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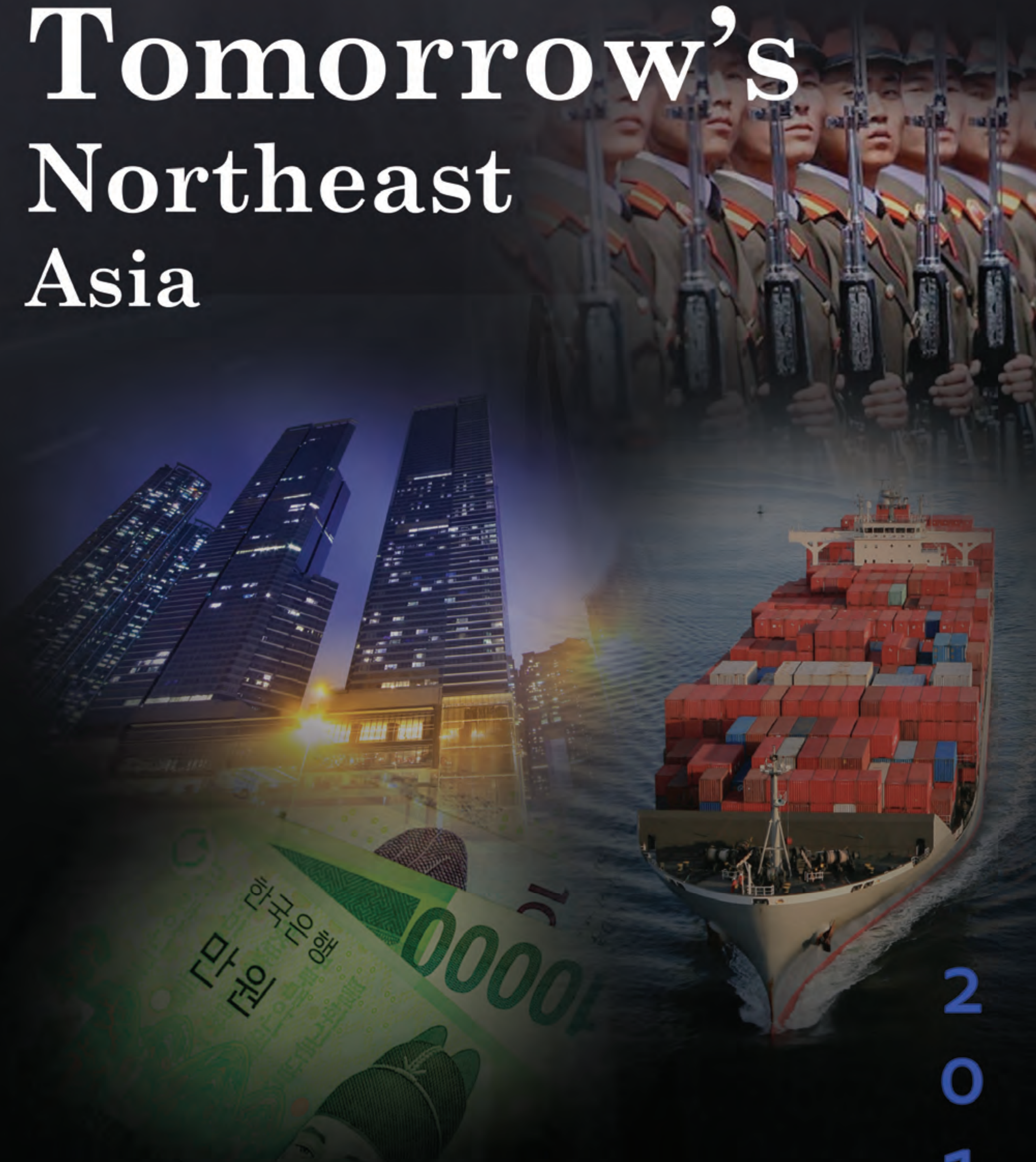
Tomorrow's Northeast Asia



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CONTENTS

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PREFACE

The Korea Economic Institute (KEI) in Washington, D.C., in cooperation with the School of International Service (SIS) at American University, also in Washington, D.C., cosponsored an academic symposium at SIS on 20–22 October 2010 on "Tomorrow's Northeast Asia." This volume contains the papers that were presented at the symposium and subsequently refined.

The 2010 symposium focused on emerging and future challenges facing Northeast Asia. Papers and discussions fell under five broad topics:

- Prospects for emerging East Asian cooperation and implications for the United States
- The emerging role of South Korea on a global stage
- The future of energy security in Northeast Asia
- Engaging and transforming North Korea's economy
- Finding room for a six-party solution to North Korea's nuclear crisis.

The sponsors and authors welcome comments on the material in this volume. This is the 21st in a series of annual academic symposia on Asia-Pacific economic and security issues that bring together leading academics and policy professionals from throughout the region.

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December 2010

HISTORY OF KOREA ECONOMIC INSTITUTE ACADEMIC SYMPOSIA

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GOING GLOBAL: ISSUES FACING SOUTH KOREA AS AN EMERGING NUCLEAR EXPORTER

Chen Kane, Stephanie C. Lieggi, and Miles A. Pomper

ABSTRACT

In the last year, South Korea has won a number of contracts for foreign nuclear sales against stiff competition from traditional nuclear suppliers, putting it on the path towards becoming a major nuclear exporter. However, nonproliferation-related concerns could hinder South Korea's advancement of its nuclear exports, particularly as the ROK pushes its controversial efforts at pyroprocessing—a spent fuel recycling process. While Seoul has taken steps to strengthen its nonproliferation credentials, South Korea must take more of a leading role in the nuclear nonproliferation regime in order to meet its goals as a nuclear exporter.

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Introduction

In the past year, South Korea has become a significant nuclear exporter. In December 2009, the Korea Atomic Energy Research Institute (KAERI) won a contract to supply a research reactor to Jordan. Later the same month, a consortium led by the state-owned Korea Electric Power Corporation (KEPCO) beat out leading U.S. and French firms to win Korea's first agreement to supply power reactor overseas—a $20 billion deal to export four nuclear reactors to the United Arab Emirates (UAE). A few months later, in March 2010, Seoul and Ankara signed a protocol to cooperate in building a nuclear plant in Turkey. Buoyed by these achievements, Korean officials are aiming to capture 20 percent of the world market for nuclear reactors by 2030. All of a sudden the countries that have long dominated nuclear sales—Canada, Japan, and Russia as well France and the United States—have had to reckon with a serious new competitor.

For those outside of Korea, South Korea's emergence as a nuclear exporter may have come as a surprise. But for those in the country, it appears as the next natural step in a long-term evolution, in which South Korea has developed one of the world's largest nuclear fleets while moving steadily from importing foreign parts, materials, and expertise to replicating the technology and more recently to developing indigenous technologies. In this way, it follows a pattern set by other Korean industries from automobiles to semiconductors and shipping, in which Korea has become a world leader by relying on a combination of strong state guidance, high-quality engineering, and an ability to cut production costs (Barfield 2003). This development of a nuclear export sector also fits well within President Lee Myung-bak's vision of "global Korea" (Snyder 2009).

Seoul's emergence has also benefited from a resurgence of interest in nuclear power as countries look to diversify their energy portfolios away from fossil fuels and their volatile prices, lower their carbon dioxide outputs, and reduce their perceived energy insecurity. Moreover, unlike previous waves of nuclear construction, much of the anticipated growth in nuclear power is expected to take place outside nuclear energy's traditional bastions in Europe, the United States, and the richer countries of East Asia. Instead, the nuclear expansion is expected to take place predominantly in the Middle East and in less-well-off countries in Asia (particularly China and India), regions where because of geography or history Korean companies may enjoy some unique advantages.

Still, Seoul's growth as a nuclear exporter could be hindered by the fact that nuclear power is like no other industry because its chief materials and technologies can also be used to make the world's deadliest weapons. Indeed, South

Korea's nuclear development may well be constrained because countries like India and North Korea used putative civilian technology to develop nuclear weapons. Moreover, such technology is of particular concern when it is sold to volatile regions like the Middle East—South Korea's key export market.

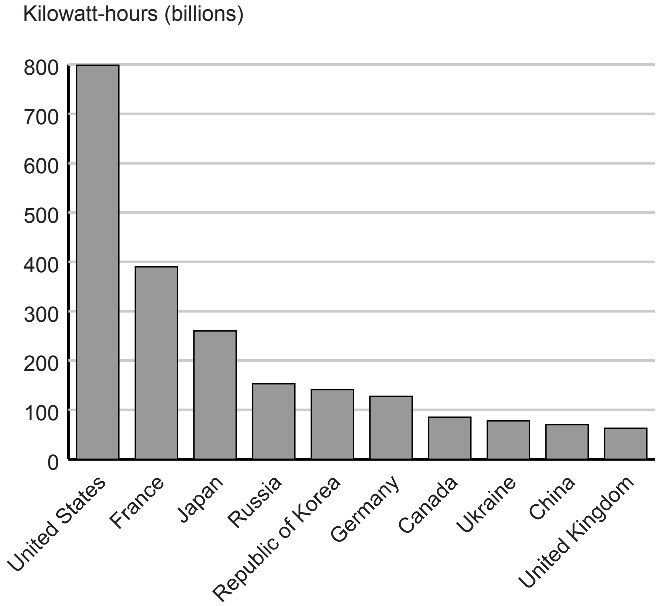
Raising additional nonproliferation-related concerns, particularly in Washington, are South Korea's efforts to develop pyroprocessing—a spent fuel recycling process that Seoul believes it needs in order to manage the increasing amount of nuclear waste coming from its reactors. South Korean officials assure the international community that pyroprocessing is not the same as traditional reprocessing and entails few proliferation risks. However, many outside experts and policymakers, particularly in the U.S. government, are concerned that the process would be difficult to safeguard and could allow diversion of sensitive nuclear materials.

In the past, South Korea has been a sometimes reluctant follower and occasional violator (or near violator) of international nuclear nonproliferation norms and rules. More recently, Seoul has taken steps to upgrade its nonproliferation credentials and comply with relevant nonproliferation obligations. Still, if South Korea is to meet its goals as a nuclear exporter, it will have to become a leader, rather than a follower, of the international nuclear nonproliferation regime.

South Korea's Past Nuclear Activities

As part of the U.S. Atoms for Peace program, South Korea began a nuclear energy program in the late 1950s with the formation of the Office of Atomic Energy and the Korea Atomic Energy Research Institute (KAERI) (MEST 2009, 20–35). In 1962, South Korea's first research reactor, a U.S. 100-kilowatt TRIGA-Mark II, began operation followed by a considerably more powerful 2-megawatt TRIGA-Mark III in 1972. South Korea's first power reactor, Westinghouse's 600-megawatt Kori-1, began operations in 1978 (MEST 2009, 62–114). During the next several decades, South Korea acquired technology licenses (largely based on Westinghouse designs) and advanced its own domestic production capabilities and expertise to the point where the bulk of the components of power reactors and its main research reactor, the High-Flux Advanced Neutron Application Reactor (HANARO) at KAERI, were built indigenously. Indeed, at a KAERI-arranged site visit to Doosan Heavy Industries, Korean officials said that by 2015 they would be entirely free of the need to obtain export licenses from Westinghouse.

Figure 1: **Top 10 Nuclear Generating Countries, 2009, Billion kWh**



Source: Nuclear Energy Institute, 2009, www.nei.org/resourcesandstats/documentlibrary/reliable-andaffordableenergy/graphicsandcharts/top10nucleargeneratingcountries/; data from IAEA and Energy Information Administration.

In the 1980s, South Korea's economy began to rely heavily on energy-intensive industries, which in turn brought about a major increase in the domestic demand for energy. Seoul's policy was therefore focused on ensuring sufficient energy resources to fuel the nation's economic growth (Lee et al. 2009, 550). With minimal domestic supply of fossil fuels and only limited access to alternative forms of power such as hydropower, the ROK turned to nuclear power to better secure its long-term energy needs. Domestically produced nuclear power currently accounts for nearly 40 percent of Korea's electricity generation. According to an assessment by the International Atomic Energy Agency (IAEA 2009), nuclear power added approximately 1.3 percent to the ROK's gross domestic product in 2005.

Booming Nuclear Industry

Today, South Korea boasts the world's fifth-largest nuclear reactor fleet. South Korea's nuclear energy production only slightly trails that of Russia although its output still falls considerably behind that of the United States, France, and Japan. (***Figure 1***).

Table 1: **Nuclear Power Reactors in South Korea (according to date connected to grid)**

Name	Type	Location	Net capacity	Date connected to grid
KORI-1	PWR	Busan	576	1977
WOLSONG-1	PHWR	Gyeongsangbuk-do	597	1982
KORI-2	PWR	Busan	637	1983
KORI-3	PWR	Busan	1007	1985
KORI-4	PWR	Busan	1007	1985
YONGGWANG-1	PWR	Jeollanam-do	953	1986
YONGGWANG-2	PWR	Jeollanam-do	947	1986
ULCHIN-1	PWR	Gyeongsangbuk-do	945	1988
ULCHIN-2	PWR	Gyeongsangbuk-do	942	1989
YONGGWANG-3	PWR	Jeollanam-do	997	1994
YONGGWANG-4	PWR	Jeollanam-do	994	1995
WOLSONG-2	PHWR	Gyeongsangbuk-do	710	1997
ULCHIN-3	PWR	Gyeongsangbuk-do	994	1998
WOLSONG-3	PHWR	Gyeongsangbuk-do	707	1998
ULCHIN-4	PWR	Gyeongsangbuk-do	998	1998
WOLSONG-4	PHWR	Gyeongsangbuk-do	708	1999
YONGGWANG-5	PWR	Jeollanam-do	988	2001
YONGGWANG-6	PWR	Jeollanam-do	996	2002
ULCHIN-5	PWR	Gyeongsangbuk-do	1001	2003
ULCHIN-6	PWR	Gyeongsangbuk-do	1001	2005

Source: IAEA, Power Reactor Information System (PRIS), www.iaea.org/programmes/a2/.

Note: PWR = pressurized water reactors; PHWR = pressurized heavy water reactors.

South Korea utilizes 20 nuclear power reactors, which generated 144.3 terawatt-hours of electricity in 2008 (***Table 1***). Six more reactors are currently under construction, including one—the Shin-Kori 1—expected to be connected to the grid in December 2010.

According to the ROK's 2008 National Energy Basic Plan, South Korea plans to increase the share of nuclear energy in its domestic electricity generation to 59 percent by 2030, with plans for building roughly 14 more nuclear reactors (MKE 2008). It set this goal in part to combat rising carbon emissions—South Korea posted the world's largest increase in greenhouse gas emissions per capita during the last two decades (Moon 2010; Baumert et al. 2005).

Domestic Protests

In developing its nuclear industry, South Korea has faced domestic anti-nuclear resistance from the time it began constructing the Kori-1 reactor in the 1970s (MEST 2009). Seoul was able to overcome those protests, but efforts during the past two decades to find interim storage sites or permanent disposal facilities for spent nuclear fuel have been repeatedly defeated by public opposition. Although the Korean public and Korean experts believe that nuclear waste in transit is the greatest danger to the public, it is interesting that the Korean public expresses greater worries about temporary storage than the experts or the Korean nuclear industry (Squassoni 2009). Even the recent agreement to site a low- and intermediate-level waste facility in Gyeongju, a city in the southeastern part of the country, required almost 20 years to negotiate and several billions of dollars in compensation to the local community.[1] It is also interesting that beyond its direct economic benefits, Korea's new export drive could also have another beneficial impact for its nuclear industry: a recent survey by the Korea Nuclear Energy Foundation found that after the UAE deal, public opposition had decreased on the issue of building nuclear plants, including siting plants near where respondents lived, although the survey still indicated continued high levels of public concern about the storage of radioactive materials.[2]

ROK's Mixed Nonproliferation Record

In 1968, South Korea signed the Nuclear Non-Proliferation Treaty (NPT), but within a few years the deterioration of South Korea's security environment and the credibility of the U.S. security guarantees led some in the ROK to search for a military nuclear option. These developments included North Korea's military buildup, the Nixon Doctrine's emphasis on greater self-reliance for Asian allies, the Sino-American rapprochement of 1971–72, and the reduction of the U.S. military presence in Asia (Solingen 2007, 85). In the early 1970s, President Park Chung-hee of South Korea took several steps to initiate a nuclear weapons program such as instructing KAERI to make the acquisition of a reprocessing capability—to provide the plutonium for nuclear weapons—a top priority. These attempts were blocked by the United States, and South Korea ratified the NPT in 1975 and adopted an IAEA safeguards agreement, after the United States

1 For more details on the history of protests over spent nuclear fuel in South Korea, see Park, Pomper, and Scheinman (2010).

2 The Korea Nuclear Energy Foundation is a research body of the Ministry of Knowledge and Economy, which supports the nuclear industry's exports. The results were published in a number of Korean publications, including Kim R. (2010).

threatened to withdraw its security guarantees if Seoul did not halt its weapons development plans (McGoldrick 2008, 5–6).

The announcement by President Jimmy Carter in the late 1970s that the United States intended to withdraw all ground troops from the peninsula by the early 1980s revived Park's interest in a nuclear weapons option. Seoul renewed its efforts to acquire a reprocessing capability from France—an effort thwarted by Carter's personal intervention with the French prime minister and his nearly simultaneous decision to halt the withdrawal of U.S. forces from the Korean peninsula (McGoldrick 2008; Kim S-y 2001, 55; NYT 1977).

In recent years, South Korea has steadily gone beyond its NPT commitments to enhance the transparency of its nuclear program and to distance itself from an immediate nuclear weapons option. It has chosen to rely on imported enriched uranium, for example, despite its technical capabilities and considerable economic incentives to produce it indigenously. In addition, in 1992 the ROK and the DPRK signed the "Joint Declaration on the Denuclearization of the Korean Peninsula," whereby Seoul and Pyongyang agreed not to "possess nuclear reprocessing and uranium enrichment facilities." The two sides also declared they "would not test, manufacture, produce, receive, possess, store, deploy or use nuclear weapons." This agreement was meant "to create an environment and conditions favorable for peace and peaceful unification . . . and contribute to peace and security in Asia and the world."

The 1992 joint declaration included a verification agreement that was meant to allow reciprocal inspections. However, this agreement was never fully implemented by either side. Although numerous negotiations were held to establish the inspection regime for this agreement, talks collapsed in 1993 after months of bitter disputes revolving around, among other issues, South Korea's suspicions about the DPRK's reprocessing activities and North Korea's demand to be allowed to inspect U.S. military bases in the ROK to assure they did not house nuclear weapons (CNS 2009). It is widely agreed that North Korea's nuclear activities during the past decade—particularly its reprocessing and nuclear tests—have been in clear violation of the 1992 agreement. Despite this, South Korea has never officially abandoned the joint declaration and has called on Pyongyang to abide by the pact. Informally, however, South Korean officials claim the 1992 statement is legally void because of the North's violations.

U.S. concerns about pyroprocessing are heavily impacted by how it will impact the denuclearization pact, as many in Washington fear that if South Korea were to openly break with the agreement by constructing its own nuclear reprocessing

South Korea's Rise: A Threat to Regional Competitors?

South Korea's potential role as a major nuclear supplier is likely to be viewed with some concern by other states in the region, particularly other nuclear suppliers such as Japan, China, and Russia. Although these actors will also have nonproliferation concerns, the most prominent concerns in the short term are likely to be economic, as Seoul competes with these other suppliers for business from a similar market of the nuclear newcomers.

Japanese companies have supplied reactors and reactor components for years, but lack of coordination and government support has hindered Japan's growth as a major player in the nuclear reactor export market. Japanese firms were topped by the ROK's bid for the UAE's business, and much of the blame was placed on the lack of a coordinated effort in Japan to provide customers with a full package of services. Another problem is cost: South Korea's bid was estimated as being about 20 percent less than Japan's (Soble 2010). The rise of South Korea as a competitor, especially if the ROK can offer full fuel cycle services, is viewed with trepidation by the Japanese nuclear industry.

Recent government and industry efforts in Japan are aiming to gain new ground in emerging markets in Asia and the Middle East (Wallace 2010). Japan recently signed nuclear cooperation agreements with Jordan and Kuwait. Japan is in the process of finalizing one with Vietnam, and it directly competed with South Korea on a Turkish bid. In October 2010, Japan launched a consortium, the International Nuclear Energy Development of Japan Co. (JINED), comprising nine electric utilities and three nuclear engineering companies to help Japan win business for nuclear power plants in emerging countries. Japan is also considering lending as much as $4 billion for a nuclear plant project in

facilities, that action might provide a pretext for Pyongyang to claim its behavior was no more illegitimate than that of its southern neighbor. South Korean officials seek to sidestep this problem by differentiating pyroprocessing from standard reprocessing, and they point to the somewhat greater proliferation resistance of pyroprocessing. Traditional reprocessing uses liquid solvents and ultimately separates pure plutonium, a weapons-usable material. Pyroprocessing leaves the plutonium mixed with other transuranic elements such as americium and neptunium.

South Korea signed an additional protocol to its IAEA safeguards agreement, which entered into force on February 2004 (IAEA 2004). The additional protocol provides IAEA inspectors greater access to a country's nuclear facilities, Texas that would be Tokyo's first government financing for an atomic power station abroad (Sato, Taniguchi, and Inajima 2010).

Russia is likewise liable to lose out to South Korea on some nuclear business. Russia has made a strong showing in the markets of eastern and central Europe and is looking to expand to other areas, including Asia, Africa, the Middle East, and South America. Russia's current work in the Middle East largely revolves around its controversial cooperation with Iran on the Bushehr reactor although it also is working with Turkey to build the nation's first reactor at Akkuyu, and its VVER-1000 is one of the three reactor designs Jordan is currently considering for its first nuclear power plant (WNN 2010a). Reports indicate that Turkey is working with ROK companies on its second reactor, which shows how South Korea can compete directly with Russia (WNN 2010c). At the same time, Russia and South Korea also see each other as potential partners in the nuclear market: in 2008, the Russian firm ARMZ signed an agreement with a Korean consortium led by KEPCO for the development of uranium projects, including exploration, mining, and sales (WNN 2008). For the South Korean side, which must import most of its uranium, this deal represents a secure source of fuel for domestic needs and possibly for future customers.

For China, which has undertaken fewer nuclear-related exports than others in the region, South Korea remains a trading partner, and the ROK still sees China as lucrative market (MacLachlan 2010). As Beijing seeks to expand its market share, however, Seoul's new nuclear ambition may become an impediment. In burgeoning markets, like that in Vietnam, for example, which recently announced a bold nuclear industry expansion, Chinese nuclear exporters are competing head to head with Korean firms (WNN 2010d).

materials, and records, particularly undeclared facilities. A statement by the Ministry of Foreign Affairs and Trade (MOFAT 2004) noted: "With the Additional Protocol brought into force, the [ROK] . . . is expected to . . . gain the greater trust of the international community by securing full transparency with regard to its nuclear activities."

Despite these demonstrations of good nuclear intentions, the entry into force of the ROK's Additional Protocol also brought with it revelations of past transgressions. When the ROK submitted its initial declaration, as required by the Additional Protocol, it disclosed to the IAEA a series of previously undeclared laboratory-scale experiments conducted by scientists at KAERI.

The resulting IAEA investigations revealed that South Korean scientists had engaged in experiments related to uranium enrichment, conversion, and plutonium separation (Pinkston 2004; IAEA 2008a; IAEA 2008b, app. 1). These included activities in chemical enrichment from 1979 to 1981, plutonium separation from 1981 to 1982, uranium conversion activities from 1982 to 1994, and laser enrichment activities from 1991 to 2000. Although all of the experiments produced only very small quantities of nuclear material and did not appear to have been part of an organized nuclear weapons effort, each of the experiments involved technical skills that would be applicable in a weapons program. In addition, the undeclared use of nuclear material in the experiments constitutes a violation of the ROK's IAEA safeguards agreement, and South Korea had denied conducting several of these activities before finally admitting them (IAEA 2008a, 5:26–27, 3:12e). According to the IAEA director general's report to the board of governors, South Korea informed the IAEA that the "experiments were performed without the knowledge or authorization of the government" and were "conducted solely to satisfy the scientific interest of the scientists involved" (IAEA 2008a, 2:6, 6:34). In May 2008, the IAEA concluded that it "considers all past undeclared activities involving uranium enrichment, . . . conversion, and plutonium separation experiments as resolved" (IAEA 2008b, 9:34). Some have nevertheless disputed South Korea's claims that knowledge of the experiments was confined solely to officials within the technical and scientific community.[3] Seoul's claim to have not known of the unreported nuclear research raised further concerns regarding bureaucratic oversight and control in the ROK's nuclear industry (Pinkston 2004; Kang et al. 2005, 40–49).

Still, the majority of the reporting discrepancies were cleared up relatively quickly by IAEA inspector visits during the latter part of 2004, and in 2007 the IAEA closed its investigation.[4] All told, the undeclared experiments discussed above seem to be part of scattered attempts to test or prove capabilities rather than a dedicated attempt by Seoul to produce nuclear weapons. Seoul has since

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3 Kang et al. (2005) write: "Although KAERI did not report the plutonium separation activity to MOST [Ministry of Science and Technology] in 1982, it seems likely that MOST knew about it all along, not least because the separation activity had been well-known in American intelligence circles and to nuclear specialists since the early 1980s. Presumably, a South Korean investigation will cast further light on how the higher levels of government remained ignorant of an activity that was widely known at the time among specialists, both inside and outside intelligence and nuclear circles." An article in *Arms Control Today* (Kerr 2004a) reports similar skepticism: "However, the Vienna source told [*ACT*] that there are serious questions as to whether this claim is accurate, pointing out that the experiments were conducted in government facilities."

4 The IAEA director general's report to the board of governors on 11 November 2004 listed the outstanding questions as being foreign assistance to the ROK's AVLIS program, the origin of the phosphate ore that was used to process the yellowcake uranium, and more information surrounding the plutonium separation experiments (Kerr 2004b).

implemented several institutional reforms and educational programs aimed at strengthening its oversight of the activities taking place in its own nuclear research facilities (Yoon 2008). But these past activities have made it even more difficult for Korea to gain support for acquiring dual-use technologies like uranium enrichment or spent fuel reprocessing that could be used to produce nuclear weapons as well as nuclear energy.

The ROK is a member of all multilateral export control regimes, including the Nuclear Suppliers Group (NSG), [5] and has domestic legislation controlling the export of dangerous materials and technologies. Under the Foreign Trade Act, the Ministry of Knowledge Economy is the government agency responsible for export control policy. The Korea Strategic Trade Institute (KOSTI) is a semi-governmental agency that works with private firms to increase awareness and assist with export control compliance.[6] Prior to 2006, a number of high-profile cases highlighted weaknesses in the ROK export control system. These cases included one involving the A. Q. Khan network's assistance with Libya's nuclear program (CNS 2004). South Korean firms have also been used as brokering agents for the DPRK and elsewhere in the past. However, in 2006 and 2007 the ROK government made significant revisions to the county's export control regulations—including strengthened brokering controls (Nash and Young 2007).

South Korea as a Nuclear Exporter

Since December 2009, South Korea has been playing a growing role in the international nuclear market. The ROK has won two lucrative nuclear export contracts in the UAE and Jordan. The first contract Seoul won was a $20.4 billion contract to construct four 1,400-megawatt reactors in the UAE by 2020. South Korea defeated the French team of GdF Suez, AREVA, and Total and a U.S.-Japanese consortium of General Electric and Hitachi. The South Korean bid was led by ROK's national power company KEPCO, which partnered with the Korean firms Samsung, Hyundai, and Doosan Heavy Industries; Japan's Toshiba; and U.S.-based Westinghouse. Seoul expects its first nuclear deal to bring in approximately $40 billion. Construction of the reactors will cost $20

5 The NSG is a group of nuclear supplier countries that adopted voluntary guidelines for nuclear and nuclear-related exports. Led by the United States, some NSG members have attempted (so far unsuccessfully) to add restrictions on exporting items used for sensitive nuclear fuel cycle activities—uranium enrichment and spent fuel reprocessing. Another initiative is to require the adoption of the IAEA Additional Protocol as a condition for future trade of all nuclear materials, equipment, and technology. The NSG postponed the discussion on the Additional Protocol requirement until reaching an agreement on the enrichment and reprocessing restrictions.

6 See South Korea's comprehensive information portal for its export control system at MKE (2010).

Table 2: **Comparison of Bids for UAE Nuclear Project**

Reactor design	Electricity cost	Overnight cost	Construction time (months)
APR-1400	$3.03/kWh	$2,300/kW	48
AREVA EPR	$3.93/kWh	$2,900/kW	57
GE ABWR	$6.86/kWh	$3,580/kW	48

Source: Adapted from Stott (2010).

billion and is expected to create approximately 110,000 jobs over the next 10 years. The remaining $20 billion will come from contracts to operate, maintain, and supply fuel to the reactors during their 60-year lifespan (Stott 2010). Westinghouse will receive $1 billion of the contract to design the technical support services and provide control equipment, instrumentation, and reactor components (PTR 2009).

The Korean bid was considered by many outside observers as the underdog because of South Korea's lack of experience in the international nuclear market, especially when compared with the high-level diplomacy undertaken by the French president, Nicolas Sarkozy, and the long-standing ties between Washington and the UAE. However, the Korean government was also heavily involved in supporting KEPCO's bid, which was considered very competitive in terms of both construction time and cost. Korean government data claims that construction and electricity generation costs are significantly lower and shorter for its APR-1400 units than for the two other reactor designs (***Table 2***). Korean officials say the low costs stem from innovative construction techniques, standard designs, extensive construction experience, and the fact that Korean reactors are the most reliable in the world in terms of their "capacity factors"— the proportion of time that the reactor is generating electricity (Moon 2010).

In March 2010, South Korea signed a second reactor supply agreement—a $130 million contract to construct a nuclear research reactor at the Jordan University of Science and Technology. The reactor is to be constructed by KAERI and Daewoo. The reactor is a 5-megawatt reactor, upgradable to 10 megawatts (Bqoor 2010), and it is a smaller version of KAERI's HANARO (ANC 2010). South Korea has agreed to finance most of the project. Seoul would initially provide a $70 million soft loan, scheduled to begin in June 2010 (TendersInfo 2010; Luck 2010).

Possible Future Contracts

Following the UAE deal, the ROK announced its objective to export 80 nuclear reactors by 2030 (Cho 2010). It has been targeting contracts in India, Indonesia, Vietnam, Thailand, Malaysia, Netherlands, South Africa, Turkey, and others (WNN 2010b). South Korea also wants to expand in the long term into bigger markets such as China and United States (JAD 2010).

Following a preliminary agreement with Turkey to build two nuclear power plants in Sinop in March 2010, KEPCO and the Turkish state power company, Elektrik Uretim AS, inked a joint feasibility study into deploying the APR-1400. If this collaboration bears fruit, a full nuclear cooperation agreement between Ankara and Seoul will be signed to facilitate the reactor supply deal (Stanton 2010). KEPCO and its subsidiary Korean Hydro and Nuclear Power (KHNP) have also agreed with the Indonesian state electricity firm PT Perusahaan Listrik Negara to undertake a feasibility study for the Indonesia's first nuclear power plant. The study will assess whether Indonesia should buy the older Korean design, the OPR-1000.

KEPCO is also keen to export Advanced Power Reactors (APRs) to India. KEPCO and the Nuclear Power Corporation of India Limited (NPCIL) signed a memorandum of understanding that includes development of nuclear power projects, operation and maintenance of nuclear power plants, supply of nuclear fuel, and manufacture and supply of equipment and components apart from a joint study for the "licensibility and constructability" of the APR-1400. New Delhi and Seoul have yet to enter civilian nuclear cooperation agreement (DH 2010).

ROK's Comparative Advantages (and Disadvantages) as a Nuclear Exporter

Contracting with South Korea as a reactor supplier brings some important benefits and advantages. South Korea provides a proven technology with ample experience in reactor construction and maintenance. During the past 20 years, U.S. companies have transferred to Korean firms the know-how to build reactors, improve designs, manufacture fuel, make key nuclear components, and manage projects (Lipschutz 2010). By comparison, other vendors are offering products that have yet to be proven or are still under development. South Korea's bid also included more significant transfer of nuclear know-how to the customer. In addition, in the case of the French bid for the UAE contract, their efforts were hindered by problems related to AREVA's work on the Olkiluoto 3 reactor in

Finland, which is significantly behind schedule, over budget, and suffering from safety problems.

Another problem most other nuclear exporters suffer chronically is lack of qualified personnel to construct the new reactors. South Korea has committed to creating a sizable cadre of nuclear specialists to assure long-term stability in its nuclear-related workforce. Many Korean scientists trained overseas and returned to the ROK to implement the "localization" of South Korea's nuclear industry (Lee et al. 2009, 550). As early as 1967, the ROK government was investing in its nuclear workforce with programs such as the Nuclear Training and Education Center (MEST 2010). This program, administered by *KAERI*, was renamed the Nuclear Human Resource Development Center (NHRDC) in 2007 and now trains nuclear industry personnel in the areas of nuclear steam supply systems, fuel design, safety analysis, and nuclear preparedness (KAERI 2010). Other programs sponsored by the Korean government include the International Nuclear Safety School, established in 2008 by the Korea Institute of Nuclear Safety (KINS), which offers training programs for Korean nuclear professionals. These programs also help train foreign nuclear scientists, assisting Seoul with its outreach to potential customers in Southeast Asia and the Middle East.

In academia, ROK universities have many advanced nuclear related programs, including those at the Seoul National University and Kyung Hee University, which houses South Korea's only educational research reactor, the Aerojet General Nucleonics Model (AGN-201) (SNU 2010; KHU 2010). The experts currently in Korean industry and those coming up in the ranks of the Korean education system will provide assurance that South Korea has the human resources needed for building and servicing domestic and exported nuclear reactors.

Korean bids are also considered very competitive in terms of safety features. In the UAE case, the APR-1400 features innovative safety measures not found in the two other reactors, such as a shield against missile attacks and structural enhancements to prevent or reduce earthquake damage to the reactor. The latest feature is particularly relevant to seismically unstable countries such as Jordan and Turkey. South Korean firms also offer a more competitive price and a more aggressive construction schedule. As noted in Table 2, the French EPR design would have taken 57 months to construct, but the APR-1400 would take only 48 months to build (Lipschutz 2010). South Korea can now forge three-and-a-half sets of reactor components each year and will soon expand so as to be able to produce five sets of reactor components each year. For reference, an

OPR-1000 requires one reactor pressure vessel, two steam turbines, and four pressurizers.[7]

Last, South Korea provided other sweeteners. For example, the ROK will operate and maintain the reactors. Under the Jordanian deal, in addition to the reactor itself, South Korea will provide a radioactive-isotope manufacturing facility and a nuclear training center. In addition, Jordan has the right to reexport this technology after 20 years (Viski 2010). South Korea will also help to finance the construction of the research reactor. Jordan received a $70 million loan from the Export and Import Bank of Korea, with a 0.2 percent interest rate and a grace period of 10 years, and the loan will be repaid over 30 years (JNA 2010). In the UAE case, Korea Nuclear Fuel (KNF), which supplies all of the fuel for Korea's nuclear power plants, will supply half the fuel for the four reactors (Westinghouse will supply the other half). According to a briefing by KNF officials on 20 July 2010, KNF has major plans for export, hoping to become the world's third-largest exporter of nuclear fuel after AREVA and Westinghouse. KNF already exports some components to Westinghouse for use in U.S. domestic reactors, and officials claim the fuel's failure rate is less than half of Westinghouse or AREVA.

Going forward, South Korea may be able to benefit from two other advantages it offers in the region. First, many Middle Eastern countries such as Saudi Arabia, Jordan, Egypt, and Kuwait are seeking to use nuclear reactors for desalination. Doosan already has a 40 percent share of the global desalination market (using conventional fuels), and it has been expanding its foothold in the Middle East (MEED 2010; Baxter 2010). Korea is also building a small modular reactor, SMART, which is particularly aimed at desalination. Second, Korean construction companies are already quite active in the region, raising the comfort level for potential customers. In fact, the Middle East is the main export market for Korean construction companies, accounting in 2009 for 67 percent of their business (MEED 2010; Baxter 2010).

Importing a reactor from South Korea nevertheless also has some disadvantages, especially for less-developed countries. So far, the ROK has avoided deals in which it needs to finance the exported reactor and make its return based on the long-term sale of electricity. Such an approach might be a serious impediment in exporting to poor Middle Eastern states. When Jordan decided in May 2010 on a public-private partnership (PPP) model—where Jordan owns the reactor and the contractor supplies financing for the construction and operation of the

7 Information acquired during a site visit to Doosan Heavy Industries, 19 July 2010.

reactor—to finance its nuclear power plant, the South Korean consortium withdrew from the bid (DS 2010). Under the PPP model, the contractor profits from the sale of electricity, and there is no government guarantee of a profit from the sale. Similar problems may befall Seoul's attempts to strike a deal with Turkey. In its agreement to build four reactors on Turkey's southern coast, Russia committed to fully cover the up-front cost of each of the plants and eventually sell 51 percent back to Turkish state power companies (Stanton 2010; AA 2010). By comparison, the UAE deal, which South Korea won, was a joint venture in which the host government has a 60 percent stake and 40 percent is owned by the joint-venture partners.

Another issue is related to Korean reliance on U.S. technology. Because the exported Korean designs are based on U.S. technology, U.S. export controls will apply. In the UAE case, for example, Westinghouse will supply equipment, engineering, and fuel-service contracts to the KEPCO consortium, which requires authorization from the U.S. Department of Energy to transfer the technology to the UAE (Holt 2010). South Korea is also not 100 percent self-sufficient in nuclear technology. For the UAE nuclear plants, the ROK will need assistance from Westinghouse for nuclear design code, reactor coolant pumps, and man-machine interface systems (MMIS). Doosan, however, has nearly completed the development of MMIS and pump technology—which means that the issue of U.S.-origin technology may be a short-term problem for ROK exports—and Doosan officials say they soon will be independent of all U.S. export license requirements (JAD 2010). Last, although South Korean domestic construction times are currently some of the fastest in the world, the country's nuclear power industry has yet to be proven on foreign soil.

Export Markets and the Lure of Enrichment and Reprocessing

As the ROK has emerged as a nuclear exporter, South Korean officials have voiced an increasing interest in acquiring enrichment and reprocessing (ENR) technology, in part to be able to provide potential customers with the full range of services for fueling their reactors and disposing of the spent fuel as many of its competitors already do.[8] To be sure, Korea's interest in the form of reprocessing known as pyroprocessing primarily results from South Korea's failure to solve its domestic spent fuel management crisis. While South Korea is far from alone in its failure to find a permanent site at which to dispose of its spent fuel, the

8 France supplies enriched uranium and nuclear fuel for reactors and reprocessing services although it sends back high-level waste, shorn of plutonium, to its customers. In some cases, such as its deal for the Bushehr reactor in Iran, Russia provides nuclear fuel or enriched uranium, takes back the spent fuel, and does not return high-level waste to the customer.

failure to win domestic political support for additional interim storage sites has led to an imminent crisis. Only a few years from now, South Korean scientists predict, the spent fuel pools at South Korea's nuclear plants will begin to reach capacity.[9] South Korea has explored pyroprocessing as a potential technical solution to this problem.

Pyroprocessing treats spent fuel to remove its extremely radioactive but relatively short-lived beta-emitter constituents (such as strontium, cesium, and iodine), and leaves behind unused uranium and the extremely long-lived transuranic alpha-emitters—plutonium, americium, and neptunium. The ROK plans to burn these materials in yet-to-be-designed fast burner reactors, ultimately reducing the overall quantity of waste requiring permanent disposal. Some in Seoul, particularly those in the Ministry of Education, Science, and Technology (MEST) and its subordinate organization, KAERI, see this as particularly advantageous because the ROK's high population density makes it difficult to find sufficient space for a single large nuclear waste permanent underground repository. KAERI also claims that pyroprocessing, a technique pioneered by the U.S. national laboratories, is more proliferation resistant than traditional reprocessing, which separates pure plutonium.

Although other elements within the Korean government are not fully convinced of the wisdom of this approach, Seoul has reached a consensus that the option of moving forward with this technology should be preserved in negotiations with the United States on its new bilateral nuclear cooperation agreement. The old agreement, set to expire in 2014, prevents South Korea from carrying out any "alteration in form and content" (such as reprocessing, pyroprocessing, or enrichment) on U.S.-origin fuel without U.S. permission. Seoul is seeking to use the talks to relax some of Washington's long-standing restrictions on the processing of spent fuel. But the U.S. government has yet to give its blessing because it is worried that the process or its output could be too easily altered to produce a less benign product, that it will be too difficult to institute safeguards to prevent such changes, and that any relaxation of U.S. rules would harm Washington's global and regional nonproliferation efforts. In fact, in the first round of the negotiation on renewing their bilateral nuclear cooperation agreement, the

9 Spent fuel from Korea's four CANDU reactors is now in interim dry cask storage at a reactor site in Wolsong, but this facility will be full by 2017. Additional construction of any interim spent fuel storage facilities at Wolsong is effectively prohibited by the special law established on 31 March 2005 (law no. 7444), which prohibits any construction of spent fuel–related facilities in the same region as the low- and intermediate-level radioactive waste disposal facility. Such a facility is now under construction near the Wolsong reactors in Geongju. The text in Korean is available at http://likms.assembly.go.kr/law/jsp/Law.jsp?WORK_TYPE=LAW_BON&LAW_ID=A1885&PROM_NO=09885&PROM_DT=20091230&HanChk=Y.

United States and ROK agreed to conduct a joint study on pyroprocessing and other ways of handling spent nuclear fuel in parallel with negotiating the other issues related to the agreement. According to Cho Hyun, the Korean deputy foreign minister for multilateral and global affairs, if the sides are not able to reach an understanding by March 2013 on pyroprocessing, the new cooperation agreement will have a clause that the issue of pyroprocessing technology may be considered separately after completion of the joint study (Hwang 2010).

South Korean officials have also been increasingly talking of the need to build their own facilities to enrich uranium. To date, South Korea has relied on importing enriched uranium from Europe and the United States and then fabricating the fuel domestically. But South Korea's domestic market alone has approached the point at which it could make economic sense to enrich the fuel itself. And as that market grows—and new overseas sales opportunities beckon—the lure of building enrichment facilities is likely to grow.

Given Seoul's mixed nonproliferation record and its need to respond to Pyongyang's nuclear weapons program, the United States and key regional states such as Japan and China are concerned about South Korea launching enrichment or reprocessing programs. They fret that, given South Korea's other capabilities (such as missile technology), the possession of such programs could bring the ROK within a few months of being able to build a nuclear weapon. South Korean officials complain, however, that the United States and China have long had this concern about Japan's extensive reprocessing program as well, but that the United States has granted Japan permission to reprocess U.S.-origin fuel.

South Korea's rise as a nuclear exporter has made its policies on these issues not only a regional but a global concern. South Korea has been notably quiet about efforts by some NSG members, particularly the United States, to increase restrictions on the trade of ENR technology. As a member of the regime, South Korea has been involved with the group's negotiations on adding restrictions to these types of technologies; however, other NSG members—namely Turkey and South Africa—have forcefully disagreed with efforts aimed at adding new restrictions to trade (Hibbs 2010b). South Korea is unlikely to outwardly support efforts for new restrictions if Turkey, with whom South Korea recently signed an extensive nuclear cooperation deal, continues to object (AS 2010).

Moreover, unlike Japan (explicitly) and the United States (de facto), South Korea has not made the IAEA's Additional Protocol a condition for supplying nuclear technology. As noted above, this voluntary protocol strengthens the rights of IAEA inspectors to detect the diversion of civil nuclear programs to military uses and reveal the existence of covert weapons programs, particularly by granting greater access to undeclared nuclear facilities. Jordan, Turkey, and the UAE had agreed to abide by this protocol long before negotiating with the ROK, but other potential ROK customers have not. South Korean officials have said they will support this requirement if endorsed by the NSG, but not beforehand (Hibbs 2010a).

Also, Seoul has been slow to cooperate with recent international efforts aimed against Iran's nuclear program. This hesitation is based on basic economic interests—Iran is an important trading partner for South Korea, and the ROK gets about 10 percent of its fuel from Iran (Harlan 2010). Under U.S. pressure, in September 2010, South Korea announced new sanctions on Iran. These measures included placing 102 Iranian firms and 24 people on a list "banning financial transactions without central bank approval" (Lim and Seo 2010), more thoroughly inspecting cargo from Iran, and curbing ROK investment in Iranian oil and gas enterprises (Kirk 2010). South Korea further announced plans to close temporarily the local branch of the Iranian Bank Mellat, which is the bank's only office in East Asia (Ramstad 2010). This bank is reported to be involved with about 70 percent of all South Korean-Iranian transactions (Kirk 2010). Washington has been pressuring Seoul to permanently close the Bank Mellat branch. South Korean officials had been investigating the bank for potential illegal activities involving Iranian companies under UN sanctions. Seoul appears still unwilling to completely shut down the branch at this point, signifying it is still concerned about alienating a major trading partner.

To be sure, Seoul has recently taken some very public strides toward playing a greater leadership role in global nonproliferation efforts. After hesitating for many years, Seoul agreed in 2009 to join the Proliferation Security Initiative (PSI). The apprehension of earlier ROK governments about PSI was largely based on concerns that North Korea would see South Korean participation as a hostile move; however, the election of the more conservative Lee Myung-bak and the second DPRK nuclear tests in 2009 resulted in Seoul's decision to become an active participant in the U.S.-led initiative. In fact, in November 2010 South Korea became the 21st member of the PSI Operational Experts Group—the guiding policy-making and operational body for the initiative. In April 2010, Seoul offered to host the next Nuclear Security Summit in 2012, a gathering of global leaders intended to carry out President Obama's goal of securing all vulnerable materials (particularly highly enriched uranium or plutonium) from terrorists by 2014 (White House 2010). And in June 2010, South Korea agreed to host the next plenary meeting of the Global Initiative to Combat Nuclear Terrorism (GICNT) (Abu Dhabi 2010). Seoul has been an active member of GICNT since

May 2007, focusing on law enforcement intelligence gathering (DOS 2006; Choe 2010). Recently, South Korea also presented, along with Australia, a resolution to the General Assembly's first committee demanding improved collaboration among UN member nations in preventing the proliferation of weapons of mass destruction and other armaments. The resolution, Preventing and Combating Illicit Brokering Activities, received 171 supporting votes, while North Korea opposed it and Iran abstained from the vote (GSN 2010).

South Korean officials also tout the value of their own experience—as a country that developed a strong nuclear energy program without developing nuclear weapons—as a model for nuclear novices in the developing world. Already the Korean government has several programs aimed at exporting this model to other countries. KAERI provides training to "new" nuclear states in how to operate and manage nuclear technology, while KINS and KHNP, as noted earlier, provide training for foreigners as well as Korean workers in safety, operation, and management of nuclear facilities. At the 2010 Nuclear Security Summit in Washington, D.C., South Korea also pledged to build a nuclear security training facility that will serve as a simulation center.

Conclusion

South Korea should be congratulated for its recent nonproliferation initiatives, which show a welcome recognition that its new role as a global nuclear exporter comes with new global responsibilities for preventing nuclear weapons proliferation. But if Korea is serious about its goal of becoming one of the world's top nuclear exporters, it will also have to become more serious about nonproliferation. In particular, it will have to change from being, at best, a follower of international nonproliferation norms to a leader in forging new ones. That will mean at times that Seoul will have to be willing to sacrifice potential business or take on strong domestic political constituencies (whether protestors or industry) in order to advance global nonproliferation goals—whether imposing sanctions on nonproliferation rogues, forgoing pyroprocessing, or requiring that potential customers have concluded an additional protocol to their IAEA safeguards agreement.

South Korea's hosting of the 2012 Nuclear Security Summit and its difficulties in dealing with spent fuel offer two particular opportunities to exercise leadership. If Seoul agrees to a cautious agenda for the 2012 meeting, it will be sacrificing a chance to make its own mark. It should consider proposing a bold initiative of some type, such as seeking to conclude an agreement to phase out highly enriched uranium in the civilian sector; research reactors around the world, for example, still use enough of this material every year to make as many as 30 nuclear weapons.[10]

Because reprocessing raises nonproliferation concerns, Seoul should consider multilateral alternatives to its national effort to pyroprocess spent fuel. Such an effort would also allow South Korea to address its spent fuel problems without undermining U.S. and global efforts to minimize the spread of enrichment and reprocessing technologies.[11] Seoul could take the lead in establishing a new regional forum for more consistently and openly discussing possible options for dealing with regional spent fuel stockpiles. Many regional players are facing similar spent fuel challenges, and some of their nuclear authorities are proposing similar solutions. Sharing of best practices and lessons learned would be beneficial. Numerous smaller Asian economies (such as Vietnam and Indonesia) are contemplating nuclear power development, yet there is little regional discussion or coordination of such issues.

ROK's rise as a nuclear exporter is good news for South Korea's nuclear industry and workers. Should Seoul embrace more nonproliferation responsibilities, it will be good news for South Korean and global security as well.

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10 Research reactors require 750 kg of highly enriched uranium (HEU). That quantity of HEU could be used to create approximately 30 nuclear weapons, using the IAEA's definition of the minimum amount of HEU needed to produce a weapon (25 kg) (Reistad and Hustveit 2008, 265; IAEA 2001, 35).

11 For more details see Pomper et al. (2010).

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