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The Lightbulb or the Bomb? The Politics of Spent Nuclear Fuel in South Korea

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I. INTRODUCTION

Flip on a light switch anywhere in South Korea and chances are good that the glow from the bulb is powered by nuclear energy. The peninsular country is one of the most prolific nuclear fuel producers in the world. In a mere three decades, 20 nuclear power reactors have sprung up along the coastline from Ulchin on the East Sea to Yonggwang in the west. Together these reactors power the four nuclear plants that account for nearly 35 percent of domestic electricity.

Yet, the ROK's nuclear energy future is uncertain. With a population of 50 million and a total area equivalent to the state of Indiana, South Korea faces a dearth of sites in which to store the unavoidable and hazardous byproducts of nuclear power generation. The government estimates that by 2016, the storage pool for radioactive waste, known as "spent fuel," at its Kori plant near Busan will have reached maximum capacity. If the adjacent nuclear plant cannot find another domestic storage facility that will accept its fuel, it will have to shut down. Officials at the Korea Atomic Energy Research Institute (KAERI) estimate that pools at three other nuclear plants will reach capacity within the next decade. The dangerous nature of spent fuel precludes the option of exporting the material. The risks to global nuclear security and the financial cost of physically safeguarding the material would simply be too high. Without resolution of the storage issue, the gradual shuttering of plants could seriously debilitate the ROK's nuclear industry, according to KAERI scientists.

Several nations, including France and Japan, have reduced the amount of space needed to store spent fuel through "reprocessing," or feeding the radioactive waste back into the reactors. Reprocessing might be a viable option for South Korea, but for the Jekyll-and-Hyde nature of nuclear power, every type of reprocessing technology in current commercial use produces a grade of plutonium waste pure enough to fuel atomic weapons.

Reprocessing is so fundamental to creating weapons of mass destruction that

the Republic of Korea vowed to abstain from the practice in a 1992 nuclear agreement with North Korea. Instead, KAERI scientists are championing a new, commercially unproven technology called "pyroprocessing," which they claim will be proliferation-safe. The Barack Obama administration in the United States, however, has expressed reluctance about allowing South Korea to proceed with pyroprocessing research and development. The American position can appear rather puzzling given the history of good relations between the two countries. The United States and South Korea are longtime allies that recently finalized a landmark free trade agreement and are both signatories of the Nuclear Non-Proliferation Treaty (NPT). Since the 1970s they have regularly exercised a bilateral agreement to collaborate on nuclear research in the civil sector. In fact, the pyroprocessing concept that South Korea so badly wants to pursue was first developed by scientists in an American government laboratory and freely shared with the ROK.

This paper will describe how inconclusive science, the North Korea factor, insufficient trust between allies, and an imbalance in economic imperatives underlie the disagreement over whether America should approve South Korea's desire to research and develop the pyroprocessing of spent fuel on a scale that would feasibly lead to use of the technology in the ROK's nuclear power plants. It will ultimately examine the most feasible policy options available thus far and make recommendations to each government on how best to proceed. The topic is a timely one. As of October, the United States had agreed to conduct joint pyroprocessing research with South Korea while the countries work toward revising their civil nuclear pact before it expires in 2014. The research is scheduled to span a 10-year period and will presumably lead the United States to a final decision over whether to allow South Korea to continue its pursuit of pyroprocessing technology. Thus, it is highly possible that the pyroprocessing issue will not be resolved in time to alter the terms of the civil nuclear pact.

II. INCONCLUSIVE SCIENCE AND THE PROLIFERATION QUESTION

On October 25, 2010, a delegation led by Cho Hyun, South Korea's deputy foreign minister for multilateral and global affairs, met with a U.S. delegation headed by Robert Einhorn, special advisor for nonproliferation and arms control at the State Department. The purpose was to begin a formal renegotiation of the bilateral agreement struck in 1972, and amended in 1974, concerning the cooperative development of peaceful nuclear energy technologies and applications.

South Korea sees the renewal of the agreement, which expires in 2014, as an opportunity to secure an amendment that would allow it to research and develop pyroprocessing technology. The United States has not staked out a firm position, but so far appears less than convinced about the wisdom of such an amendment. South Korea has no choice but to accede to U.S. demands; if the agreement lapses, South Korean firms would have to halt their plans to continue reactor-building with U.S. partners, both in Korea and abroad. The agreement is crucial for the continuation of South Korea's nuclear industry. It lays out the prices, quantities, and other terms for enriched uranium shipments into South Korea, and its language indicates that the ROK's nuclear industry would not be nearly as advanced as it is today without the approval and assistance of the United States.

U.S. negotiators signaled a degree of open-mindedness by agreeing to begin preparing for a decade-long joint study of spent-fuel disposal options, "including pyroprocessing." The U.S. commitment to participate in such research, which will happen in conjunction with the negotiation process, will give South Korea the opportunity to make its case for the technology. The research is warranted because pyroprocessing is a nascent technology and no one can say for sure whether it differs all that dramatically from reprocessing. However, the study will last for ten years, indicating that the United States is in no hurry to change the terms of the civil nuclear pact.

The vastly simplified description of reprocessing goes something like this: uranium, plutonium, and, sometimes, other radioactive elements are separated out from spent fuel and fed back into a facility to generate more electricity. This very same process of separating plutonium was originally developed and used to build atomic weapons, which is why nonproliferation experts oppose it. Pyroprocessing is supposed to eliminate the problem of separating pure plutonium by extracting from the spent fuel plutonium mixed with uranium and other heavy elements—rather than pure plutonium—and feeding them all back into the reactor. The United States (as well as nonproliferation activists in South Korea) argues that it is still very easy to separate pure plutonium from the mix. Because pyroprocessing is a relatively new idea, the proliferation dangers it poses are still open to interpretation. And so, where South Korea sees lightbulbs, the United States sees the bomb.

Without conclusive findings, the science of pyroprocessing is currently an instrument of politics. On the South Korean side, officials argue that the plutonium product from pyroprocessing is simply not pure enough to produce

weapons of mass destruction. In an op-ed in 2009, Park Seong-won, a former vice president at KAERI, went so far as to assert that pyroprocessing is "proliferation resistant" and "differs completely from conventional spent fuel reprocessing." To further distance the two technologies from one another, South Korea insists that the correct synonym for pyroprocessing is "recycling" spent fuel, not "reprocessing." Taking the environmental analogy even further, they assiduously emphasize the untapped potential of pyroprocessing as a way to check the ROK's steadily increasing greenhouse gas emissions and its heavy dependence on hydrocarbons.

The Obama administration has made no official pronouncement regarding pyroprocessing, but various American nuclear policy experts say the administration favors the following viewpoints: pyroprocessing is no different from reprocessing, and South Korea possesses the nuclear infrastructure and expertise to extract weapons-grade plutonium from the pyroprocessing product fairly easily.

Given that even the most indisputable science is vulnerable to political controversy, it is not surprising that the lack of white-coat consensus regarding pyroprocessing leaves ample room for a wide range of views. But the United States and South Korea are not choosing opposite sides simply because the scientific void allows for it.

III. THE BOMB: STRONG BILATERAL TIES DO NOT ASSUAGE U.S. SKEPTICISM

The Korean War, fought in the early 1950s, forged what the United States and South Korea termed a "blood alliance" between the two nations. In practical terms, this has translated into a highly coordinated military relationship, with North Korea as the common and most worrisome enemy. South Korea has also sent troops to take part in U.S. war efforts in Iraq and Afghanistan. In addition, the two nations share common political systems and in 2007, signed a free trade agreement. The close bilateral ties, however, have not been enough to sway the United States in the pyroprocessing debate.

For one thing, the United States prioritizes nuclear disarmament, nonproliferation, and security above its bilateral relationship with South Korea. America's crackdown mentality regarding nuclear bombs and the materials used to make them naturally shifts its policy focus toward the threat aspect

of reprocessing. The United States places a very high priority on preventing antagonistic states and nonstate actors from acquiring the specialized chemicals and other materials necessary to engineer nuclear weapons. The law of probability underpins the U.S. argument for minimizing the reprocessing of nuclear fuels: the more plutonium is recovered from spent fuel and the more widely that plutonium is distributed throughout the world, the greater the risk of its diversion to states that do not have nuclear weapons. South Korea's proximity to the antagonistic nuclear state of North Korea makes America all the more cautious. American administrations tend to believe that allowing South Korea to develop pyroprocessing would make North Korea and Iran more resistant to dismantling their nuclear programs and could cause unease in the region if China and Japan suspect South Korea of pursuing weapons.

The strength of the alliance represents no guarantee, from the American viewpoint, that South Korea will quash any ambitions to establish a nuclear arsenal. Other countries have already used reprocessing technology to attain nuclear status, against the wishes of the United States. The most notorious case involves India. Once upon a time, the United States actually encouraged other countries to reprocess spent nuclear fuel. Under the "Atoms for Peace" program of the 1970s, the United States transmitted reprocessing capabilities to India, which used the resulting plutonium to explode its first atomic bomb. (The spin doctors in New Delhi called it a "peaceful nuclear explosion.") North Korea's development of nuclear weapons can also be traced to reprocessing in nuclear power reactor plants. And a U.S. government report from 1993 warned that Israel, which is highly secretive in regard to its nuclear arsenal, likely possessed "plutonium derived from a secret reprocessing facility."

South Korea, for its part, is not guiltless. The occasional surfacing of nuclear ambitions in Seoul also explains the Obama administration's wary stance. South Korea secretly began a nuclear program in the mid-1970s, but had progressed no further than the preliminary stages when the United States discovered it and convinced President Park Chung-hee to abandon it. At the time, South Korea had intended to use the facilities in its young civilian nuclear power program to paper over its effort to develop a weapon. In 1982, South Korea separated a small amount of plutonium from irradiated depleted uranium. Then, in 2004, Seoul admitted to the International Atomic Energy Agency that its scientists had secretly enriched uranium and purposely concealed the information from international inspectors. (Researchers had separated uranium-235, the isotope necessary for atomic weapons, from heavier uranium-238.) South Korea carried out the experiments despite signing both the Nuclear Non-Proliferation Treaty of

1970 and an agreement with North Korea in 1992 to rid the peninsula of nuclear weapons. The ROK's activities have, unsurprisingly, caused enough skepticism in the Obama administration to question South Korea's reasons for pursuing pyroprocessing.

Aside from its own doubt regarding the ROK's motives, the United States believes North Korea would respond unfavorably should the civil nuclear agreement allow the South to pyroprocess. North Korea has exhibited jitteriness in the past when it has felt that South Korea has overstepped its bounds in the nuclear technology arena. Based on this behavior, American nuclear policymakers foresee the following scenario: pyroprocessing in the South would produce a stockpile of weapons-grade fissile material south of the 38th parallel and stoke paranoia in the North that South Korea is developing nuclear weapons. Feeling threatened, North Korea would then cling to its weapons program with even greater tenacity, and denuclearization talks would go nowhere.

Indeed, Pyongyang harbors long-held suspicions regarding the ROK's nuclear weapons aspirations. The South Korean revelations to the IAEA in 2004 reportedly derailed the George W. Bush administration's efforts to negotiate with Iran and North Korea over abandoning their nuclear weapons programs. Responding to the findings, a spokesperson for the North Korean Foreign Ministry said that Pyongyang "can never sit at the table to negotiate its nuclear weapon program unless the truth about the secret nuclear experiments in South Korea is fully probed." The Bush administration had actually been partnering with South Korea to conduct pyroprocessing research in the mid-2000s, but stopped in 2006, reportedly because the research was a sticking point in denuclearization negotiations with North Korea. The United States appears unlikely to budge on this point. "It is difficult to imagine that the United States would agree to South Korean pyroprocessing until the North Korean nuclear issue reaches a satisfactory resolution," Fred McGoldrick, a former chief U.S. representative to the International Atomic Energy Agency, wrote in 2009.

America must also consider the fact that the ROK's other regional neighbors would prefer South Korea to remain a nonnuclear state and would likely voice some dissent should the United States allow South Korea to proceed with large-scale pyroprocessing research. The civilian side of the nuclear industry is growing in East Asia and complicating the relationships between states in the region. Japan is a nonnuclear state but carries out reprocessing. China possesses nuclear weapons capabilities and is researching reprocessing. The ROK's neighbors could interpret its push to pyroprocess as a roundabout way to

develop latent nuclear capabilities, thus complicating U.S. relations with every other country in East Asia. “China, Japan, and North Korea would be deeply suspicious of a decision by South Korea to reprocess,” said one U.S. nuclear expert.

IV. THE LIGHTBULB: SOUTH KOREA’S BID FOR ENERGY INDEPENDENCE

Despite living under immediate threat of nuclear destruction, South Korea, for a variety of reasons, has embraced the upside of nuclear energy far more readily than has the United States. South Korea considers the development of homegrown nuclear power generation essential to tempering its heavy dependence on energy imports, to growing its economy, and to reducing greenhouse gas emissions. Unlike the United States, South Korea seems to believe that any regional tensions caused by pyroprocessing can be managed or overcome.

Energy consumption in South Korea has closely tracked the upward trajectory of its economy. Four decades ago, GDP per capita was comparable to the poorer countries of Africa and Asia, but by 2004, South Korea had become one of the world’s largest economies. Rapid growth has transformed South Korea into the tenth-largest global consumer of energy products, almost all of which comes from abroad. Domestic energy resources are practically nonexistent in South Korea. Natural gas fields number exactly one, and the country has no proven oil reserves. It produces only a small amount of fairly low-quality coal.

As a large energy importer, South Korea is extremely vulnerable to volatility in global energy markets. The economic havoc wreaked by the Arab oil embargos of the 1970s instilled in the country a sense that self-reliance is crucial to the security of its energy economy. Nuclear power is the only kind of energy South Korea can currently produce in amounts large enough to keep pace with economic growth and provide a buffer against oil-price spikes. South Korea also views nuclear energy as critical to reducing the country’s greenhouse gas emissions, which were the ninth-highest in the world as of 2008. Since its first nuclear plant opened in 1978, South Korea has grown its nuclear generation capacity into the sixth-largest in the world, according to the U.S. Energy Information Administration. Domestically produced nuclear power makes up 14 percent of the ROK’s total energy mix, and Korea Hydro and Nuclear Power Company, which operates every nuclear plant in the country, intends to build another twelve reactors by 2022. Despite the fact that it imports all the uranium

used to fuel its nuclear plants, the government considers nuclear power South Korea's "only reliable domestic energy resource." The market for uranium is highly volatile. For example, today prices range between $40 and $60 per pound, down from $138 per pound in 2007.

In the past 30 years, South Korea has transitioned from being a net importer of nuclear power plant technologies to exporting design technologies and core nuclear power plant equipment, including nuclear reactors and steam generators. Eager to increase its comparative advantage, South Korea has stated its intent to capture 20 percent of the world market for nuclear reactors by 2030. "The nuclear power-related business will be the most profitable market after automobiles, semiconductors, and shipbuilding," the Ministry of Knowledge Economy stated in a 2010 report. If successful, South Korea would become the third-largest nuclear exporter in the world, behind the United States and either France or Russia. Target markets include the United Arab Emirates, Turkey, India, Jordan, South Africa, China, and Vietnam. South Korea's prospects appear promising. It recently bested leading U.S. and French firms to win its first major nuclear export agreement: a four-year, $20 billion deal to export reactors to the UAE. Backed by the national government, the ROK consortium, led by Korea Electric Power Corporation, reportedly offered a better price and more aggressive construction schedule than did competitors. Underscoring the importance of the contract to South Korea, President Lee Myung-bak flew to Abu Dhabi during the award deliberations and later attended the signing ceremony in December 2009 with UAE president Sheikh Khalifa bin Zayed Al Nahyan. South Korea also won a $132 million contract in 2010 to construct a research reactor in Jordan.

The ROK's economic and energy security interests in the nuclear sector are thus driving its side of the pyroprocessing debate. Like the United States, it wants regional stability, and good bilateral relations, but domestic energy imperatives weigh heavily in its calculus. In order for its nuclear export industry to thrive, Seoul argues, the United States must allow it to conduct research and development on a variety of peaceful nuclear technologies, including pyroprocessing. An October 2010 editorial in the *Korea Herald* espoused this view and pointed out that South Korea "is the only player among the countries capable of exporting nuclear power plants that lacks the ability to reprocess spent fuel." South Korea is also hoping to expand its nuclear technologies to power desalinization plants and is studying the feasibility of building a nuclear plant in Indonesia that would produce both potable water and electricity.

Domestic political pressures also play a role. Although officials from KAERI say there are no polls that confirm the claim, ROK officials cite public opposition to expanding spent-fuel storage sites as a reason for pursuing pyroprocessing. Citizens tend to oppose any plans to hold spent fuel in above ground or subterranean facilities because they believe such facilities are hazardous to human health and the environment. Negative attitudes toward nuclear storage facilities tend to drive down the value of surrounding real estate. It is also important to note that an anti-nuclear activist community does exist in South Korea, but has been largely ignored by the Lee government, which has renewed the nation's emphasis on nuclear power and made it a key part of its energy policy.

The domestic stakes are high enough to put South Korea on a different track from the United States in the pyroprocessing debate. South Korea and the United States have no quibble over the goals of ensuring regional stability, minimizing the proliferation of nuclear weapons, and maintaining a healthy bilateral alliance, but the ROK's expansion of its self-reliant energy policy lies beyond the scope of U.S. interests. South Korea thus faces the quandary of having to balance the preferences of its most important military ally with securitizing its energy supply.

V. NUCLEAR CHIAROSCURO: BALANCING THE LIGHT AND DARK ASPECTS OF ATOMIC ENERGY

The mere existence of an alliance cannot, of course, prevent disagreement and doubt over pyroprocessing, but the bond between the two countries nevertheless functions as ballast in the debate. Military and economic ties, along with the general culture of cooperation between the two nations, ensure that the dialogue will remain civil. As the deadline for renewing the nuclear agreement nears, the two nations have begun to draw upon the alliance to fashion a resolution that satisfies both sides.

For South Korea, this means referencing the alliance to remind the United States that it is trustworthy and that its pyroprocessing research would be intended solely to minimize the proliferation risk caused by reprocessing spent fuel. As one ROK scientist put it: "It doesn't matter whether we have the ability to make a nuclear weapon or not. What's more relevant is whether South Korea would actually make the nuclear weapons."

South Korea points to the fact that six countries—not all of which have as strong an alliance with America—already reprocess their spent fuel and as a result are producing enough weapons-grade plutonium each year to fuel thousands of weapons equivalent in power to the bomb dropped on Nagasaki. (Those countries are Japan, France, the United Kingdom, Russia, India, and the Netherlands.) China, meanwhile, is researching a pilot reprocessing program. Moreover, the United States historically has allowed states to build their reprocessing programs, and even gone so far as to assist them, despite the potential negative ramifications for global nonproliferation. In 1988, the United States ratified an agreement authorizing Japan to reprocess spent fuel and use plutonium commercially, knowing that doing so "may have implications for future agreements between the United States and other countries that use nuclear materials of U.S. origin." One U.S. official said, presciently, that the Japan deal "set a bad precedent for North and South Korea that will complicate U.S. discussions on reprocessing with them." South Korea has indeed been sensitive to the inconsistency of U.S. nuclear policy. Japan's reprocessing program "has been a major source of suspicion and envy in South Korea," according to one American nuclear nonproliferation expert. More recently, a U.S. deal with India has presented South Korea with another example of American double standards. In 2008, India and the United States finalized an agreement formulated during the Bush administration that gives India advance consent to reprocess nuclear material of U.S. origin at a new national facility. The India deal gives South Korea an especially solid argument for winning an amendment in the civil nuclear agreement to allow it to research pyroprocessing. Here is why: aside from its 60-year history as a U.S. ally, South Korea is a signatory of the NPT, along with 186 other states. In contrast, India has refused to sign the NPT and only recently, in 2005, signed an alliance agreement with the United States.

As negotiations have unfolded over pyroprocessing, South Korea has presented the United States with evidence of its lack of nuclear weapons ambitions and reminding America of the longstanding ties between the two countries. The ROK argues that the pursuit of weapons of mass destruction would jeopardize its trade relationships by angering the consumer nations that contribute to its positive trade balance. China, the United States, and Japan, none of whom wants to see a nuclear-armed South Korea, are the three largest consumers of ROK semiconductors, telecom equipment, cars, and other exports. Recently, an official from the Korean Institute for National Unification (KINU) told American nuclear experts and government officials that "if we decide to go nuclear, we will anger the international community and they will impose sanctions and other punishments." He also noted that Seoul "realizes our energy and nuclear security

will be halted if there is a proliferation issue." The same official said that the upcoming international nuclear summit, which will be hosted by Seoul in 2012, is further evidence that South Korea "stands on the front line of stopping nuclear terrorism" and will "create conditions to strengthen and solidify our alliance." Seoul also affirmed its stance against nuclear proliferation at a conference in March 2010, where government officials vowed that South Korea "actively supports the move towards a nuclear weapons free world" and "fully upholds international efforts to revitalize the NPT regime." The Lee government has made sure to distance itself from advocates of "nuclear sovereignty," who argue that recent nuclear tests by North Korea justify the ROK's development of its own nuclear weapons. Pyroprocessing advocates classify the technology as "peaceful nuclear sovereignty" to emphasize that weapons production is not the end goal.

South Korea has also moved to directly address its recent nuclear weapons infractions. South Korea argues that its undeclared uranium enrichment and plutonium separation activities discovered by the IAEA in 2004 were relatively minor and "had nothing to do with systematic efforts to develop nuclear weapons." The experiments "were conducted by a few scientists out of 'scientific curiosity,'" and "all related equipment was destroyed." The government said it cooperated fully with the IAEA's inspection and "took measures to prevent similar incidents from recurring." Ultimately, the IAEA board of governors concluded that South Korea deserved nothing more than a verbal rebuke. Following an investigation, the IAEA announced that the ROK's failure to report its activities was "of serious concern," but noted that "the quantities of nuclear material involved have not been significant."

Recognizing that North Korea's nuclear aspirations pose a major impediment to its pyroprocessing goals, South Korea has offered to help the United States in encouraging North Korean denuclearization. Unlike the United States, South Korea seems to believe that developing the ROK's pyroprocessing capabilities and convincing North Korea to stand down from its nuclear weapons program are not mutually exclusive goals. At a joint U.S.-ROK nuclear energy workshop in December 2010, a KINU official stated, somewhat naively, that the international nuclear summit, which Seoul is scheduled to host in 2012, will intimidate North Korea into reconsidering its nuclear weapons buildup. South Korea also seems to think that bulldozing more money into North Korea will help to do the trick. "It is important to convince North Korea that nuclear weapons do not help its security," the government said in a statement in 2010. "South Korea is willing to offer massive economic aid (to the North) to help

economic development and social stabilization."

Aside from agreeing to host the nuclear summit, South Korea has already begun to take on new global nonproliferation commitments and is encouraging other countries in a more forceful manner to promise not to engage in enrichment and reprocessing. Its imposition of sanctions on the nuclearizing state of Iran is tangible evidence that it is trying to win American trust in the nonproliferation arena.

South Korea, then, is taking full advantage of the alliance in its bid to compel the United States to amend the nuclear agreement. The United States, however, has been less candid over its desired policy. As the dominant member of the alliance, the United States will ultimately decide what sort of nuclear research South Korea can pursue. Its options range from turning South Korea down flat to agreeing to the amendment and allowing the ROK to go ahead with research, unimpeded. The decision to recommence joint pyroprocessing research indicates that the American side is keeping all options open, as it has yet to settle on a final position.

VI. POLICY SUGGESTIONS: JOINT RESEARCH, OTHER STORAGE, OTHER ENERGIES, AND CONSIDERING NORTH KOREA

Decisions about how to source energy are usually domestic, but the dual nature of nuclear power demands global oversight and consensus. South Korea's domestic energy and economic goals must be weighed within the context of international nuclear security, but neither should the ROK be forced to relinquish an inordinate amount of sovereignty over its energy policy. With the United States holding so much control over the future of South Korea's nuclear energy industry, it has an obligation to do more than say no. Instead, it should help South Korea develop solutions. With these principles in mind, the United States should take full advantage of the alliance by working in tandem with South Korea to solve its nuclear energy problem as a partner, not dictator. Beyond these philosophical reasons, the United States will need to consider the diplomatic ramifications of whatever course it takes. It will not win much goodwill with the South Korean public if it imposes a blanket ban on pyroprocessing research and development. Already, the public is none too pleased that reprocessing is allowed in Japan, but not in South Korea.

The long history of alliance and the language of the civil nuclear agreement

makes a joint approach relatively easy in the cultural and logistical senses. But how might the countries update the terms of their nuclear partnership? The United States might require South Korea to explore, or assist it in exploring, alternative options for disposing of nuclear fuel in conjunction with pyroprocessing. The United States itself stopped reprocessing in the 1970s after India's atomic bomb test made obvious the potential for nuclear proliferation. The American nuclear industry has since found alternative ways to handle nuclear waste. When their spent-fuel cooling pools reach capacity, American nuclear plants transfer any fuel that has been submerged for at least five years in the pool to above ground "dry cask" storage facilities, which resemble giant silos. The dry casks themselves are steel cylinders welded or bolted closed with a layer of additional steel, concrete, or other material to provide radiation shielding. Some of the most vocal and influential American nuclear energy experts argue that South Korea should follow the U.S. example and start building dry-cask storage facilities next to their nuclear reactors.

Besides the downside of heightened nuclear proliferation risk, many U.S. experts believe that neither reprocessing nor pyroprocessing is the most economic or efficient way to manage spent fuel. Frank von Hippel, an influential physicist and nuclear policy expert at Princeton University, has written that dry-cask storage costs about $100 per kilogram of spent fuel, whereas reprocessing (as practiced by Japan) costs about $2,400 per kilogram. Von Hippel also calls the storage of spent fuel in pools or containers "a far more proliferation-resistant management strategy." He writes that reprocessing makes weapons-grade plutonium relatively easy to steal because the radiation emitted by the plutonium is not strong enough to penetrate the walls of a portable, water-bottle-sized canister. Three of these canisters can hold enough plutonium for one atomic weapon. A spent fuel rod, by contrast, is toxic enough to kill a human standing a meter away within an hour. The lethality of spent fuel may make it proliferation-resistant, but it is also what pits the South Korean public against the construction of any more spent fuel storage facilities.

South Korea should not completely ignore the option of dry-cask storage, but given the shortage of land available for storage on the peninsula, the United States should give the ROK some leeway in researching options for reusing spent fuel. Spent fuel takes about 300,000 years to decay to the point where it is no longer hazardous, meaning that dry-cask storage would serve as an intermediate, not permanent, solution. At the same time, the United States might encourage South Korea to slow its ambitious schedule of adding more domestic nuclear plants. South Korea plans to bring another twelve reactors online by

2022, with the goal of generating nearly half of the nation's electric power supply from nuclear sources. Whether or not the United States decides to allow South Korea to conduct long-term pyroprocessing research, the process should be completely transparent. Any relevant facilities should be designed, managed, and operated under mutually acceptable nonproliferation conditions and meet agreed safeguards criteria. The collaborative process may allow the United States to discover solutions to some of the impasses encountered by its own nuclear power industry.

Because nuclear energy is so contentious and requires South Korea to constantly be seeking permissions from the United States, South Korea should dramatically expand its development of other, less controversial, fuel options that would give it more control over its own energy policy. South Korea, through its high-tech, shipbuilding, and auto industries, has proven its prowess as an innovator. Thus, it should not be reticent about funneling more money into researching less dangerous alternative fuels, such as solar, wind, and ocean-generated power. Energy efficiency in buildings and vehicles, which the U.S. Department of Energy deems the most effective way to reduce fossil fuel consumption, would also achieve the ROK's goal of relying less on hydrocarbon imports and reduce the need for nuclear-generated electricity. It has already committed $7.75 billion to an offshore wind project, and plans to increase the share of renewable energy in its total energy consumption to 11 percent by 2030 and 20 percent by 2050. South Korea could further bolster its renewable energy sector by developing an export market for such technologies.

Whatever decision the United States ultimately makes, it must take North Korea into account. Leaving pyroprocessing out of the equation, it is unlikely that North Korea will give up its nuclear weapons program anytime soon. The upcoming leadership succession from Kim Jong Il to Kim Jong Un is already causing the DPRK to act more belligerently as the new regime attempts to show that it is not weak. Tensions on the peninsula are higher than they have been in decades, following the Yeonpyeong Island artillery exchange initiated by North Korea in November 2010. In regard to pyroprocessing, the current North Korea situation can bolster both sides of the debate. On the one hand, if North Korea is going to cling to its weapons program regardless, then allowing South Korea to conduct pyroprocessing research will have no effect on the DPRK's actions and should therefore be allowed. On the other hand, the situation is so delicate that neither the United States nor South Korea should risk making it worse. Either way, North Korea will remain highly relevant to the ultimate decision on pyroprocessing.

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