Spreading Green Growth: Introducing Nuclear Energy in Southeast Asia

Taek Jin Han
Seoul National University

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I. Introduction

All human activities are dependent on energy. Regarding the dimension of world's energy problem, it becomes clear that resolving energy issue is the most challenging issue for sustainable development. The term, sustainable development, was first coined by the Brundtland Report, *Our Common Future*, published by the United Nations World Commission on Environment and Development in 1987. Introducing the concept of sustainable development, the report addresses "the needs of the present without compromising the ability of future generations to meet their own needs (1987:43)." In recent years, there have been a wide arrange of discussion on sustainable development in academic communities but also policymaking communities around the world. It attaches the idea of sustainability to traditional approach to development so as to ensure both economic growth and environmental protection especially in developing countries. However, as Redclift points out, the concept is more charming than meaningful (1987:3). While the concept has successfully framed the ways of understanding development, it has not been able to present concrete roadmap toward sustainable development.

The controversy over sustainable development is centered on the absence of sustainable energy. Critics of sustainable development often point out that almost all contemporary forms of energy source inherently leave their footprints on the earth. The most notable example is fossil fuels. The discovery of efficient use of fossil fuels in the nineteenth century brought industrial revolutions to every corners of the world fundamentally transforming people's standard of living. However, inflating consumption of fossil fuel also began to affect living environments of every species on the earth causing global climate change. The international community became aware of global climate change and drew consensus among the member states that all states eventually have to reduce greenhouse gas emission in order to secure living place for future generations to come. Stern Review warns that that climate change

would not only devastate the environment and cause mass migration but also cut the world's annual economic growth by 20 percent (Stern, 5:2006). Nevertheless, the international community still has not found suitable energy sources to replace fossil fuels to reduce carbon emission while scientists strongly urge policymakers to conduct every possible precaution for climate change.

The world is facing inescapable dilemma between rock and hard place. Everyone needs more energy while more energy use threats everyone’s lives. Energy is vital to transportation, protection against the weather, and manufacture of all goods. Therefore, a sufficient long-term supply of energy is essential for human survival. Particularly, developing countries are calling for more energy to support economic growth in order to satisfy increasing people’s demand for better standard of living. On the other hand, developed countries are trying to persuade developing countries to join international efforts to curb carbon emission so that the world would be less affected by global climate change. It increasingly becomes a moral issue between the rich and the poor countries. The heated debate among world leader in Cancun Climate Change Summit 2010 exhibited the sensitivity of managing sustainable world.

Finding sustainable energy sources is the key to the sustainable world. The sustainable world is possible only with sustainable source of energy that can accommodate the needs of both developing and developed countries. In order to address the energy challenge in sustainable world, this paper cautiously calls for South Korea to introduce nuclear energy in Southeast Asia. The paper reviews international status of nuclear energy in the world. Particularly, it examines vacillating concerns of “nuclear renaissance” after the accident in Fukushima, Japan. It argues that nuclear energy continues to be significant for many countries in terms of energy security for years to come. Then, the paper evaluates nuclear energy industry in South Korea in comparison with nuclear industries of other countries. It focuses on competitive attributes of Korean Consortium as a latecomer in the market. Finally,

the paper proposes the nuclear energy outreach plan for South Korea to introduce nuclear energy in Southeast Asia in order to promote sustainable development in the region.

II. International Status of Nuclear Energy

1. Nuclear Renaissance

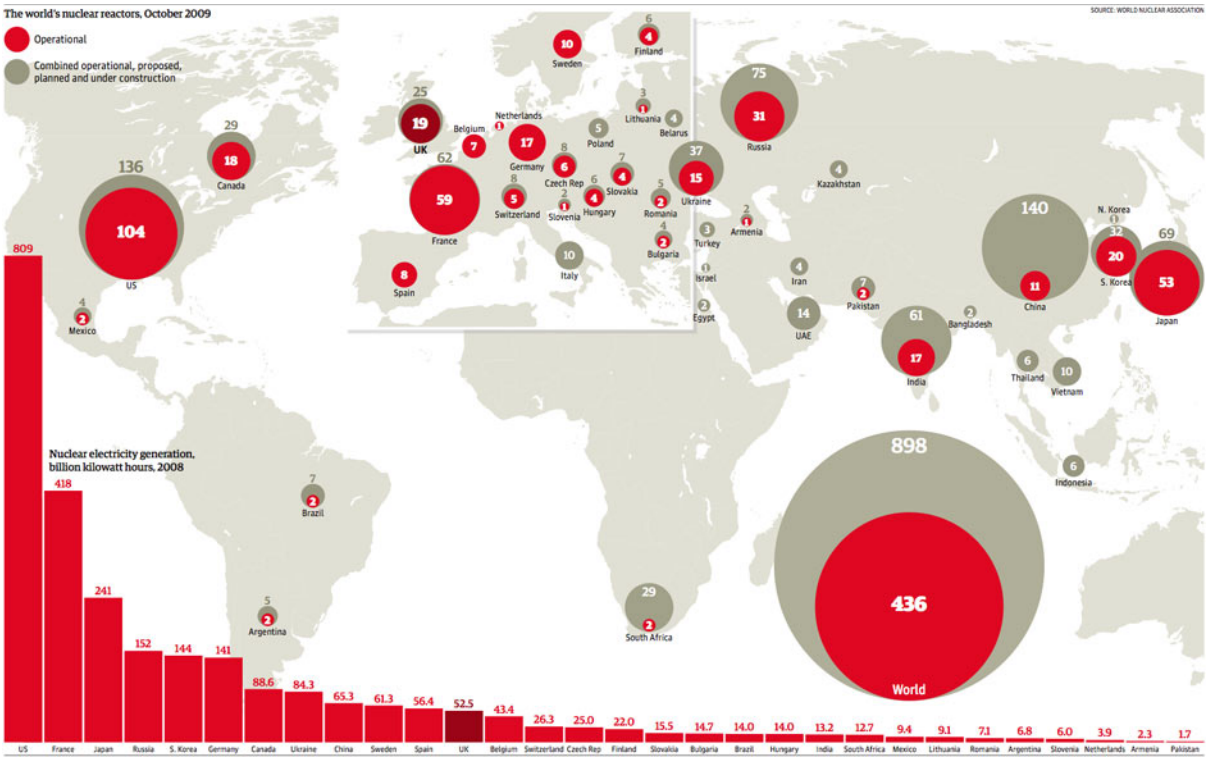

Figure 1. Nuclear Power around the World
Source: "Nuclear Power around the World", *Guardian*. 2009.

Expectations for nuclear energy have dramatically grown since 2001. More than thirty countries have plans to introduce nuclear energy for the first time. The discussions of nuclear renaissance include prospects of doubling or tripling nuclear capacity by 2050. The World Nuclear Association predicts at least 1130 GWe of nuclear capacity by 2060, and possibly up to 3500 GWe, compared with 373 GWe today (WNA, 2010). The terms "nuclear renaissance" describes the phenomenon that many countries reconsider nuclear energy as alternative energy to fossil fuels. The nuclear industry has been in decline for a while especially in the

Western Europe and the United States since the accidents at Three Mile Island and Chernobyl (조성재, 2009:91). However, nuclear energy is rapidly expanding in Eastern Europe and Asia (Squassoni, 2008:2). China has twenty-seven reactors in construction while South Korea proposes to double electricity production from nuclear energy source by 2030.

There are several drivers of the nuclear renaissance. First of all, the world is facing increasing energy demand. Global population growth in combination with industrial development is expected to result in a doubling of electricity consumption by 2030. The increase will be far greater if electric vehicles become widely available as envisioned by many automakers. The shortage of freshwater in dry regions demands for increasing use of energy-intensive desalination plants. The rising energy demand raises concerns for energy security (Perkovich, 2009:242). Over the years, countries realize their vulnerability to interrupted delivers of oil and gas. In the past few years, a diplomatic dispute in Europe resulted in temporary cutoffs of natural gas supplies from Russia. The newly industrialized countries in Asia have highly energy-intensive industries . Thus the abundance of uranium, its relatively low cost, and the convenience of storing uranium fuel supply make nuclear energy attractive from an energy security perspective.

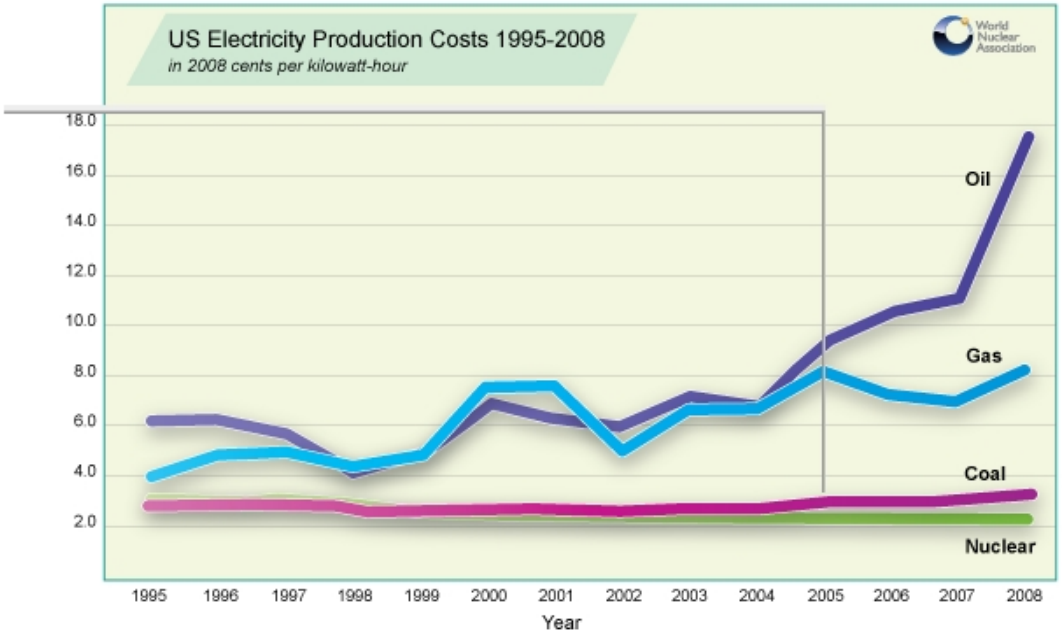

Figure 2. U.S. Electricity Production Cost 1995-2008
Source: World Nuclear Associatio. 2008.

Moreover, increased awareness of potential dangers of climate change has gradually changed the perception of both policymakers and their constituents on nuclear energy (Wilson, 1995:273). The public realized that the indiscriminate use of fossil fuels would lead to irreversible consequences in the future. The international community now continuously pressures the governments around the world to fundamentally transform their countries' behaviors of producing greenhouse gases. The general consensus was reached to reduce the use of fossil fuels worldwide and at least to replace them with low emission sources of energy. It is still controversial whether nuclear energy can be a long-term solution. However, it is generally regarded as "bridge technology" to accommodate rising demands until more sustainable energy to emerge in the market such as nuclear fusion. Compare to other energy sources, nuclear power plants produce minimal carbon emission while providing cost-efficient energy. It costs about 1.76 cents per kilowatt hour compared to coal (2.47 cents), natural gas (6.78 cents) and oil (10.26 cents) (Cheam, 2008). Among many alternative energy sources, nuclear energy is the only large-scale alternative to fossil fuels that is readily available to accommodate base-load electricity demand by producing a continuous, reliable supply of can energy.

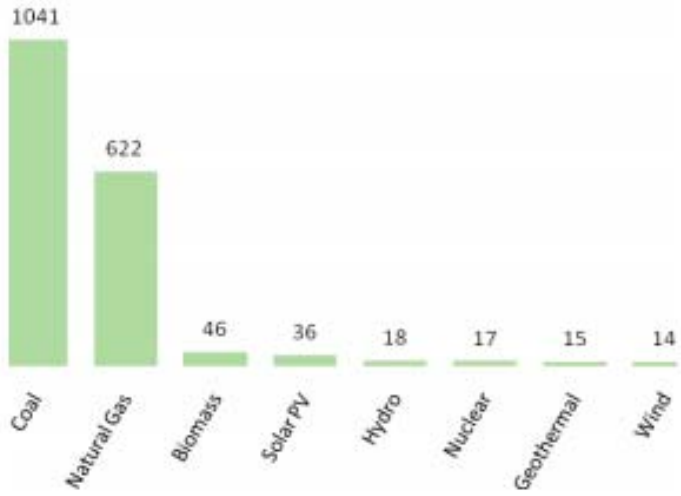

Figure 3. Nuclear Energy's Low Carbon Footprint
Source: Nuclear Energy Institute. 2009.

2. Aftermath of Fukushima

The optimistic vision of nuclear renaissance is now under public scrutiny after the nuclear accident at Fukushima in March 2011. The crisis in Japan prompted countries with nuclear energy to review the safety of their existing reactors and cast doubt on the speed and scale of planned expansion around the world. For instance, Sweden announced not to pursue nuclear energy temporarily in light of Fukushima to review a recent decision to allow existing reactors to be replaced. In addition, Germany, Switzerland, Israel, and United Kingdom are reviewing their nuclear power plant programs. In the past, nuclear accidents inhibited further expansion of nuclear energy infrastructure. For instance, the United States built no nuclear reactor since the accident in Three Mile Island. However, not every country halted nuclear expansion. China, Japan, South Korea Indonesia and Vietnam still maintain their previous nuclear energy project (Harrell, 2011).

The impact of Fukushima was curiously minimal on the growth of nuclear energy in Asia. Although the incident raised alarm for stricter regulations on nuclear safety and security, the crisis does not negate the rising concerns of energy demand in the region. The industrial structure of Asia is much more energy-intensive than that of Western Europe (Murray, 2008:445). For the reason, it is very difficult for policymakers in Asia to change the course of nuclear energy policy. Asia is the main region in the world where electricity generating capacity and specially nuclear power is significantly growing (Im Byung Ho, 2010:9). In East and South Asia, there are 112 nuclear power reactors in operation, 37 under construction and firm plans to build a further 84 reactors. In coming years, nuclear energy continues to be significant for sustainable development of Asia (Ham Jae Bong, 2010:3).

3. Continuous Significance of Nuclear Energy

In Asia, the question is not whether to close the existing nuclear reactors but how to manage the nuclear energy facilities in safe, secure and sustainable way. It is particularly true for countries in Asia with rapidly growing economy. The newly industrialized countries in Asia generally have large heavy industry without sustainable energy technology since no significant research and development was conducted for alternative source of energy. Therefore, these countries fear that international climate change regime would force them to limit their energy use for economic growth. China is the forerunner of this debate voicing the fear of developing countries in combating global warming. However, China took the practical path by adopting nuclear energy in order to replace fossil fuels while securing enough time to transform its energy consumption. The countries in Southeast Asia also continuously expressed their interest in adopting nuclear energy as an alternative energy source.

South Korea is a unique country in this circumstance. Rather than being excused from common responsibility to combat global warming as a developing country, South Korea voluntarily chose to embrace its quota to reduce domestic carbon emission. In fact, President Lee called for “Green Growth” advocating more research and development to be done for making sustainable world. However, it must be noted that nuclear energy expansion is one of core pillar of South Korea’s plan for Green Growth. South Korea also regards nuclear energy as a stable alternative energy source to accommodate its energy-intensive industry. It not only affected domestic economy but also foreign market. South Korea actively sponsored its Green Growth by exporting nuclear technology to other countries. The nuclear deal with the United Arab Emirates was the milestone achievement of South Korea’s Green Growth.

III. Review of Nuclear Energy Industry in South Korea

South Korea emerged as the world’s fifth largest nuclear energy producer in the world

within a little more than three decades (Kang et Feiveson, 2001:70). Now it aims to become a major nuclear energy supplier exporting its technology abroad. In the coming years, South Korea plans to further increase its reliance on nuclear energy as it seeks to promote economic growth without increasing carbon emissions. Recently, it won a $20 billion contract to supply four nuclear reactors to the United Arab Emirates. Despite the recent crisis at Fukushima, nuclear energy is still a strategic priority for South Korea. South Korea plans to increase the share of nuclear energy by 56% to 27.3 GWe by 2020 and then 35 GWe by 2030. The government plans to expand to 35 nuclear power reactors by 2030 including advanced reactor designs. Currently, nuclear energy accommodates 35% of its electricity consumption.

The increase of nuclear energy in South Korea has coupled with the dramatic economic growth over the years. The nuclear energy was the basis of economic growth of South Korea providing stable source of energy. Over the last three decades, South Korea has enjoyed 8.6% average annual growth in GDP, which has caused corresponding growth in electricity consumption from 33 billion kWh in 1980 to 371 billion kWh in 2006 (Im Yong Kyu, 2008:38). The rising demand of energy was accommodated by expanding nuclear energy infrastructure. For this reason, South Korea is often regarded as a nuclear energy model for other developing countries to follow. With incredible success of fostering nuclear energy and economic development, South Korea now expands its market beyond domestic sphere. Now, South Korea actively seeks foreign market.

1. Strength

With years of continuous construction of nuclear power plants, South Korea acquired a high level of technology and operational experiences. While the United States halted its nuclear energy construction after Three Miles Island accident, South Korea has continued its nuclear energy projects constructing domestic nuclear power plants (Im Eun Hae, 2009:37).

Thus, it has accumulated a great deal of technological and operational expertise (Yang Yong Suk, 2008:215). In collaboration with Westinghouse, South Korea developed the 1000 MWe OPR-1000 nuclear reactor which is 95% locally designed components (WNA, 2010). OPR1000 (Optimized Power Reactor) was developed as an integral part of the nuclear power plant standardization program which began in 1984. It incorporated the latest technologies and experience acquired during the years of design, construction and operation of nuclear power plants in South Korea. It shortens the construction period from 56 months to 48 months, which makes the model more competitive than other models. Ulchin unit 3 is was the first OPR1000 constructed.

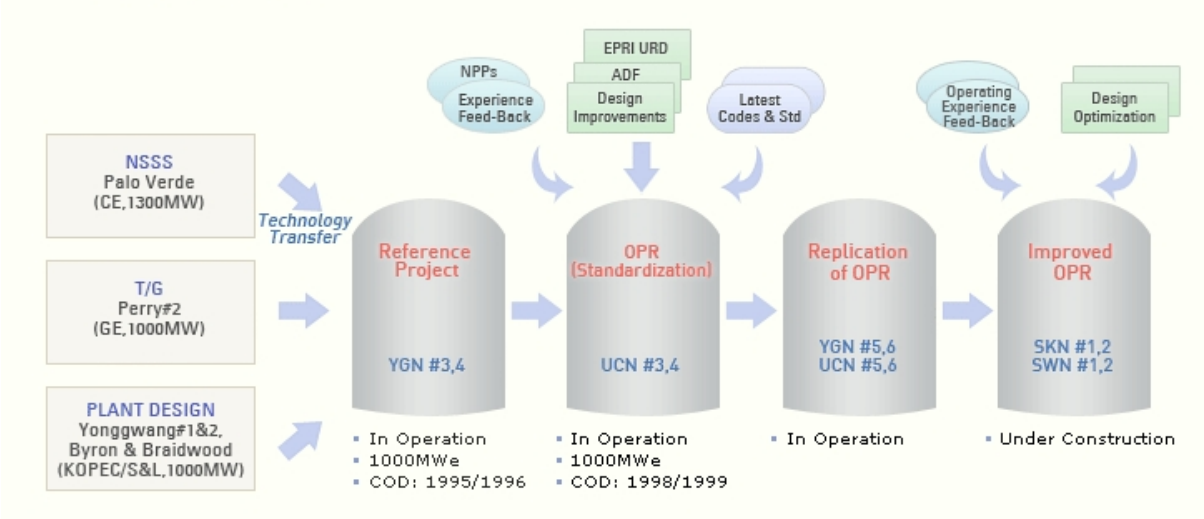

Figure 4. OPR1000 Development Process
Source: KHNP (Korean Hydro Nuclear Power), http://www.opr1000.com/.

Thermal Output	2,825Mwt
Rated Electric Power	1,000MWe
Design Life Time	40years
Seismic design basis	SSE 0.2g, OBE 0.1g
Refueling Interval	12~18months

Table 1. OPR1000 Major Design Requirements
Source: Source: KHNP (Korean Hydro Nuclear Power), http://www.opr1000.com/.

To improve competitiveness of the reactor, South Korea introduced the APR 1400 (Advanced Power Reactor). . The new version of APR 1400 model is based on this model and was sold to United Arab Emirates. The APR1400 is an evolutionary pressured water reactor

with thermal output of 4000MWt. Furthermore, South Korea introduced SAMRT (System-integrated Modular Advanced Reactor), a 330MWt pressured water reactor with integral steam generators and advanced safety features. It is designed by the Korean Atomic energy Research Institute (KAERI) for generating electricity (up to 100Mwe) and thermal applications such as seawater desalination. Design life is 60 years with a three-year refueling cycle. The innovative reactors designed by South Korea outperform competitors' models. It shows the competitiveness of South Korean nuclear industry in the global market. Also, both regular and small modular reactors can accommodate diversified demands of nuclear energy.

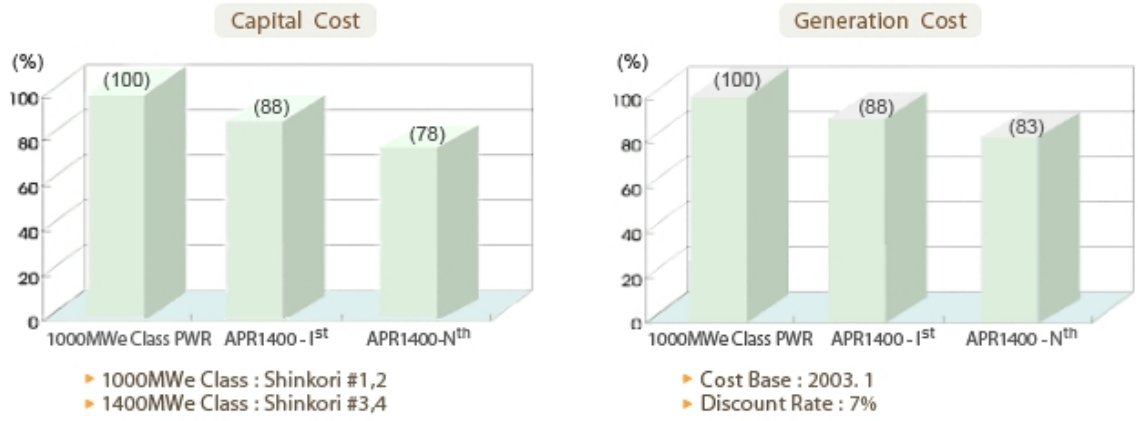

Figure 5. APR1400 Competitive Electric Power Generation
Source: KHNP (Korean Hydro Nuclear Power), http://www.apr1400.com/.

2. Weakness

South Korea has not acquired entirely independent ownership of its nuclear technology. First of all, South Korea is still dependent on Westinghouse on the man machine interface system. It is equivalent to the brain and nerve system of a nuclear power plant. It monitors and controls the operating conditions to proactively preserve accidents. Moreover, South Korea is still dependent on reactor coolant pump from Westinghouse. Without independent ownership of these technologies, South Korea would not be able to export nuclear power plants abroad unless Westinghouse explicitly agrees to provide the system. The issue was brought up when South Korea competed with Japanese Consortium in China, Turkey and

Vietnam since Westinghouse merged with Toshiba, Westinghouse was reluctant to provide South Korea these essential technologies when both South Korea and Japan bid for major construction contracts abroad (Noh Seung Jae, 2010:26). Therefore, acquiring independent ownership of these technologies would be the main concern of South Korea in competition with Japanese counterparts.

3. Opportunity

Nuclear power is now on an ascendant path, after years of stagnation. The environmental fight against fossil fuels is heating up and as informed people start to ask questions about what renewables will be able to achieve. In the policymaking community, nuclear power is coming back. In 2009 there are 439 nuclear power reactors in operation in 38 countries, with a total generating capacity of 370,721 MW. A further 36 nuclear plants are under construction and 316 are planned or proposed. The International Atomic Energy Agency in its 2010 report significantly increased its projection of world nuclear generating capacity. It now anticipates at least 73 GWe in net new capacity by 2020, and then 546 to 803 GWe in place in 2030 – much more than projected previously, and 45% to 113% more than 377 GWe actually operating at the end of 2010. Organization for Economic Co-operation and Development (OECD) estimates range up to 816 GWe in 2030. The change is based on specific plans and actions in a number of countries, including China, India, Russia, Finland and France, coupled with the changed outlook due to constraints on carbon emissions. The IAEA projections would give nuclear power a 13.5 to 14.6% share in electricity production in 2020, and 12.6 to 15.9% in 2030. The fastest growth is in Asia.

	Reactors in Operation	Reactors under Construction	Planned Reactors	Research Reactors	Other Stages of Fuel Cycle
Australia				1	UM
Bangladeshi			2	1	
China	11	22	35	13	UM, C, E, FF
India	19	4	20	5	UM, FF, R, WM
Indonesia			2	3	FF

Japan	54	2	12	17+1	C, E, FF, R, WM
South Korea	20	6	6	2	C, FF
Taiwan	6	2		4	
North Korea			1	1	C, FF?, R
Malaysia				1	
Pakistan	2	1	2	1	UM, E, FF
Philippine				1	
Thailand			2	1+1	
Vietnam			2	1	
Total	112	37	64	56	

Key: UM Uranium Mining, C Conversion, E Enrichment, FF Fuel Fabrication, R Reprocessing, WM Waste Management facilities for spent fuel away from reactors.

Table 2. Nuclear Power in Asia and Involvement with the Nuclear Fuel Cycle
Source: OECD/IEA World Energy Outlook 2000

4. Threat

South Korea has consistently promoted nuclear energy in both domestic and international arena. However, nuclear energy brought one particularly negative consequence. The accumulation of spent nuclear fuel will soon outstrip the country's storage capacity for highly radioactive waste. Seoul pledged not to "possess nuclear reprocessing and uranium enrichment facilities" in the 1992 Joint Declaration of South and North Korea of the Denuclearization of the Korean Peninsula. Also, South Korea is bound by the bilateral agreement with the United States to "jointly determine" the management of spent fuels in South Korea (Lee Sang Hyun, 2010:89). The absence of reprocessing technology and facilities raises the concerns over increasing spent fuels produced by existing nuclear power plants. While France and Japan offer reprocessing services for their future client countries (Yoon Ho Taek, 2009:50), South Korea is struggling with its own spent fuels. Although Seoul and Washington recently agree to jointly research pyroprocessing technology in order to find innovative path to manage spent fuels (Park Sang Won, Ko Won Il, 2008:3), the realization of such technology would take another decade to come (Cho Dong Kun, 2008:225).

However, it also must be noted that the concerns over nuclear spent fuel are not exclusive to South Korea. There have been numerous international initiatives to manage the spent fuel

(Hogselius, 2009:254), yet the international community has not reached the level to effectively utilize this resources. The current negotiation over pyroprocessing between South Korea and the United States also reflects the international concerns over increasing spent fuels around the world. Since the spent fuel is highly radioactive products that can be used for weaponization, the United States has been extremely hesitant to grant reprocessing facilities for foreign country. However, the United States exceptionally single out such restrictions for India and Vietnam when it concluded the nuclear deal. These diplomatic moves may well serve South Korea if it can push for building nuclear reprocessing facilities in foreign country with international supervision.

Year	PWR(고리)	PWR(영광)	PWR(울진)	PWR(신월성)	CANDU(월성)
2002	1,288	866	656	0	2,978
2010	1,896	1,735	1,495	52	6,904
2020	3,274	2,748	2,509	708	9,212
2030	4,448	3,747	3,573	1,532	12,051
2040	5,272	4,393	4,322	2,357	12,323
2050	6,158	4,575	4,590	3,277	12,323
2060	6,639	4,575	4,590	3,758	14,323
2070	7,199	4,575	4,590	4,239	14,323
2080	7,302	4,575	4,590	4,613	14,323

Table 3. Estimated Spent Fuel Accumulation in South Korea
Source: Kim, Yoon Kyung. 2004

IV. Korea’s Nuclear Energy Outreach to Southeast Asia

1. Place

Southeast Asian countries are embarking on a pursuit for nuclear energy. Southeast Asia still largely views nuclear energy as a promise to help satisfy the region’s growing energy thirst in a more cost-efficient and climate-friendly way. More Southeast Asian states will likely pursue nuclear energy over the next few decades. Rising energy demand and soaring energy prices, coupled with increasing consciousness about climate change and the relative unattractiveness and unavailability of alternative energy sources, will combine to create a

strong impetus to embark on a nuclear path (Kim Sih Hwan, 2007:14). Electricity in Southeast Asia is primarily sourced from coal, oil, natural gas, and hydro-power. While the region is awash with energy resources, rising demand has placed a strain on them. Southeast Asia has been a net oil importer for some years, and significant natural gas reserves are often located far from demand centers and hence require massive infrastructure investments. Given this gloomy picture, the region is turning to alternative sources, including nuclear power, to satiate its growing appetite for energy. Several regional trends suggest that this trend will accelerate in the decades to come.

2. Product

South Korea can effectively outreach to Southeast Asia with SMART (System-Integrated Modular Advanced Reacto) reactor. Southeast Asia consists of many archipelagos. Thus, concentrated electricity generation requires extensive infrastructure in addition. However, small-medium size reactor can accommodate electricity demands in isolated regions. In fact, SMART reactor was intended for developing countries for which small reactors are the best option, either because their power grids are small, or because their power grids need to be geographically scattered. A feasibility study with Indonesia has shown that two SMART plants are an optimal choice for Madura to provide tap water as well as electricity to the island`s residents (Im Yong Kyu, 2006:8). The SMART reactor is characterized by a drastically enhanced safety standard and its capability to undertake diverse functions - electricity generation, seawater desalination and district heating. One SMART reactor can supply power and water to a city with a population of 100,000. All of these features are well suited with the needs of Southeast Asia.

3. Price

South Korea demonstrated its price competitiveness when it won the construction

contract with the United Arab Emirates. The primary factor in the selection of the South Korean nuclear power plant model was its cost competitiveness. According to data from the Ministry of Knowledge Economy, the APR's construction unit cost of 2,300 dollars per kilowatt (kW) was lower than those of its competitors AREVA at 2,900 dollars per kW, and GE at 3,583 dollars per kW. In terms of electricity generation unit cost, the South Korean model's 3.03 cents per kilowatt hour (kWh) was lower than AREVA's 3.93 cents per kWh, and less than half Hitachi's 6.86 cents per kWh. In case of SMART reactor, a small-sized reactor is known to be economically less competitive than a large-capacity commercial power reactor, but the simplified features contribute to the reduction of construction costs (Lee Eun Chul, 2009:12). One advantage of SMRs is that they can easily accommodate advanced design concepts and technology. It can also negate economies of scale enjoyed by large-scale reactors by pursuing innovative approaches that lower costs system simplification, component modularization, on-site fabrication and reduction of the construction time.

4. Promotion

South Korea should outreach to Southeast Asia not only interacting with each individual country in the region but also engaging with the ASEAN (association of Southeast Asian Nations). Regarding the sensitivity of nuclear energy, mutual understanding is necessary for the countries in the region to in traduce nuclear reactors in their countries. Furthermore, South Korea can provide nuclear fuel cycle service in the region increasing reliability of fuel supply and waste management. There has been much discussion about possible cooperation among the countries in Northeast Asia (Hwan Yong Soo, 2005:167) (Kim Yoon Kyung, 2004:71), yet no significant proposal has been addressed in regard to Southeast Asia. However, as the nuclear deal between the United States and Vietnam demonstrates, Southeast Asian countries are making exceptional partnership with foreign assistance. Also, the

policymakers in the region are actively pursuing nuclear energy as an alternative energy source.

In order to build sustainable future for the region and for itself, South Korea must promote nuclear energy in Southeast Asia. First, South Korea can provide reliable energy with cost-effective technology and infrastructure. As it demonstrated in the United Arab Emirates, South Korea can provide nuclear reactors with less expansive price tag than its counter parts. Second, South Korea can utilize Southeast Asia as a zone for nuclear fuel cycle service. While South Korea is not permitted to have enrichment and reprocessing facilities in domestic territory, it can construct them in foreign countries preferably geographically close region to South Korea. South Korea and ASEAN can negotiate the project in exchange with transfer of nuclear technology.

V. Conclusion

Despite the nuclear accident at Fukushima, nuclear energy remains strategically important source of energy around the world. No reliable source of alternative energy has been introduced to the international community while the countries around the world are facing a series of energy challenges. The optimistic vision of nuclear energy, so called nuclear renaissance, phased out in public, but policymakers still regard nuclear energy as at least a bridge technology to accommodate rising energy demand of the world. South Korea is one of the countries which firmly maintain existing nuclear energy projects after the accident at Fukushima along with China, Japan, France, etc. In nuclear energy market, South Korea assumes unique role as the fifth largest producer of nuclear energy in the world. Despite the challenges inside and outside of the country, South Korea acquired cost-effective expertise to construct nuclear reactors within a short period of time. Naturally, South Korea now aims to supply nuclear energy for developing countries. Southeast Asia is attractive market for South

Korea since there has not been significant presence of nuclear energy. Thus, it provides great opportunity for South Korea to develop nuclear infrastructure. Cooperating with ASEAN, South Korea would be able to fundamentally transform the region providing nuclear fuel cycle services in the future.

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THE EAST ASIA INSTITUTE 909 Sampoong Bldg., 310-68 Euljiro 4-ga, Jung-gu, Seoul 100-786, Korea