The U.S.-Republic of Korea Nuclear Relationship – An Indispensable Alliance

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Introduction

The United States and the Republic of Korea (ROK) have enjoyed a close relationship on the research, development, and deployment of civil nuclear energy since the dawn of the nuclear era. In 1956, both nations signed a Nuclear Cooperation Agreement on the Non-Military Uses of Nuclear Energy (1956 Agreement). Two years later, through President Dwight Eisenhower's Atoms for Peace Program,[1] General Atomics[2] agreed to work with Seoul to construct the TRIGA[3] Mark II research reactor using U.S.-origin fuel, which was brought online in 1962.

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Cooperative efforts on nuclear power generation began in May 1972, replacing the 1956 Agreement with a section of the U.S. Atomic Energy Act that sets limitations and guidelines for peaceful international nuclear energy cooperation.[4, 5] Later that year, the ROK began its nuclear power program in conjunction with Westinghouse Electric Corporation and secondarily, the General Electric (GE) Company's United Kingdom affiliate – the primary drivers in U.S. reactor design.[6] In 1978, ROK's first power reactor went online, followed by eight reactors constructed in the 1980s.

Today, the ROK is an advanced economy that relies heavily on nuclear power, given its lack of indigenous energy sources for power generation.[7] As of September 2016, a total of 25 nuclear units provide roughly one-third of the country's electricity with current plans for adding 70 percent more capacity by 2029.[8]

The ROK's nuclear industry is globally competitive given its one-stop service that can provide almost all nuclear related items from domestic vendors and manufacturers. The ROK also has a sophisticated nuclear energy research and development program, largely through the Korea Atomic Energy Research Institute (KAERI), which has actively participated in the localization of ROK's own nuclear plant design, the OPR-1000, since the early 1990s.

In 2009, the ROK stunned the world by catapulting into the exclusive club of global reactor providers by winning a $20 billion contract to construct four reactors in the United Arab Emirates (UAE).[9] The deal was a major coup for the ROK, establishing the country as a credible and safe supplier of nuclear reactors. This rapid rise has been impressive, but more importantly, timely and beneficial to the U.S. nuclear industry and American national security interests.[10]

With the decline of its own civil nuclear program,[11] the United States needs ROK's nuclear prowess to strengthen its own market position and help uphold its nonproliferation and safety goals, especially with the looming threat of a Chinese commercial nuclear monopoly. Furthermore, the ROK provides the United States with additional foreign commercial opportunities and critical added investment.

ROK's Rising Civil Nuclear Capabilities

The ROK, with a population of over 50 million, consumes a considerable amount of energy – the eighth most energy intensive economy in the world.[12] Coal, natural gas, and oil account for the bulk of its fuels for power plants and 68 percent of its electricity generation.[13] The desire to improve energy security, air quality, and its balance of payments has resulted in Seoul spending significant resources on building a commercial nuclear program. Currently, the ROK owns the sixth largest nuclear reactor fleet in the world.[14]

Photo: The Shin Kori 3 nuclear reactor (APR1400) went online early 2016. Courtesy: KHNP

Nuclear waste is becoming an increasing concern, especially as the nuclear program continues to grow. Considering the ROK's plans to increase generating capacity, limited geography for disposal of spent fuel, and a high population density, the nation is challenged with what to do with its waste.

Existing reactor sites will have reached their designed storage capacity for spent fuel by 2024, and isolated locations to dispose of high level nuclear waste are scarce. Seoul must pursue innovative solutions, including the development of new technologies to condense spent fuel volumes and radiological toxicity that would allow for a disposal facility with a reduced footprint. In the meantime, the ROK must rely on interim dry cask storage, which is, unfortunately, the only near-term option.

To help manage its waste challenge, Seoul has decided to develop a next generation "Gen IV" reactor – the Sodium-cooled Fast Reactor (SFR). The design will be completed by 2017 with government approval expected three years later. In combination with the SFR, the ROK has also decided to pursue a specific type of spent nuclear fuel recycling technology called "pyroprocessing."[15]

If scaled commercially, pyroprocessing would drastically reduce the volume of spent fuel designated for geological high level waste (HLW) disposal. Moreover, the radiotoxicity for the remaining waste would drop from hundreds of thousands of years to only a few hundred – a remarkable achievement. Plans also call for some of the waste to be recovered and manufactured into fuels for SFRs.

The ROK is a significant player in the commercial nuclear business, exporting its own "Gen III" reactor design, the APR1400. As mentioned earlier, a ROK consortium led by the Korea Electric Power Company (KEPCO) won the bid to build the first four reactors in the United Arab Emirates (UAE).[16] The first unit is expected to go online by 2017 with the remaining three units by 2020. These reactors are manufactured by Doosan and other major suppliers including KEPCO E&C, Hyundai, Samsung, and Westinghouse.[17]

ROK manufacturers are today capable of servicing nearly the entire nuclear supply chain, including design engineering, components, construction, operation, and maintenance of nuclear power plants and fuels.[18] Through strategic decision-making over decades, the nation has built up and supported its nuclear industries to be capable of delivering products and services for its domestic program and, more recently, for export. Doosan is the component manufacturer for the reactor nuclear island, the heart of a reactor; Daewoo, Doosan, Hyundai and Samsung are involved in the construction and the balance of the plant construction, including the extensive rebar and concrete installation, the control room and steam turbines; while the Korea Hydro and Nuclear Power Company (KHNP) is involved in construction planning and nuclear operations; KEPCO E&C is the nation's chief design and engineering company; and KEPCO NF is a nuclear fuel fabricator.

Missing from the ROK nuclear portfolio is enrichment and the ability to close the fuel cycle. To address this challenge, the ROK is seeking U.S. permission, as required by the Atomic Energy Act (AEA), to conduct these nuclear activities. Most ROK reactors were exported from the United States or are based on U.S. designs through technology-transfer arrangements. Under the AEA, the ROK can only reprocess or alter U.S.-origin spent fuel, including spent fuel from the ROK's U.S.-designed reactors, if permission is granted by Washington.[19]

The Declining U.S. Civil Nuclear Program

Despite having the largest commercial nuclear fleet in the world, the United States is moving away from nuclear as an energy source, relying increasingly on lower-cost natural gas for baseload power and added renewable energy. The recent announcement that Exelon, a leading U.S. utility, plans to shutter two of its nuclear plants[20] is a harbinger of things to come. In contrast to ROK's planned expansion of its nuclear program, U.S. civil nuclear capacity is expected to shrink by 20 percent or more in the coming decade without a significant policy shift. Undeniably, the U.S. nuclear sector is in rapid decline, including losing a lot of high salary jobs and with it, America's ability to shape the global nonproliferation and safety regimes.[21]

As recently as the 1980s, U.S. nuclear technology dominated the global market, but since then the U.S. civil nuclear industry has atrophied with bleak prospects for recovery.[22] American nuclear vendors have become peripheral players, increasingly dependent on foreign markets and supply chains, as well as the goodwill of governments that are not always friendly to Washington.

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Forging capabilities for large reactor components have never materialized, resulting in U.S. reactor vendors turning to foreign factories that can melt and press larger ingots, which require less welding of smaller pieces of steel and improve safety.[23] The United States relies heavily on Japan Steel Works and ROK's Doosan to provide forgings and components for reactor vessels and steam generators. Doosan, for example, is supplying all reactor components for the new-builds (four Westinghouse AP1000s) in South Carolina and Georgia.

While Lehigh Heavy Forge in Pennsylvania can press smaller ingots into forgings for small modular reactors (SMRs),[24] it cannot handle requirements for today's large reactor barrels and closure heads. Numerous other suppliers exist in the United States to supply or manufacture commercial nuclear-grade or N-Stamp parts and components, but even those industries have consolidated over the last three decades from approximately 400 to 255 nuclear-qualified suppliers.[25] National security requirements for U.S. aircraft carrier and submarine naval nuclear propulsion are largely responsible for preserving this remaining capacity.[26]

On the fuel side, the outlook is actually worse with little foreseeable chance of improvement. With the Yucca Mountain Nuclear Waste Repository sidelined by domestic politics, the United States has no long-term waste disposal strategy. Often overlooked is the fact that the lack of a deep geological repository storage facility in the United States for spent nuclear fuel reduces the nation's ability to negotiate civil nuclear agreements with other countries. U.S. negotiators, unlike their counterparts in Russia and elsewhere, cannot offer wide-ranging fuel take-back options as a means of reducing proliferation risks.

Given the current weakness of the U.S. nuclear industry, Washington has diminished capabilities – compared to past decades – in managing the global spread of civil nuclear technology and its inherent link with bomb making.

Reprocessing in the United States does not appear to be a viable solution either. At the Davison Chemical Company in West Valley, New York, the United States developed the commercial capability to reprocess spent nuclear fuel, and did so from 1966 to 1972. However, ensuing years brought increasing regulatory requirements that drove up costs to the point that reprocessing became uneconomical, which is why West Valley is now a U.S. Department of Energy cleanup site.[27]

The United States does not even possess a commercial uranium enrichment program. While Washington has blessed Iran's ability to produce low-enriched uranium, the Obama Administration shelved the only U.S. plan to do so, ironically, on September 11, 2015. The termination of the American Centrifuge Project (ACP) ended any near-term possibility for a U.S. entity to enrich uranium for the commercial nuclear fuel market.[28]

Domestic U.S. fuel manufacturers, such as Westinghouse – now owned by Japan's Toshiba and AREVA – largely depend on foreign enrichment sources.[29] In addition, U.S. nuclear utilities must rely on foreign-owned uranium enrichment suppliers, such as URENCO – a British, German, and Dutch consortium – which launched a major centrifuge enrichment plant in New Mexico in 2010.[30] AREVA, the French nuclear company now acquired by the French utility EDF, attempted the same at Eagle Rock in Eastern Idaho, but has since suspended the project because of poor market conditions for nuclear fuel.[31]

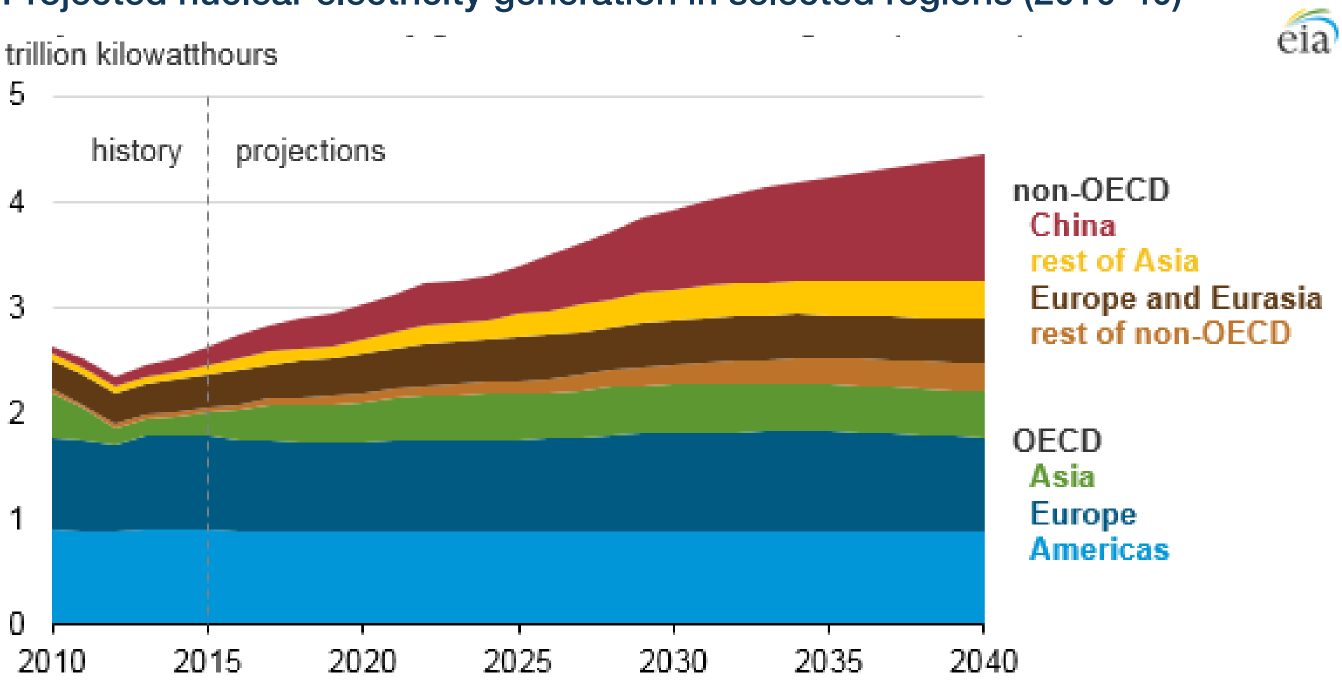
Given the current weakness of the U.S. nuclear industry, Washington has diminished capabilities – compared to past decades – in managing the global spread of civil nuclear technology and its inherent link with bomb making. To ensure some authority and influence over the international commercial nuclear regime, the United States must rely increasingly on diplomacy and bilateral cooperation with key partners and allies, particularly the ROK.

ROK's Pivotal Role

Before the Fukushima Daiichi nuclear disaster, Japan had a vibrant civil nuclear sector, with plans to expand domestically and capture a greater share of the global nuclear market. Japanese companies aggressively sought foreign acquisitions and partnerships in the nuclear sector, particularly in the United States, where Toshiba bought Westinghouse in 2006[32] and Hitachi teamed up with GE a year later.[33] In 2010, Toshiba struck again, purchasing a $100-million stake in United States Enrichment Corporation (USEC).[34] Japan was clearly a global leader in civil nuclear technology, particularly in the Asia Pacific.

The 2011 tsunami, however, paralyzed the Japanese nuclear industry, resulting in the shut-down of all 54 of the country's reactors.[35] Only five of 43 potentially operational reactors have

Projected nuclear electricity generation in selected regions (2010-40)



Source: Energy Information Administration (EIA)

been restarted under the more stringent post-Fukushima safety regulations.[36] Japanese utilities have chosen to retire a number of plants largely due to the cost of repairs and upgrades. Some analysts estimate that only about one third of Japan's remaining plants will be restarted because of their locations near fault lines or failure to meet safety standards.[37] More modern reactors may be built to replace older ones in some locations, but only if there is local public support – a difficult objective in many cases.

In an effort to protect Japan's struggling nuclear industry, preparations have recently been made for a realignment and consolidation of its big three nuclear companies – Hitachi, Toshiba, and Mitsubishi Heavy Industries (MHI).[38] International competition has become too stiff to support three separate reactor designs, especially given the limited demand for GE-Hitachi's advanced boiling water reactor (ABWR).

Analysts have questioned whether Japan's nuclear sector can rebound and, in the process, provide the necessary regional leadership on nuclear matters. Under even the most optimistic scenario, a full recovery is likely to take many years. While America needs to maintain its partnership with Japan on civil nuclear matters, Washington cannot count solely on Tokyo to help check China's growing domination as an international provider of commercial nuclear technology and services.

A nuclear technology backwater only 15 years ago, China is currently making significant strides in the civil nuclear field for strategic, economic, and environmental reasons. In the early 1990s, China operated just three commercial reactors. According to the American Nuclear Society's "World List of Nuclear Power Plants," China had brought 31 plants online by the end of 2015.[39] In less than a year, another four plants were connected to the grid, bringing the total to 35 plants.[40] By 2030, China is projected to have 150 gigawatts of operational nuclear power, which is roughly equivalent to Germany's total capacity in electricity.[41] In little more than a decade, China could have twice the number of reactors as the United States, given the vulnerability of much of the existing fleet to premature closures.

For strategic reasons, Beijing has a clear motivation to expand its civil nuclear power beyond its domestic market. The county also has the means to do it, including vast cash resources and a colossal manufacturing base. China recently signed agreements to export nuclear technology to the United Kingdom (UK), where the need to replace aging Magnox reactors provided an opportunity to invest in two new units at a cost of about $23 billion.[42] Beyond the UK, China is involved in roughly a dozen projects in Africa, Asia, and South America; and continues to establish itself as the global manufacturing supplier of nuclear components. The country has the capacity to produce up to eight reactors each year, with plans to increase its annual output to 20 reactors.[43] China is believed to be in the process of surpassing the nuclear manufacturing base of Japan, ROK, and the United States combined – an event that would reshape the global nuclear market.

If left unchecked, this significant growth and accompanying influence would result in China becoming the undisputed global leader in commercial nuclear power, which could have negative consequences for the United States and its allies. China's vibrant nuclear industry would secure for Beijing a strong voice in determining the world's nonproliferation and nuclear safety regimes. A foreign government seeking to build a civilian nuclear program – and potentially using it as a means to develop nuclear weapons – would have to first go to Beijing, not Washington, for approval. Under such a scenario, American policymakers could be forced to watch from the sidelines as China decides which countries join the nuclear energy club.

Backed by large cash reserves, a Chinese monopoly of the nuclear market would dismantle much of what remains of the United States' influence on nuclear and nonproliferation issues. It would also nullify the significant investments made by the ROK to position itself as an exporter. Accordingly, the United States and the ROK need to remain as competitive as possible and work side-by-side to ensure continued competition in the global nuclear market.

A number of foreign officials are wary of closer nuclear cooperation with China, considering Beijing's track record of industrial espionage and questionable commitment to nonproliferation. During recent discussions related to Chinese-UK collaboration, critics expressed concerns about China gaining access to critical infrastructure.[44] Much like European concerns over dependency on Russian oil and natural gas supplies, nuclear countries would prefer to maintain a diverse nuclear energy supply market to avoid becoming too dependent on Chinese financing, technology, and services.

A strengthened U.S. partnership with the ROK and Japan could take advantage of those anxieties. Given the robust capabilities of the ROK civil nuclear industry, Seoul is well positioned to play an invaluable role – jointly with the United States – in checking China's growing dominance. U.S. and ROK nuclear industries could prosper through joint ventures in high energy growth markets, especially in the Asia Pacific.

Expansion of the U.S.-ROK Civil Nuclear Partnership

The most recent 20-year U.S.-ROK Agreement for Civil Nuclear Cooperation (123 Agreement) was signed on June 15, 2015. Despite a longstanding history of cooperation, though, there are points of contention that remain unresolved between the two countries.

Two principle issues, both under joint development with U.S. entities, are outstanding and remain a work-in-progress:

1. ROK's aspiration to obtain U.S. permission to develop its uranium enrichment capabilities to secure a reliable and stable supply of nuclear fuel; and,
2. ROK's plans to develop its pyroprocessing capabilities to reduce its nuclear waste stockpiles, and produce fast reactor fuel.

A High Level Bilateral Commission (HLBC), mandated in the U.S.-ROK Agreement, was officially launched on March 3, 2016, following a meeting between U.S. Deputy Secretary of Energy Elizabeth Sherwood Randall and Vice Minister for Foreign Affairs for the ROK Cho Tae-yul. In an effort to address unresolved issues between the two countries, the following working groups were created:

1. Spent nuclear fuel management;
2. Promotion of nuclear exports and export control cooperation;
3. Assurances of nuclear fuel supply; and,
4. Nuclear security.

In addition to American support and guidance for developing its nuclear program, the ROK is also working directly with U.S. institutions on nuclear technological initiatives and advancements. The renewal of the U.S.-ROK cooperation agreement reinforces the Idaho National Laboratory's 2011 U.S.-Korea Joint Fuel Cycle Study by "[reviewing] and [identifying] appropriate options for addressing spent fuel management challenges, and [facilitating] cooperation on [R&D] in this context including R&D at specified facilities on the use of electrochemical reduction."[45]

As previously discussed, the ROK lacks a fully developed fuel cycle program, which is partly being addressed by a joint U.S.-ROK effort at the Department of Energy's (DOE) Idaho National Laboratory (INL). Idaho has a long history with sodium-cooled fast reactors (SFR). In the 1960s, INL built the first such reactor – the Experimental Breeder Reactor (EBR II) – which ran for 30 years.[47] The ROK and INL have already confirmed the technical feasibility of the electrochemical recycling technology (pyroprocessing) on a laboratory-scale basis. Joint work to evaluate technical feasibility, economic viability, and nonproliferation acceptability of the technology is scheduled to continue through 2020.

Through their joint effort to develop pyroprocessing, the United States and the ROK have a historic opportunity to resolve a longstanding waste storage problem and use the solution as a joint platform to market "Gen IV" fast reactor technology to the rest of the world.[47] Washington, however, has not allowed the ROK to fully conduct pyroprocessing activities because of a number of security concerns. The most significant being the ongoing concern of proliferation and how it is viewed in the context of managing neighboring North Korea's nuclear weapons tests and provocations. It is important to note that pyroprocessing produces an impure form of plutonium as a byproduct, not pure plutonium.

Nonproliferation advocates have argued that pyroprocessing produces a byproduct that is "closer" to weapons-grade plutonium – closer, perhaps, but almost worthless because of the remaining transuranic contaminates that end up mixed in with the plutonium, including neptunium, americium, and curium. According to the World Nuclear Association, "the pyroprocessing process is intrinsically proliferation-resistant because it is too hot radiologically and the curium provides a high level of spontaneous neutrons. It recycles over 96% of the used fuel."[48] As a consequence, the likelihood of obtaining weapons-grade plutonium from pyroprocessing is virtually nonexistent.

In 2012, Seoul built a "cold" or non-radiological pyroprocessing demonstration facility called PRIDE (Pyroprocessing Integrated Inactive Demonstration). The ROK hopes to evaluate and learn from the performance of PRIDE in order to see scale-up possibility of pyroprocessing.

In addition to pyroprocessing, the ROK has joint R&D efforts underway with DOE's Argonne National Laboratory in Chicago to perfect the design of a "Gen IV" sodium-cooled fast reactor (SFR). These collaborations are crucial to U.S. efforts to stay ahead of China in the commercialization of next-generation nuclear power technologies. Unfortunately, U.S. progress in addressing its own domestic nuclear waste challenges could stand in the way of this important R&D partnership.

Recommendations for Further Cooperation

Enhanced civil nuclear energy cooperation should promote policies and measures that advance core national interests, including strengthening the global nonproliferation regime, increasing energy independence, promoting economic expansion, and protecting the environment, as well as efforts to mitigate climate change.

The following list of recommendations, peer reviewed by experts on both sides of the Pacific, supports one or more of the above objectives:

I. Effective implementation of the High Level Bilateral Commission

The High Level Bilateral Commission (HLBC) is an important tool to advance collaborative R&D efforts between the ROK and the United States, transcending election cycles on both sides of the Pacific. The Commission should guarantee that joint R&D collaborations seek the most secure methods to protect nuclear materials while providing maximum transparency to the International Atomic Energy Agency.

- The Commission should back joint fuel cycle development, quickly address any obstacles, and safeguard proper funding for ongoing research. It should work to address current challenges to high level waste disposition in both the United States and the ROK, covering all levels of government.
- The Commission should facilitate, rather than block, the ROK's development of pyroprocessing technology. It should consider ROK's current waste disposition situation as it weighs the economic viability of pyroprocessing, particularly given the size of the overall ROK economy and its civilian nuclear program.
- The Commission should examine multiple pathways for the United States and the ROK to invest in enrichment technologies, including joint research into more efficient and market competitive methods.
- The Commission should encourage greater transpacific business-to-business cooperation for joint ventures and invite collaboration among top business executives to guarantee the safe and secure deployment of nuclear technology.

II. Promotion of first-rate global standards for safety, sustainability, and non-proliferation

Enhanced bilateral cooperation can promote safer nuclear power through more secure designs, increase sustainability and environmental quality, and strengthen the global nonproliferation regime. Continued joint development of fast reactor technology with pyroprocessing would improve nuclear safety, provided it is economically feasible and can be commercially deployed.

Additional joint efforts should include:

- Maintaining the highest safety standards, including regular exchanges of knowledge and experience and best practices.
- Licensing of advanced nuclear systems, including Small Modular Reactors (SMRs) and "Gen IV" reactors.
- Enhancing regional nuclear safety cooperation across the Pacific region.

The U.S.-ROK cooperation on nuclear energy should serve as a model for other bilateral partnerships. Any new nuclear cooperation agreement with a country that has earned the trust of the United States through its longstanding responsible use of nuclear energy for power generation over weapons development, should be granted authority to maximize its peaceful activities. This should include the use of advanced fuel cycle technologies that adhere to the highest standards of safety, sustainability, and nonproliferation. This is consistent with the spirit of the Non-Proliferation Treaty (NPT).

Some additional efforts to demonstrate mutual commitment to reducing proliferation include:

- Joint development of a safeguards system for Advance Fuel Cycle facilities.
- Joint development of nuclear security technologies, such as physical protection and nuclear forensics.
- Joint efforts to minimize legacy stocks of global highly enriched uranium (HEU) from the Atoms for Peace program, including development and demonstration of low-enriched uranium (LEU) U-Mo high density fuel for the remaining research reactors and development of LEU-based fission Molybdenum-99 production technologies.

III. Increasing R&D cooperation for advanced technologies

There are opportunities to develop additional advanced nuclear technologies jointly between the United States and the ROK beyond the collaborative fuel cycle study and the "Gen IV" sodium-cooled fast reactor (SFR) designs. For instance, both countries could take the lead in the development of SFRs and very high temperature reactors, including joint ventures in the Generation IV International Forum.

Both governments could also further bilateral collaboration between the Argonne National Laboratory and KAERI in the development of SFRs. Other partnerships could focus on advanced metal fuels, streamlining the licensing process, small modular reactor development, and joint design and demonstration work at Idaho National Laboratory and in the ROK, with the opportunity for direct involvement of commercial vendors.

- Special bilateral attention should be given to the challenge of financing new nuclear facilities, and to addressing high capital costs in countries, such as the United States, where nuclear energy faces competition from large reserves of low-cost natural gas and relatively inexpensive construction costs for combined-cycle natural gas power generation.
- Cooperation should be increased in the development of spent fuel management technologies, including storage, transportation, and disposal; as well as in the advancement of technologies to minimize the impact of spent fuel management.

IV. Searching for trade and commercial opportunities

Great potential exists for expanding trade and commercial opportunities between the U.S. and ROK nuclear industries if the right collaborative steps are taken, including:

- Creation of nuclear business partnerships for strategic collaboration in third-country markets;
- Formation of joint ventures and investment;
- The offering of joint support for "newcomer" countries, with the ROK serving as a role model in the areas of infrastructure and human resources development; and,
- Taking leadership roles in international efforts through pre-existing mechanisms, such as IAEA Technical Cooperation, IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), IAEA Peaceful Uses Initiative, and the International Framework for Nuclear Energy Cooperation.

Conclusion

An enhanced diplomatic nuclear partnership between the United States and the ROK is important for promoting competition in the international marketplace and in helping check the almost certain monopoly on nuclear technology that China will enjoy in the not too distant future. Given the evolving multipolar global system, multiple voices are needed to shape and manage healthy nuclear nonproliferation and safety regimes. For the United States, closer alliance with the ROK would bolster domestic nuclear research and development programs, and help stop the decline of U.S. nuclear trade and related political influence.

Joint U.S.-ROK efforts to develop safer and more secure methods regarding nuclear waste management and disposal look increasingly promising for the future. While elements of the ROK's civil nuclear program – particularly the nation's desire to develop its advanced fuel cycle capabilities – are controversial in U.S. nonproliferation circles, transparency and advanced technologies can be used to ensure peaceful use consistent with the Non-proliferation Treaty (NPT). As described by American diplomat and nonproliferation expert George Bunn:

> *"Further, uranium enrichment and plutonium separation does not violate the NPT if done for peaceful purposes under IAEA inspection. In fact, a number of more developed countries (e.g., Japan) conduct such activities. In the three countries where uranium enrichment or plutonium separation was thought to have been conducted for weapons purposes—Iran, Iraq, and North Korea—the activities had taken place largely at locations not declared open for inspection to the IAEA."*[49]

The ROK is a steadfast adherent to the global nonproliferation regime. Despite its vulnerable geographical position in relation to North Korea, the ROK has no desire to develop a nuclear weapon. Still, Washington has pushed back on Seoul's desire to pursue a fuel cycle program that would provide substantial benefits to the United States – most notably innovation in waste management and diversification of fuel supply.

Some may argue that the development of fuel cycle capabilities in the ROK could complicate matters with North Korea or, worse yet, increase the probability of conflict. While that may be a sincere concern, it is hard to believe that Pyongyang's nuclear weapons development and aggressive approach toward the United States and its allies is actually dependent – even in the slightest way – on ROK's commercial nuclear program. In this case, the benefits of an enhanced ROK civil nuclear sector to the United States likely far outweigh any theoretical and unlikely cost imposed by the North.

Perhaps worse is a kind of discrimination toward the ROK that the current limits on its civilian nuclear program exposes. The United States has grudgingly accepted the actions of other nations – some of which are openly hostile to American interests – that have either failed to commit fully to international norms or blatantly disregarded nonproliferation policies. Moreover, Washington has clearly shown Tokyo far more respect, having already blessed its fuel cycle program – a step that reflects American trust in a full partner and ally. Given Japan's proximity to the Korean Peninsula and the maturation of the ROK as a commercial world class leader in civil nuclear energy, it is difficult to justify such differences in policy by Washington.

Nonetheless, if the United States wishes to counterbalance China's rise in nuclear competence and what that could mean for geopolitical relations, Washington must take steps to construct a civil nuclear alliance with key countries – and the sooner the better. Given Japan's post-Fukushima struggles, the United States should place its largest bet on the ROK, a country with shared strategic interests, especially in the Asia Pacific. With an enhanced nuclear partnership with the ROK, the United States would find an ally that has embraced a strategic vision for commercial nuclear power that provides the best pathway for the preservation of U.S. influence in global nuclear matters.

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Endnotes

1 The "Atoms for Peace" speech was delivered by President Eisenhower to the UN General Assembly in 1953. The program was designed, in part, to help U.S. allies develop commercial nuclear power for electricity purposes.

2 A newly formed division of General Dynamics in 1955 dedicated to the R&D of peaceful nuclear energy before being sold to Gulf Oil in 1967. It was acquired by a company owned by Neal and Linden Blue in 1986.

3 Training, Research, Isotopes, General Atoms (TRIGA) reactor. Class of small nuclear reactors produced by General Atomics.

4 This 123 Agreement was signed by Robert S. Ingersoll, just prior to his appointment as Deputy Secretary of State in the Nixon Administration, and Dixy Lee Ray, a vehemently pronuclear Democrat and the first woman to head the Atomic Energy Commission and its successor agencies, which today is the U.S. Department of Energy. The documents were countersigned by Pyong Choon Hahm, who held the position of Special Assistant to President Chung Hee Park of Korea for Political Affairs. Interestingly, Korea's current President Park Geun-hye is the daughter of Park.

5 Section 123 mandates that any agreement for cooperation meet nine criteria, including prior U.S. approval for enrichment of uranium and reprocessing of spent nuclear fuel into new fuel. (Industry has coined the term used fuel to replace spent fuel because there remains over 90 percent of low enriched uranium to be recovered and remanufactured into fresh fuel). Kerr, Paul K. and Nikitin, Mary Beth. "Nuclear Cooperation with Other Countries: A Primer," CRS Report for Congress, August 12 2008 http://fpc.state.gov/documents/organization/108958.pdf

6 Combustion Engineering (its nuclear division was eventually acquired by Westinghouse) and The Babcock & Wilcox Company (its nuclear division was spun off in 2015 and renamed BWXT) also had significant nuclear reactor designs deployed in the United States.

7 The ROK imports over 95 percent of its energy.

8 World Nuclear Association, Nuclear Power in South Korea, September 20, 2016 http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx

9 World Nuclear News, "UAE Picks Korea as Nuclear Partner," December 29, 2009 http://www.world-nuclear-news.org/NN_UAE_picks_Korea_as_nuclear_partner_2812091.html

10 Banks, George David, "U.S. Resource Nationalism: The Impact of Energy Trade Restrictions on National Security," American Council for Capital Formation, July 2015, pp. 5-7 http://accf.org/wp-content/uploads/2015/07/ACCF-Nationalism-Report_FINAL.pdf

11 Wallace, Michael and Banks, George David; "Restoring U.S. Leadership in Nuclear Energy: A National Security Imperative," Center for Strategic & International Studies, June 2013 http://csis.org/files/publication/130614_RestoringUSLeadershipNuclearEnergy_WEB.pdf

12 International Energy Agency (IEA), Energy Statistics, 2013.

13 IEA CHP/DHC Country Scorecard: Republic of Korea, 2013.

14 Korea is just behind China and indeed ahead of Japan for online reactors, which would place it fifth: U.S. (99 reactors/101,416 MWe), France (58 reactors/63,130MWe), Japan (42, only 2 operating/40,179MWe), Russia (34/24,593MWe), China (28/24,268We). American Nuclear Society. "Power Reactors by Nation" Nuclear News, 18 Annual Reference Issue (59)3, March 2016

15 Through pyroprocessing, uranium and transuranic elements can be separated from spent fuel for reuse as fuel for SFR.

16 Emirates Nuclear Energy Cooperation (ENEC) Chief Executive Officer Mohamed Al Hammadi, further explained the decision, saying: 'We were impressed with the KEPCO team's world-class safety performance, and its demonstrated ability to meet the UAE program goals. Additionally, the KEPCO team dedicated a highly experienced team to our project and has shown a serious commitment to transferring the knowledge gained from Korea's 30 years of successful nuclear industry operation into the UAE program.' ENEC press release. "ENEC Selects Korean Electric Power Corp. As Prime Team, As Prime Contractor for Peaceful Nuclear Power," ENEC, December 27, 2009, https://www.enec.gov.ae/media-centre/news/content/uae-selects-korea-electric-power-corp.-as-prime-team-as-prime-contractor-fo

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18 Global America Business Institute (GABI). "Globalization of Korean Nuclear Energy, Self-Sufficiency of the Korean Nuclear Industry" March 20, 2013

19 Nikitin, Mary Beth and Hold, Mark. "U.S.-Republic of Korea Nuclear Cooperation Agreement," CRS Insights, June 20, 2015 https://www.fas.org/sgp/crs/nuke/IN10304.pdf

20 Exelon Newsroom. "Exelon Announces Early Retirement of Clinton and Quad Cities Nuclear Plants" June 2, 2016 http://www.exeloncorp.com/newsroom/clinton-and-quad-cities-retirement

21 Wallace, Michael and Banks, George David et al. "Restoring U.S. Leadership in Nuclear Technology" Center for Strategic & International Studies, June 2013 https://csis-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/130614_RestoringUSLeadershipNuclearEnergy_WEB.pdf

22 U.S. Department of Commerce. "2010 Energy Industry Assessment" Washington, D.C., January 2010.

23 Alpern, Peter B. "U.S. Cedes Capability for Large Nuclear Forgings" Forging Magazine, June 17, 2009, http://forgingmagazine.com/feature/us-cedes-capability-largest-nuclear-forgings

24 Small forgings for small modular reactors, <300MWe, vice large reactors >300MWe and today mostly >1000MWe

25 BWX Technologies, Inc., which has manufacturing plants in Ohio and Indiana, is currently the last remaining U.S. component manufacturer. World Nuclear Association. "Heavy Manufacturing of Power Plants" August 2016, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/heavy-manufacturing-of-power-plants.aspx

26 The Naval Nuclear Propulsion Program has built more nuclear reactors than any other entity in the world. The Program developed the first nuclear pressurized water reactor prototype at Idaho National Laboratory, the S1W, that went critical in March 1953. In less than two years, the first U.S. Naval nuclear-powered submarine, the Nautilus – based on the S1W prototype – went critical at sea on January 17, 1955.

27 West Valley Demonstration Project Nuclear Timeline, http://www.wv.doe.gov/Site_History.html

28 The United States Enrichment Corporation or USEC (later renamed Centrus Energy) had been working on advanced centrifuge technology for both commercial and defense uranium enrichment purposes to replace aging, massive, and costly gaseous diffusion enrichment plants. The plants were expensive to operate because they were highly electricity-intensive, powered by massive coal-fired power plants from the Tennessee Valley Authority. The first gaseous diffusion plant was built in the 1940s for the Manhattan project, the K-25 plant in Oak Ridge, Tennessee. This plant, renamed the East Tennessee Technology Park in the hopes for a brighter economic future, is expected to be entirely demolished and cleaned up this year. Two other plants built in the 1950s and privatized by the Federal government are located in Paducah, Kentucky and Portsmouth, Ohio. The Paducah plant has been shut down and is also undergoing extensive cleanup. The Portsmouth (Piketon)

plant has been in cold stand-by under the control of the U.S. Department of Energy. Last year, Centrus Energy shut down the enormous 120 enrichment cascades of the American Centrifuge Project (ACP) due to a lack of government financial support, just after three years of rigorous and successful testing. ACP was co-located with the Portsmouth, Ohio gaseous diffusion plant with primary centrifuge manufacturing in Oak Ridge, Tennessee.

29 AREVA acquired its first U.S. fuel plant from U.S.-based, BWXT.

30 Robinson-Avila, Kevin. "Desert Facility Spins Uranium" Albuquerque Journal, May 11, 2015 https://www.abqjournal.com/582632/spins.html

31 One capability somewhat unique to the United States is the dilution of nuclear weapons-grade highly enriched uranium to commercial nuclear-grade low enriched uranium, which is then fabricated into commercial nuclear fuel. During the Cold War, the United States enriched tons of uranium for nuclear weapons that have been and are still being dismantled in significant numbers since 2005. This highly enriched uranium is downblended to low-enriched uranium at Nuclear Fuel Services in Tennessee, a BWXT company, and later transferred to a nuclear fuel manufacturer. The amount of downblended uranium could be significant enough to affect the price of uranium if large quantities were dumped in to the market, but not significant enough to power U.S. reactors for any great length of time.

32 Olson, Parmy. "Nishida's Toshiba Wins Westinghouse With $5.4B Bid," Forbes, February 6, 2006 http://www.forbes.com/2006/02/06/toshiba-westinghouse-generalelectric-cx_po_0206autofacescan08.html

33 Hitachi official press release. "Hitachi Announces Profile of New Nuclear Business Company Hitachi-GE Nuclear Energy, Ltd." Hitachi, May 16, 2007 http://www.hitachi.com/New/cnews/f_070516b.pdf

34 France-Presse Agence. "Toshiba Buys Stake in Uranium Firm USEC," Industry Week, May 25, 2010 http://www.industryweek.com/companies-amp-executives/toshiba-buys-stake-uranium-firm-usec

35 The nuclear disaster was the result of a massive tsunami off the Japanese coast.

36 American Nuclear Society. "Ikata-3 Became Japan's Fifth Nuclear Unit to Restart," Nuclear News, September 2016, pp. 17.

37 Saito, Mari, Sheldrick, Aaron and Hamada, Kenataro. "Japan May Be Only Able to Restart One-third of its Nuclear Reactors," Reuters, April 1, 2014, http://www.reuters.com/article/us-japan-nuclear-restarts-insight-idUSBREA3020020140401

38 Sentaku official press release. "Hitachi's Nuclear Plant Business Fending for Itself," Sentaku, August 8, 2016, https://sentaku-en.com/articles/2016/07/hitachis-nuclear-plant-business-fending-for-itself.html

39 American Nuclear Society. Nuclear News, 18th Annual Reference Issue (59)3, March 2016.

40 World Nuclear Association. "Nuclear Power in China," September 20, 2016, http://world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx

41 The pace of China's build-out is not unprecedented; the United States brought 41 plants online between 1970-1975 and another 45 plants in the 1980s.

42 Yu, He. "CGN boss: The UK is the perfect country to showcase China's nuclear expertise" The Telegraph, September 29, 2016 http://www.telegraph.co.uk/business/2016/09/29/cgn-boss-the-uk-is-the-perfect-country-to-showcase-chinas-nuclea/

43 World Nuclear Association. "Heavy Manufacturing of Power Plants," August 2016. http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/heavy-manufacturing-of-power-plants.aspx

44 Gross, Jenny and Wong, Chun Han. "U.K. Delay on Hinkley Point Nuclear Power Plant Strains Relations with China" The Wall Street Journal, August 5, 2016. http://www.wsj.com/articles/u-k-delay-on-hinkley-point-nuclear-power-plant-strains-relations-with-china-1470402457

45 U.S. Department of State, Bureau of International Security and Nonproliferation. "U.S.-Republic of Korea (R.O.K.) Agreement for Peaceful Nuclear Cooperation," June 16, 2015. http://www.state.gov/t/isn/rls/fs/2015/243872.htm

46 INL developed the first fast reactor, called EBR II, but was outgunned by another technology, the pressurized light water reactor or PWR. After the PWRs were developed in connection with the Navy nuclear propulsion program and the first PWR went online – which was a cancelled aircraft carrier reactor-- U.S. industry leaned forward with the PWR design and uranium fuels.

47 McMahon, Jeff. "South Korea Plans Advanced Reactor to Burn Spent Nuclear Fuel," Forbes, October 29, 2014, http://www.forbes.com/sites/jeffmcmahon/2014/10/29/south-korea-advances-reactor-to-burn-spent-nuclear-fuel/#3b533d376f40

48 World Nuclear Association. "Processing of Used Nuclear Fuel" September 2016, http://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx

49 Bunn, George. "The Nuclear Nonproliferation Treaty: History and Current Problems," Arms Control Association, Arms Control Today, December 1, 2003. George Bunn, the first general counsel for the U.S. Arms Control and Disarmament Agency, helped negotiate the nuclear Nonproliferation Treaty, and later became U.S. ambassador to the Geneva Disarmament Conference.

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