent successful commercial nuclear disaster horror movie called *Pandora*. The film depicts a man-made disaster resulting from a catastrophically severe accident in a nuclear power plant. Public concerns about nuclear energy were heightened by a number of incidents of misconduct: for example, the concealment of a station blackout (that is, unavailability of the onsite emergency AC power system) at Kori Unit 1, and the use of falsified quality documents. In these circumstances, in order to ensure nuclear safety after the Fukushima disaster, significant efforts were made to improve the national safety regulatory framework, including the establishment of the Nuclear Safety Act.

6. In addition, several significant decisions were made about the nuclear power program in South Korea. For instance, in February 2015, the Nuclear Safety and Security Commission approved the continued operation of Wolsung Unit 1 until November 2022, when it will be 40 years old. In this process, the plant was subjected to a stress test to evaluate its coping capability against extreme natural hazards and the results were evaluated by the Korea Institute of Nuclear Safety, and by a community, non-governmental committee. Kori Unit 1 has also undergone a stress test evaluated by the Korea Institute of Nuclear Safety as well, and this testing will be extended to all operating nuclear power plants.

7. For the first time, it was decided in 2015 that Kori Unit 1, the first nuclear power plant in South Korea, would be permanently shut down for decommissioning starting in 2017 after 40 years of operation. Accordingly, the Nuclear Safety and Security Commission revised the Nuclear Safety Act to regulate the decommissioning process, and the reactor's owner, the Korea Hydro and Nuclear Power Co Ltd, prepared for decommissioning according to the law.

8. On the other hand, Shin Kori Unit 3, the first advanced power plant in South Korea called APR1400, which is the same type of plant as that under construction in the United Arab Emirates, started commercial operation in December 2016. In light of the Fukushima disaster, additional contingency protection measures were agreed in consultation with the local government, and with consideration given to local environmental conditions. The Act on Physical Protection and Radiological Emergency was revised to subdivide the existing Emergency Planning Zone into two: a Precautionary Action Zone and an Urgent Protective Action Planning Zone. The Precautionary and Urgent Protective Action zones were set within the radius of 3-5 km and 20-30 km, respectively, from the power plant.

National Nuclear Safety Infrastructure

9. In South Korea before 2011, the Ministry of Education, Science and Technology was responsible for the long term R&D on nuclear engineering and the regulation of nuclear safety. The Ministry of Knowledge and Economy was in charge of promoting the nuclear industry. After the Fukushima accident, the Nuclear Safety and Security Commission was founded as an independent presidential commission and the regulatory body to take responsibility for national nuclear safety in accordance with the Nuclear Safety Act. In 2013, the Nuclear Safety and Security Commission was moved from the president's office and placed under the prime minister's office.

10. The Nuclear Safety and Security Commission comprises two standing (that is, full-time) commissioners (Chair and Secretary-General) and seven non-standing (that is, part-time) commissioners. Two standing and three non-standing commissioners are appointed by the president on the recommendation of the government and four non-standing commissioners are appointed by the president on the recommendation of the National Assembly. The Nu-

clear Safety and Security Commission initiated and leads the Nuclear Safety Policy Coordination Committee in managing nuclear safety policies and coordination of issues between ministries.

11. Other bodies supporting nuclear safety in Korea are the Korea Institute of Nuclear Safety, established in 1990 to support the regulatory body as the technical expert organization for nuclear safety, and the Korea Institute of Nuclear Nonproliferation and Control, established as another technical expert organization for nuclear security in 2006. Both organizations support the Nuclear Safety and Security Commission in safety and security regulatory works, respectively.

12. Although South Korea has been faced with the increasing threat of nuclear missiles from North Korea, South Korea joined the Nuclear Non-proliferation Treaty (NPT) in 1975 and has developed no military programs. Any nuclear security issues are strictly managed by the Korea Institute of Nuclear Nonproliferation and Control.

13. All nuclear installations in South Korea must go through a safety assessment first by an application for Construction Permit and Operating Licence, and then be licensed through safety reviews and inspections by the regulatory body before their construction and operations. The operator of nuclear installations must conduct a safety assessment for the refuelled reactor core during a refuelling outage and the regulatory body approves its criticality only when the result of a comprehensive safety and performance evaluation is deemed satisfactory through a regulatory inspection. The operator also performs periodic safety reviews for all nuclear installations every 10 years after the date of Operating Licence issuance and submits the reports to the regulatory body for review.

14. Moreover, after the Three Mile Island (1979, USA) and Chernobyl (1986, Ukraine in the then-Soviet Union) accidents, the South Korean government issued an administrative order to prepare a severe accident management plan. After the Fukushima accident, special inspections on nuclear power plants were carried out immediately and 50 Fukushima follow-up actions were identified to improve the safety against severe accidents. In addition, the Nuclear Safety Act was revised to include a legal basis for regulatory control of severe accidents, as recommended by the Integrated Regulatory Review Service of the International Atomic Energy Agency (IAEA) in 2011.

15. According to the revised law, those who want to operate the power reactor and related facilities must submit a severe accident management plan when they apply for an Operating Licence. Operating Licence holders must submit their plans by June 2019. Fundamentally, existing power plants should aim for the same safety goals as those of new power plants, by identifying and managing applicable safety improvements to achieve that goal.

16. Following the reports in late 2012 of the use of falsified quality documents, the "Nuclear Safety Ombudsman" system was initiated by the Nuclear Safety and Security Commission in 2013. This system is designed to prevent corruption and wrongdoing within the nuclear industry and a tip-off by inside/outside informants promptly initiates an investigation of any alleged corruption. Also, the Korea Foundation of Nuclear Safety has been designated as the responsible institute for accreditation and post-accreditation. A performance qualification institute needs to be accredited by the Korea Foundation of Nuclear Safety in order to carry out a quality assurance of components or facilities.

17. Before 2014, regulatory inspection of a nuclear power plant had been carried out on the licensees that construct and operate it. However, since then the inspection regime was expanded from licensees to designers, manufacturers, and performance verifiers of safety related equipment, with a view to enhancing safety and reliability. To regulate this effectively, licensees are required to report contracts on safety-related facilities to the regulatory body. Moreover, the Korea Hydro and Nuclear Power company launched a "radio frequency identification based equipment and material tracking system" in 2014 to monitor equipment and parts in different stages. In addition, an integrated information system for nuclear parts

was established to track and search information related to key equipment and parts.

18. With the concealment of a station blackout at Kori Unit 1 in 2012, the regulatory body initiated regulatory supervision and special inspection on the licensee's safety culture. Also, the Korea Institute of Nuclear Safety initiated a research project on "Development of regulatory infrastructure for the oversight of safety culture" and it is expected to develop a system for practical implementation of regulatory oversight of licensee's safety culture.

19. In accordance with the "right to know," the regulatory body has opened information related to safety regulation to the public, including licensing-related review reports, investigation reports on nuclear accident and failures. Recently, licensee's application documents for construction permits and operating licenses were added to the list of information to be made available publicly. In addition, a Nuclear Safety Information Center was initiated to hold and make available a comprehensive collection of safety information, as a portal service to the public.

20. Regional offices of the Nuclear Safety and Security Commission were launched to enhance oversight of nuclear power plant sites and to strengthen local communication. Regional safety councils were organized to discuss matters related to safety of the nuclear power plants with local residents. However, more precise and timely release of information related to the operation of nuclear power plants is still being requested by the public.

21. During the processing of the construction permit for Shin Kori Units 5 and 6, the public raised issues of the environmental and economic effects of building additional power plants in one site. Especially, the need for probability risk analysis for multi-units was raised, but the proposal has not yet been fully evaluated, because of the absence of proper tools at this moment. It is strongly recommended that a probability risk analysis tool for multi-unit power stations be developed in the near future.

Engagement with International Safety and Liability Regimes

22. At the invitation of South Korea an IAEA Integrated Regulatory Review Service team visit in 2011 resulted in 10 recommendations and 12 suggestions. A follow-up mission in 2014 looked at additional areas including radiation safety. This follow-up mission confirmed that most of recommendations and suggestions from 2011 had been implemented. As for the new area of radiation safety, the mission team recognized that safety management of radiation sources licensees, and integrated full-scope inspections of fuel cycle facilities, as good practices. A total of three good practices, nine recommendations and nine suggestions were identified as a result of this mission.

23. Following the Fukushima accident, the World Association of Nuclear Operators (WANO) shortened the periodicity of its peer reviews from six to four years and expanded its scope to include emergency preparedness in an effort to enhance safety and regain reliability of the nuclear power stations around the world. In the case of the Korea Hydro and Nuclear Power company, the company received a total of 32 WANO peer reviews starting from Wolsong Unit 1 in 1997 until December 2016, and hosted a corporate peer review in 2013. In order to reinforce nuclear safety, the Korea Hydro and Nuclear Power company has been sharing best practices identified from peer reviews throughout the fleet of nuclear power plant operators while effectively taking action on areas identified for improvements. The Korea Hydro and Nuclear Power company plans to further develop its operating system utilizing international reviews on nuclear safety, including WANO peer reviews, as a strengthened basis for stable nuclear operation.

24. With the efforts described above, South Korea has participated in various multilateral cooperative activities to enhance international nuclear safety. It participates actively in the policy decision-making processes of international organizations including the IAEA and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD), contributing to a global framework of enhanced nuclear safety, and it shares its nu-

clear safety experience with member countries through strategic participation in subcommittees of international organizations and technical working groups. Also, South Korea has supported the regional networks under the framework of IAEA Global Nuclear Safety and Security Network, to build infrastructures and to nurture competent personnel of newly emerging nuclear countries to strengthen nuclear safety.

Bilateral and Regional Cooperation in Nuclear Safety

25. Even after the Fukushima accident, the number of nuclear power plants in Northeast Asia is still rapidly increasing and is expected to reach approximately 200 by 2025 and over 300 by 2040. The number corresponds to nearly a half of the total nuclear power facilities in the world. This means that Northeast Asia may become the most nuclear power plant-populated region in the world in the near future. This simple recognition alerts us to pay close attention to assurance of nuclear safety in this region, since nuclear safety is the indisputable vital issue for the sustainable development of society and the protection of human health and the environment of the region.

26. In 2014, on the initiative of Korea's president, China, Japan and South Korea established the Top Regulators' Meeting, a trilateral consultative body, in order to enhance nuclear safety capability of Northeast Asia and to secure a nuclear safety cooperation system. The Top Regulators' Meeting pursues cooperative activities for enhanced nuclear safety capability in the region by exchanging valuable nuclear safety experiences and maintaining a close information exchange. The Top Regulators' Meeting has observed emergency drills in each country and discussed cooperative procedures for emergency preparedness.

27. It is indisputable that the countries in Northeast Asia collectively face the inevitable expansion of nuclear energy use and ultimately share a common fate of needing to ensure sound nuclear safety. However, the absence of a regional economic union, regional nuclear law, regional supply agency and the lack of political integration are the biggest challenges for this region. With such challenges, and the increased importance of regional cooperation, the countries in the region need to put in efforts to establish a joint consultative body to share views and to conduct joint research. To that end, the Northeast Asia Peace and Cooperation Initiative was established by South Korea to promote multilateral cooperation in the region in several areas including nuclear safety. Since these countries have for a long time shared similar cultural traditions, it is also important to recognize region-specific and tradition-oriented nuclear safety culture, based on the international standards including safety regulation and safety practices.

28. Public safety in this region should be revisited and ensured soundly. In terms of the importance of emergency preparedness, it must be recognized that all the countries in Northeast Asia are located in geopolitical and geological proximity to one another. Also, in addition to the countries which currently have nuclear facilities and plans to expand nuclear power generation, some other countries currently without nuclear facilities are considering embarking on utilizing nuclear power. For this reason, it is even more imperative to cooperate in the area of emergency preparedness among Northeast Asian countries.

29. When a nuclear emergency threatens public safety, the neighbouring countries can be affected by radioactive materials being dispersed through the air and seawater. During and after the tragic event at Fukushima-Daiichi, radioactive materials leaked out to the waters off Fukushima and diffused into the Pacific Ocean, riding along the Kuroshio Current which flows to the north and east into the Pacific. However, if any such tragic event involving the leak of radioactive material into ocean takes place in the Northeast Asian region, especially in South Korea and China, it would be inevitable for the coastal states in the region to be affected with the current being circulated. Taking such circumstances into account, international cooperation in the area of emergency preparedness is deemed crucial.

30. In consideration of the rapidly growing number of nuclear power plants in the Northeast Asian region and Russia, coordinated

training of experts to ensure their safe operation is one of the issues that can be addressed under the framework of the Northeast Asia Peace and Cooperation Initiative. It was concluded at the latter forum in Washington in 2016 that "coordination in training among China, Japan, and South Korea could be valuable," citing the IAEA Centres of Excellence as an example. It is an undeniable fact that human resources development is an issue of greatest importance to nuclear safety, and coordinated training among the countries in this area will certainly contribute to enhancing regional nuclear safety. It leaves us with the further need for discussion to achieve the optimal form of cooperation and to enable coordinated training involving regulators and industry personnel.

Conclusion

31. The Fukushima nuclear disaster in 2011 produced much scepticism in the global community about the safety of nuclear power, and the concealment of a station blackout at Kori Unit 1, along with the use of falsified quality documents, resulted in increased scepticism amongst the Korean general public. To enhance nuclear safety and recover the public credibility on nuclear safety, more independent and transparent regulatory efforts (or functions) are required.

32. To ensure regulatory independence, the Nuclear Safety and Security Commission was established in October 2011 after the Fukushima accident, and the Nuclear Safety Act was separated from Atomic Energy Act. The legal framework for nuclear safety has been revised and expanded to ensure nuclear safety, including the emergency management of severe accidents. Also, several actions were taken to enhance transparency with the opening of the Nuclear Safety Information Center, the launching of regional offices of the Nuclear Safety and Security Commission, and the creation of regional safety councils.

33. With these efforts to enhance nuclear safety, the continued operation of Wolsung Unit 1 was approved, Shin Kori Unit 3 started commercial operation, Shin Kori Units 5 and 6 received construction permits, and Kori Unit 1 was decided to be permanently shut down in 2017. During these processes, there were many debates among the industry, the regulatory body and the public. It is estimated that the transparency of these processes has been improving, but more transparency continues to be requested by the public.

34. With more than 200 nuclear power plants expected across Northeast Asia by 2025, this region is expected to become the most densely nuclear power plant-populated area in the world. Currently, there is no definitive governmental cooperation in this region with the exception of the Top Regulators' Meeting. It is clear that effective international cooperation in this region is required in order to entrench strong nuclear safety standards and build a resilient safety culture with effective emergency preparedness.

35. All the countries in Northeast Asia are called to make their best efforts to implement the Vienna Declaration issued in 2015. The Declaration, which is part of an ongoing international effort to strengthen nuclear safety in the wake of the Fukushima-Daiichi accident in Japan, was approved by consensus by the Contracting Parties to the Convention on Nuclear Safety (CNS) at a Diplomatic Conference held on 9 February 2015 at the headquarters of the IAEA in Vienna. The Declaration contains a series of principles to guide countries in the implementation of the objectives of the CNS and to cooperate with one another, encouraging and ensuring their efforts together.

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