AVOIDING MELTDOWNS + BLACKOUTS

EDITED BY KAYLA ORTA

CONFIDENCE-BUILDING IN INTER-KOREAN ENGAGEMENT ON NUCLEAR SAFETY AND ENERGY DEVELOPMENT

Wilson Center | Hyundai Motor-Korea Foundation Center for Korean History and Public Policy
IFES The Institute for Far Eastern Studies

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INTRODUCTION

NUCLEAR ENERGY ON THE KOREAN PENINSULA: A WAY TOWARDS THE FUTURE?

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In the 21st century, amidst record-breaking environmental disasters—hurricanes, wildfires, droughts, and floods—governments around the world are under increased pressure to address climate change, resilient infrastructure development, and sustainable energy needs. Increasingly, energy policy is one of the most critical areas of foreign policy and is a space of both contention and potential cooperation in global politics today. A case in point, Russia's invasion into Ukraine in February 2022 triggered geopolitical, economic, and energy shockwaves, which continue to be felt around the world. An unprecedented energy shock, as described by the International Energy Agency, the crisis may be the "first truly global energy crisis" (2022, 3). The truth is, in our modern, multidimensional, interwoven world, energy policy is security policy.[1]

This year, the World Economic Forum's Global Risks Report listed the ever-growing environmental risks as presenting the "most critical long-term threats to the world" (2022, 7). Though global, these manifestations of climate inaction will not be felt evenly around the world. Environmental consequences of climate inaction disproportionally effects the poorest countries in the world. North Korea is no exception.[2] Like many low-resourced countries, North Korea will be faced with increasing climate threats and continued degradation of its energy infrastructure, if action is not taken. In a country, which relies heavily on hydroelectric—up to 76% of total electricity production in 2015—and thermal power plants (von Hippel and Hayes, 2013), upsurges in the frequency of draughts and floods will prove highly damaging to North Korean infrastructure. Already, over 5.6 million North Korean citizens have been affected by natural disasters since 2004 (United Nations, 2021, 20). Despite this, very little successful development has been made in North Korea to offset climate risks and reduce widespread energy poverty.[3]

> IN OUR MODERN, MULTIDIMENSIONAL, INTERWOVEN WORLD, ENERGY POLICY IS SECURITY POLICY

South Korea, on the other hand, has reaped the benefits of an expanding energy industry. Over the past 15 years, several South Korean administrations have prioritized leadership initiatives in advancing international climate resilience and domestic enhancement of its own low-carbon energy industries (Chung, 2022). An example of both energy growth and security, South Korea is one of the world's largest nuclear energy producers, recently bringing online the country's 27th nuclear power plant, Shin Hanul Unit 1, a 13 GWe net capacity APR-1400. While the previous Moon Jae-in administration's nuclear 'phase out' policy sought reduction of nuclear energy production, current South Korean President Yoon Suk-yeol's has restored plans for Korea's long-term nuclear energy ambitions, aiming for domestic nuclear energy contributions to reach 30% of South Korea's total needs by 2030. Much has already been learned from South Korea's experiences with nuclear energy development, safety and security enhancement, public opinion relations, and, since the 2010s, nuclear exportation diplomacy and industry development.

But, what about South Korea's neighbor to the North? Unfortunately, while South Korea's achievements in forward-leaning energy policy are well-known, more often than not the question of North Korea's energy development policies and potential is left out of the conversation.

Now, however, is a crucial time for U.S.-South Korean energy cooperation. Energy infrastructure resilience, across the spectrum of low-carbon energy, is high on both U.S. President Joe Biden and South Korean President Yoon Suk-yeol's national agendas—Never before have the two countries' energy views been more aligned. Should the window for dialogue with North Korea re-open, the United States and South Korea may choose a form of limited engagement with the North.

Recent years have shown an undeniable—and highly concerning—expansion of North Korea's nuclear weapons program. According a recent RAND report, estimates place North Korea's nuclear stockpile as high as 40-60 weapons with enough fissile material for over 200 nuclear warheads by 2027 (Bennet, et al., 2021). This circumstance, however, should not rule out discussion on humanitarian progress towards energy security and sustainability in North Korea. International sustainability reports show clear evidence of widespread energy poverty in North Korea. There has been nearly 10% reduction of total energy generation from 1990 to 2018, and only 26% of citizens in the country have access to electricity—3:1 ratio between urban and rural areas (Forster, 2014; CIA, 2019; also see Koen and Beom 2020). Driving progress towards substantial improvement in North Korea's energy security could play a crucial role in transforming North Korea's economy and developing peaceful relations with its regional neighbors and beyond (von Hippel and Hayes, 2013).

Given Biden's proactive push to re-position the United States as an active participant in the global effort to combat climate change, a South Korean engagement policy which includes carbon-free, renewable energy cooperation—as suggested in Yoon's "Audacious Plan"—may be palatable to Washington. Given South Korea and the United States' shared concern on nuclear safety and climate change, cooperation initiatives between the two Koreas on nuclear safety and carbon-free energy are two areas where the new South Korean administration and Washington could potentially see eye-to-eye on.

In this light, this volume features an "exploratory research" project titled Avoiding Meltdowns & Blackouts Confidence-building in Inter-Korean Engagement on Nuclear Safety and Energy Development. It explores, in high detail, the history, current policy, and future possibilities of nuclear energy development on the Korean Peninsula. It also calls attention to the similar, yet unique, histories of the two Koreas and highlights U.S. and South Korean engagement successes, failures, and opportunities for recalibration of future policies. Overall it aims to address the lack of policy discussion on energy engagement with North Korea. Each chapter in this study offers a distinct viewpoint from which readers may explore the question, "What are the potential avenues for the U.S. and South Korean engagement on nuclear energy and safety in North Korea?"

While possibilities for U.S.-ROK-DPRK, as well as direct inter-Korean cooperation on energy policies exist, the potential landscape for cooperative development still faces several key challenges, to mention a few:

- Increased North Korean military provocations.
- U.S.-DPRK diplomatic stagnation on denuclearization.
- Weakened inter-Korean political, economic, and diplomatic relations.
- U.S.-China strategic competition and the resulting solidarity among China, Russia, and North Korea.

That being said, in South Korea today, a pro-nuclear government has bolstered efforts towards expansive exportation of South Korea's nuclear power plant and safety models outside the Korean Peninsula. But the question of how South Korea's experience can be shared with North Korea—to improve energy conditions for North Korean citizens and, overarching, safety and security of energy industries—remains to be explored.

Divided into two main sections, the five key chapters in this volume elucidate on several strategic considerations, each of which explore insights into the history and present policy on nuclear energy, nonproliferation, nuclear safety which exist within the discussion of U.S.-ROK-DPRK energy relations as well as inter-Korean cooperative projects. These key areas are as follows:

- Considerations of comparative history of cooperative threat reduction (CTR) initiatives and implications for future U.S.-DPRK efforts towards North Korea nonproliferation.
- Consideration of nuclear power, civil and military, development on the Korean Peninsula.
- Considerations for future nuclear energy development in North Korea.
- Considerations for the exportation of ROK safety and security control standards to North Korea.
- Considerations of the real-time threats of nuclear energy development in North Korea.

In each case, the question of North Korean interest in cooperation with the United States and South Korea was called into question. Simultaneously, each chapter illustrates that while, unlikely for immediate implementation, future scenarios towards U.S.-DPRK and U.S.-ROK-DPRK cooperation on energy policy should be explored.

In all five of the above listed considerations, South Korea's role in improving Peninsula-wide energy generation is undeniable. While support from the international community will be needed, alongside cooperative interest from the North Korean regime, forward-leaning policy suggestions led by South Korea and the United States will be essential to overcome the inertia and compel successful engagement between in the two Koreas.

Clearly, while this report lists specific policy suggestions, future refinement and clarification based on international factors, including U.S.-China strategic competition, condition of ROK-DPRK relations, and political leadership in South Korea and the United States is also needed. However, that being said, the following volume is exceptional in its efforts to bring together U.S. and South Korean experts to explore future possibilities for energy cooperation on the Korean Peninsula in the 2020s and beyond.

NUCLEAR HISTORY, NONPROLIFERATION AND FUTURE IMPLICATIONS

It is no understatement to say that North Korea continues to present one of the largest and most threatening security challenges in the Indo-Pacific region. From increased missile tests to the North's aggressive posturing and recent revisions to its nuclear doctrine, the question of how to deal with an apparently emboldened North Korean regime, remains difficult to answer.

The first section of the volume explores the viability, desirability, and feasibility of nuclear energy engagement with North Korea. To investigate opportunities for future nuclear energy cooperation, the first portion of the volume offers an overarching contextualization of U.S.-Korea nuclear policy, including the history of nuclear advancements on the Korean Peninsula and the current standing of U.S.-North Korean denuclearization diplomacy.

The section concludes that while the current stalemate with North Korea makes foreseeable diplomatic breakthrough unlikely, the future is yet uncertain. Inter-Korean engagement on energy policy, especially in coordination with the United States and alongside active agendas for denuclearization, remains a potential platform for policy engagement should the window of opportunity present itself.

A CTR Model for U.S.-North Korean Engagement

In the first chapter, Siegfried S. Hecker explores routes towards U.S. and South Korean engagement with North Korea by suggesting four diplomatic scenarios towards energy cooperation and elimination of nuclear weapons on the Korean Peninsula. Recounting critical lessons learned from U.S.-Soviet Union (and later Russian) nuclear relations, the chapter provides examples of how cooperation can be desirable, beneficial, and ultimately feasible even within the most contentious of political relationships.

Future dialogue with North Korea, if realized, may benefit from a historical understanding of past U.S. cooperative threat reduction (CTR) initiatives; and, in particular, U.S.-Soviet Union cooperation could serve as a backdrop for consideration of possible nuclear cooperation strategies between the United States and North Korea. As Hecker describes, "To realize the benefits of nuclear energy and to avoid its worst potential consequences it is necessary to have dialogue and some level of cooperation internationally."

During the Cold War, U.S.-Soviet Union cooperation on nuclear threat reduction led to a series of foundational launching points for the building of today's nonproliferation regime. Though relations waxed and waned, Washington and Moscow's efforts led to the establishment of the International Atomic Energy Agency (IAEA) and the signing of the Nuclear Nonproliferation Treaty (NPT). With the collapse of the Soviet Union, efforts to mitigate risks from Soviet technology spillover to border regions gained rapid traction, receiving support from the U.S. executive and—importantly—bipartisan support in the legislative branch. Beyond Washington, one of the most successful proponents of nuclear cooperation, according to Hecker, was the relationship between nuclear laboratories in Russia and the United States, which within the political context offered a route toward positive and productive joint-scientific engagement.

Today, U.S.-Russian relations have progressively soured, with opportunities towards cooperation increasingly bleak. However, the history of U.S.-Russian nuclear cooperative framework may yet offer lessons for the prospects of U.S. nuclear policy towards North Korea. Similar to U.S.-Russian history, so too have U.S.-North Korean relations experienced both upswings and stagnation. The United States, alongside allies, gained traction in its North Korean engagement, most notably in reaching the 1994 Agreed Framework and establishment of the Korean Energy Development Organization (KEDO). Again, Washington saw positive gains during the 2007-2008 Six-Party Talks period as North Korea seemed to show serious disablement actions of its nuclear facilities. Though history witnessed the stalemate and eventual collapse of the Agreed Framework's KEDO initiative, Six-Party Talks, and, later, the short-lived Trump-Kim summit diplomacy, these examples of cooperative engagement should not be overlooked.

Building upon the lessons of history, Hecker documents four possible diplomatic scenarios—from current diplomatic stalemate to full diplomatic breakthrough—and offers steps forward for Washington and Seoul to work together. Even within continued diplomatic stalemate, Washington should establish avenues to mitigate the risks of misunderstanding and miscalculation by opening communication lines with Pyongyang and consider forging agreements to avoid or respond to nuclear emergencies.

On the other end of the spectrum, if North Korea returns to the negotiating table, in exchange for denuclearization, a grand bargain to assist Pyongyang in converting its military program to civilian use could be offered. Building a civilian nuclear power enterprise would introduce long-term U.S., and potentially South Korean, bilateral commitments as well as a long-term dependency. North Korea has shown interest in energy engagement before, and may do so again—Washington and Seoul should be ready with serious proposals in-hand.

Strategies for Balancing Nuclear Ambitions on the Korean Peninsula

The second chapter by Jeffrey Lewis delves deep into the historical context of the nuclear pursuits on the Korean Peninsula, in particular the parallel development and residual legacies of both North and South Korea's nuclear agendas. The chapter highlights the often overlooked dual history of nuclear—both military and civilian use—programs on the Korean Peninsula. Reviewing safeguard agreements and nonproliferation measures, Lewis, explores what such measures might look like today. Under the auspice of North Korea's self-proclaimed nuclear power status, any energy cooperation agreements would rely on clear distinctions between engagements toward civilian nuclear use and distinctly away from continued weapons program development.

Often, the peaceful and military uses of nuclear power is inextricably intertwined. While nonproliferation policy places a premium on political security and external threat response as key drivers behind a country's pursuit of nuclear weapons, national power is demonstratively rooted in economic, energy, and technology advancement. As such, global nonproliferation structures have often attempted to balance the domestic benefits of civilian nuclear programs and international risk of covert military weapon development. As Lewis details, the United States and international community have utilized two primary methods of promoting peaceful use of nuclear power: 1) by encouraging technical choices which reduce proliferation risks, and 2) by devising increasingly effect safeguard measures.

As history shows, multilateral efforts to curb nuclear development for military usage on the Korean Peninsula proved successful for only one of the two Koreas. South Korea, today, boasts an expanding nuclear energy industry, and is without a nuclear weapons program. For South

Korea, nuclear pursuit was initiated in the context of the U.S. "Atoms for Peace" proposal and was most likely seen as instrumental for the country's movement toward economic modernization in the 1960s. South Korea relied heavily on the United States for the development of its nuclear energy project, which resulted in the implementation of South Korea's first IAEA safeguards—an INFCIR/66-type agreement—in 1968 on a trilateral basis among the United States, South Korea, and the IAEA. South Korea's early exploration into nuclear technology was viewed as component of the country's national nuclear energy policy.

However, in the 1970s South Korea experienced two events, which shock it's nuclear policy: 1) the withdraw of U.S. troops under U.S. President Richard Nixon's Guam Doctrine in 1971, and 2) the later-ensuing Arab oil embargo in 1973. Both shocks led then-President Park Chung-hee to question the country's security and energy-dependencies, and South Korea began exploring avenues for fuel reprocessing. It was at this time that U.S. concern rose over South Korea's nuclear intentions and risk of nuclear breakout. The U.S. strategy for preventing a South Korean nuclear weapon was to offer limited support for a nuclear energy program in the form of proliferation-resistant LWRs under safeguards, while denying South Korea sensitive fuel cycle capabilities like uranium enrichment or plutonium reprocessing. Ultimately, South Korea gave into international pressure, signing the NPT in 1975 and agreeing to more stringent INFCIR/153-type IAEA safeguards. As a result, South Korea has enjoyed expansive nuclear energy growth, both domestically and internationally, and remains a non-nuclear weapon power.

In contrast, North Korea, a self-proclaimed nuclear weapons state with an expanding nuclear weapons program, remains one of the poorest, most energy deficient countries in the word. North Korea's nuclear history, though, began similarly to South Korea. Paralleling the U.S. "Atoms for Peace," the Soviet Union initiated its own assistance program, which included North Korea in 1959. By the 1960s, however, Soviet support has largely wound down, beginning and ending with a small research reactor. Consequently, North Korea elected to pursue its own program in the 1980s, prompting response from the Soviet Union and an agreement to supply a VVER-type reactor to North Korea. Possibly in exchange, North Korea signed the NPT in 1985 but delayed agreeing to the required INFCIR/153-type safeguards until 1992.

While the United States utilized strategies to encourage relatively proliferation resistant technical choices and increasingly effective safeguard agreements to influence South Korea's nuclear agenda, this was not the case for North Korea. Although Seoul's relationship with its superpower patron was often fraught with tension, Seoul was largely able to achieve its energy and security needs within the framework established by the United States. North Korea, by contrast, received far less support from its nuclear patron and, even before the Soviet Union's collapse, devised an independent path to develop its nuclear program.

Looking towards future engagement with North Korea, Lewis reasons, the challenges for nuclear nonproliferation are less likely to depend on technical considerations but rather will hinge on the form of political arrangements. Any future course of action will be contingent on workable diplomatic outcomes that are acceptable to the major players—first and foremost Pyongyang and Washington, but also Beijing, Moscow, Seoul, and Tokyo. Today's IAEA safeguard regime offers a variety of case-in-point examples of country-specific strategies. Which avenue should the United States and South Korea work collaboratively towards to address North Korea is the question that remains.

NUCLEAR ENERGY & SAFETY ON THE KOREAN PENINSULA

While the first section of the volume analyzes historical examples, contextualize the question of nuclear energy on the Korean Peninsula, the second half of the volume explores forward-leaning policy opportunities for energy and safety between the two Koreas.

Benefits, Risks, and Possibilities for Nuclear Energy

In his chapter, Man-sung Yim details possible future paths towards the expansion of North Korea's national energy infrastructure through nuclear energy. A cooperation initiative among the United States, South Korea, and North Korea could provide a renewed opportunity for technology diplomacy among the three countries, such as attempted during the 1990s-2000s Korean Peninsula Energy Development (KEDO) project. In tandem with a U.S.-led denuclearization effort, energy cooperation towards the peaceful use of civil nuclear energy, according to Yim, could provide a diplomatic acknowledgement of humanitarian support for North Korea, one of the poorest energy producing countries in the world.

North Korea's nuclear capabilities since the 1990s has expanded greatly. Through an overview of North Korea's current energy development, the chapter first sets the stage for possibility of energy cooperation and expansion. Since the signing of the 1994 Agreed Framework, which initiated the original joint nuclear energy project in North Korea in exchange for a "nuclear freeze" on the country's nuclear weapons program, North Korea's infrastructure, technical know-how, and human capacity in the nuclear field have improved significantly. It is necessary to devise a path toward confidence-building leading to denuclearization of North Korea with the dismantling, conversion, and decontamination of North Korean nuclear facilities. Such processes, according to Yim, may include parallel initiatives for realizing peaceful use of nuclear energy in North Korea, supporting the country's future industrial and economic development.

Several benefits exist for U.S. and inter-Korean nuclear energy cooperation, though the most important would be the long-term and sustained diplomatic relations needed to support technical cooperation. The nature of nuclear energy projects includes high up-front costs, long construction time, and continual international support for plant operations. For the United States and South Korea, a nuclear energy development program, coupled with denuclearization, would present opportunities for continued diplomatic and economic engagement with North Korea.

The author outlines four potential stages for a cooperative nuclear energy expansion program in North Korea: 1) research and reactor development, 2) experimental light water reactor (ELWR), 3) small modular reactor (SMR) development, and 4) large light water reactors (LWR). Based on the assertion that North Korean denuclearization remains a possible and realistic, Yim stresses that the pursuit of energy cooperation among the United States, South Korea, and North Korea, would require a clear, well-defined framework for concurrent denuclearization and development of nuclear energy.

While opportunities for engagement exist, such cooperative energy policy and investment in North Korea's domestic politics is not without risks. There is no guarantee that North Korea will open and dismantle its entire infrastructure as there is no physical possibility of verifiably identifying and eliminating all aspects of its nuclear weapons capability. In this regard, designing the steps of denuclearization in sequential manner is essential as part of nuclear energy project. Progress in any foreseeable nuclear energy project should commensurate to denuclearization progress and the success and significance of respective processes achieved by the participating parties.

Most importantly, Yim highlights the importance of U.S. and South Korean joint efforts in the development of future energy development assistance towards North Korea. Both country's respective strengths in the nuclear technology, safeguards, and security should be maximally utilize towards the common goal of denuclearization and transference of North Korea's nuclear military program to civil nuclear use. Successful implementation of a peaceful nuclear energy project in North Korea will require careful plans for conducting verification and decommissioning and environmental restoration of nuclear weapons complex facilities. Future nuclear energy cooperation among the United States, South Korea, and North Korea will require considerable financial and political commitment. If the opportunity to re-engage North Korea occurs, the United States and South Korea, similar to the 1994-2006 KEDO initiative, should work together towards effective, implementable, nuclear energy frameworks.

Status of North Korea's Nuclear Safety

In this chapter, Francesca Giovannini examines the question of nuclear safety in North Korea. Whereas the debate over North Korea, especially in the West, has been predominantly confined to the discussion over its nuclear arsenal, its delivery system, and its ill-formed nuclear posture, much less has been discussed over the nuclear safety culture that ultimately rules over the management of an ever-extending nuclear infrastructure.

According to Giovannini, this thinking presents a fundamental contradiction. On the one hand, North Korea's nuclear program is posited as vital to the security and survival of the North Korean regime. On the other, the safety standards in the country are so abysmal and primitive that an accident is not a matter of if but a matter of when.

Through a comprehensive examination, this chapter presents a typology of safety risks posed by North Korea's nuclear infrastructure. Five key areas of risk are explored: 1) risk of reactor overheating due to cooling system challenges, 2) environmental damages and contamination leakages, 3) primitive regulatory infrastructure and continued isolation for international technical expertise, 4) potential of flawed reactor safety design and inadequate construction quality, and 5) hazards related to plutonium reprocessing and general management of nuclear waste.

Despite these risks, the author asserts that North Korea's attitude towards nuclear safety may present promising ground for improvement. In particular, Giovannini highlights four key drivers which may serve as strong incentives for the North Korean regime to take actions: 1) moving forward, nuclear energy may be vital in mitigating North Korea's catastrophic domestic energy insecurity, 2) failure to prevent a nuclear disaster in North Korea would have damaging consequences for the North Korean regime's legitimacy and credibility; 3) though limited, historical precedence—in particular, the critical legacy of KEDO—exists for North Korean cooperation on nuclear safety, and 4) the risk of transnational spillover into China, during a nuclear accident, may further incentivize North Korea's pre-emptive cautionary action on nuclear safety.

While reviving cooperation with North Korea on nuclear safety issues is not unthinkable, Giovannini closes the chapter with a reminder that safety cooperation alone will not guarantee deeper cooperation on North Korean denuclearization and disarmament. Nuclear safety, though important, should be not be traded for nuclear disarmament concessions.

Despite this critical dilemma, the international community should work to avoid any nuclear accidents at all costs in any part of the world—preventing nuclear accidents is fundamentally a global responsibility. Importantly, the history of U.S. and South Korean engagement with North Korea tells us that cooperation is possible, though, short-lived. While future engagement with North Korea remains unclear and uncertain, successful nuclear cooperation has historically occurred amid tremendous challenges. Should a window open for dialogue on greater safety on the Korean Peninsula, the United States and South Korea may choose to engage North Korea under a framework for nuclear safety (see Chapter 4), within the larger context of denuclearization.

Lessons from South Korea's Nuclear Safety

In the final chapter, Ho Kee Kim offers critical insights into the legacy of KEDO and nuclear safety mechanism in North and South Korea. Regardless of whether the peaceful use of nuclear power is used as an alternative means to resolve the North Korean nuclear issue, as once attempted by the KEDO light-water reactor (LWR) project of the 1990s, or whether nuclear safety itself is the focal point following the alleviation of international tensions, the nuclear safety capacity, management, and implementation of North Korea should be considered. Nuclear safety, Kim asserts, is a common global concern to be addressed through global normative and cooperative frameworks. While the future ahead is unclear, nuclear safety should not be overlooked in potential inter-Korean engagement.

In the chapter, Kim details nuclear safety experience and capacity in both Koreas. South Korea not only holds consistent policies and ample experience in nuclear power production but also nuclear safety regulation. Since the conception of South Korea's nuclear power pursuit, South Korea has set up a comprehensive regulatory infrastructure for nuclear safety—through a collection of legal and institutional mechanisms—which has continuously evolved the competency through feedback from increased regulatory demands and international and domestic movements on nuclear safety.

North Korea's energy infrastructure, on the other hand, is severely underdeveloped and, even given the existence of the North's State Nuclear Safety Regulatory Commission (SNSRC), North Korea's establishment of overarching nuclear safety system is questionable. If the opportunity arises, North Korean may choose to restart its nuclear energy ambitions.

Lessons from the KEDO LWR project are an invaluable legacy for future discussions on nuclear safety engagement on the Korean Peninsula. With the launch of the Geneva Agreed Framework in October 1994, the newly initiated LWR project necessitated the creation of a multinational organization and the Korean Peninsula Energy Development Organization was founded in March 1995. From the very beginning, South Korea's Institute for Nuclear Safety (KINS) served a crucial role. From conducting a 14-month safety review of the LWR nuclear power plant construction stage to hosting safety trainings for North Korean nuclear scientists, KINS was instrumental in working alongside KEDO's Nuclear Safety Confirmation System (NSCS) for the analysis, observation, and recommendations on nuclear safety during the project. Though early progress between North and South Korean nuclear regulators occurred, political tensions between the Koreas delayed engagement and, most likely, reduced interest from the North Korean side. A reminder that inter-Korean safety engagement hinges on the viability of the political environment.

Bearing in mind the lessons of the past, strategies for achieving cooperation for building North Korea's safety capacity should be effective and efficient. In this process, South Korea can take a leading role. The ultimate goal of inter-Korean engagement for nuclear safety would be to establish a collaborative framework on the Korean Peninsula. In reality however, Kim argues, without a major shift in thinking, it is difficult to expect inter-Korean engagement for nuclear safety beyond the North Korean nuclear weapon issue and within the current global sanctions regime. Although it should be cautiously enacted, such engagement could be considered as a subject of inter-Korean engagement or international cooperation of North Korea apart from the international situation.

LOOKING FORWARD: U.S.-SOUTH KOREAN COOPERATION

As demonstrated, now is a pivotal time for U.S.-South Korean energy cooperation. Energy infrastructure resilience, across the spectrum of low-carbon energy, is high on both U.S. and South Korean presidential agendas—Never before have the two countries energy views been more aligned.

North Korea, however, has not made engagement policy easy for either the Biden or Yoon administrations. The North's escalatory saber-rattling has reached unprecedented levels, raising concerns in both Washington and Seoul. It is often the case, however, that periods of high-tension with North Korea resolve into opportunities for engagement. Though the cyclical nature of diplomacy with North Korea invites cynicism, it also suggest a future window may open. North Korea's brinkmanship diplomacy is just that, to the brink but—as of yet—not further.

Should the window for dialogue with North Korea re-open, the United States and South Korea may choose a form of limited engagement with the North. Both countries will need to formulate a framework for proactive reduction of tensions on the Korean Peninsula. Trends in both U.S. and South Korean foreign relations and energy policy signify shared concern on nuclear safety and climate change. A cooperative energy initiative between the two Koreas, in particular in tandem with U.S. policy on denuclearization, may be desirable to all parties.

Though much remains, yet, uncertain, the chapters in this volume (as described above) explore areas for potential U.S. and South Korean nuclear energy and safety cooperation with North Korea. In each chapter senior nuclear policy experts discuss the 'what if's' of civil nuclear development in North Korea with the goal of producing up-to-date, well-defined, and applicable policy analysis on future opportunities and challenges.

While the future is unknown, one point holds true: U.S.-South Korean cooperation will be vital. Washington and Seoul will need to work together to address the future of global nuclear energy and safety, avoiding meltdowns and blackouts on the Korean Peninsula and beyond.

ENDNOTES

[1] The Wilson Center's Environmental Change and Security Program (ECSP) recently launched an in-depth publication on the changing dynamics foreign policy and climate action; See Carius, Gordon, and Risi (2020).

[2] While North Korea ranked 60th in the world for total energy production in 2019. For statistical information on North Korea's current energy infrastructure, see EIA (2018). For comprehensive analysis, see Koen and Beom (2020).

[3] In the last decade, there has been consistent interest in research on renewable energy in North Korea (See Yi, et al., 2011; Han, 2020 for example). Though to a lesser degree, nuclear energy has also been explored within the context of energy development plans in North Korea (See von Hippel and Hayes, 2013, 2007 as an example).

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SECTION 1

NUCLEAR HISTORY, NONPROLIFERATION & FUTURE IMPLICATIONS

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1 NUCLEAR COOPERATION WITH NORTH KOREA: IS IT DESIRABLE? IS IT POSSIBLE?

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INTRODUCTION

To realize the benefits of nuclear energy and to avoid its worst potential consequences it is necessary to have dialogue and some level of cooperation internationally. That was true during the Cold War U.S.-Soviet rivalry and became imperative after the breakup of the Soviet Union. It is also true for North Korea today despite the contentious political relationship between Pyongyang and Washington.

In this chapter, I explore what kind of nuclear cooperation is desirable and what is possible with North Korea. First, I briefly review the history of U.S.-Soviet (and later Russian) nuclear relations to provide examples of how cooperation can be beneficial even during adversarial times and how such engagement transitioned into cooperative threat reduction at the end of the Cold War. Then, I describe previous nuclear cooperation initiatives between Washington and Pyongyang, what was accomplished, and why it failed. The lessons from previous cooperation with Russia and with North Korea help to inform what levels of nuclear cooperation are advisable now. Examination of history suggests four different diplomatic scenarios which range from one extreme, the current diplomatic stalemate, to the other extreme, a diplomatic breakthrough in which the two sides would agree to eliminate nuclear weapons on the Korean Peninsula through cooperative conversion from military to peaceful nuclear programs.

Even in the current stalemate scenario, a degree of dialogue and cooperation is nevertheless essential. Avenues for direct engagement exist. For example, Washington should seek out cooperation with Pyongyang to establish a hotline to avoid a nuclear exchange that could result from miscalculations and misunderstandings. They should also establish cooperative emergency response mechanisms in case of nuclear accidents. And whereas North Korea's desire to have a civilian nuclear energy program has been viewed in Washington as a cover for pursuing military nuclear programs, it also offers the potential of transforming the political relationship. In the most extreme diplomatic breakthrough scenario, for example, the United States and South Korea would engage North Korea in cooperative conversion of its military nuclear program to civilian programs, opening a stepwise process toward verifiable elimination of nuclear weapons on the Korean Peninsula. Washington and Seoul are encouraged to recognize Pyongyang's desire for a civilian nuclear program as genuine in all diplomatic scenarios examined in this chapter. Not only would it open the door for cooperation, but it may prevent Pyongyang from seeking civilian nuclear cooperation elsewhere, such as with China or Russia, which would surely close that door for many years, perhaps decades, to come.

NUCLEAR COOPERATION BETWEEN POLITICAL RIVALS: THE COLD WAR EXAMPLE

In this section, I present examples of nuclear cooperation between Washington and Moscow and how it waxed and waned depending on the political climate. These historical examples serve as a backdrop for consideration of possible nuclear cooperation between the United States and North Korea during changing political times. Whereas the United States and the Soviet Union became bitter political rivals immediately after the end of World War II and engaged in a massive nuclear arms race beginning in the 1950s, the two nations found it in their national interest to cooperate in several areas. Despite the arms race and some close calls of nuclear armageddon, such as the Cuban Missile Crisis in 1962, Washington and Moscow cooperation ultimately resulted in a global nuclear order. Through a series of arms control treaties and agreements, these two superpowers avoided the use of nuclear weapons in war—establishing what some call a nuclear taboo.

By supporting the establishment of the International Atomic Energy Agency (IAEA) and building a strong nonproliferation regime, centered on the core pillar of the Nuclear Nonproliferation Treaty (NPT), Washington and Moscow helped to limit the number of countries with nuclear weapons to less than ten. They have cooperated on key elements of global nuclear security and safeguards that helped to prevent the use of nuclear weapons or radiological materials by non-state actors and terrorists. And with separate but parallel programs for Atoms for Peace, they brought the benefits of nuclear electricity and nuclear medicine to millions of people around the globe.

With the ascent of Mikhail Gorbachev to the leadership of the Soviet Union in 1985, the nuclear dialogue and limited cooperation took a strong positive turn. The historic Gorbachev-Reagan summit at Reykjavik in October 1986 opened the door to the Intermediate-Range Nuclear Forces (INF) treaty signed in 1988—the first to eliminate an entire class of nuclear weapons. In July 1991, Gorbachev and President George H.W. Bush signed the START I treaty to limit and greatly reduce each side's strategic offensive arms. Reykjavik also led to the nuclear weapons laboratories of the two countries conducting nuclear tests at each other's nuclear test sites in 1988. These U.S.-Soviet joint tests helped to develop verification techniques to enable ratification of nuclear test ban treaties.

In the latter half of 1991, Gorbachev-Bush nuclear initiatives laid the groundwork for a truly cooperative relationship. The seminal event that tilted the stage toward nuclear assistance was the attempted coup by Soviet hardliners that put Gorbachev under house arrest at his dacha in the Crimea in mid-August 1991. Although, the president of the Russian Republic, Boris Yeltsin, helped to end the putsch three days later and restored Gorbachev to power, Gorbachev had apparently been relieved of the possession of the nuclear suitcase, the launch codes for the Soviet nuclear arsenal. This turned out to be the wake-up call to the new and potential dangers of instability in the Soviet Union. It led to the dissolution of the Soviet Union on December 25 into fifteen independent states, with Boris Yeltsin leading the Russian Federation.

As the Soviet Union disintegrated, President George H.W. Bush launched the Presidential Nuclear Initiatives to help successor states enhance the security of their endangered nuclear enterprises. In early September, Secretary of State, James A. Baker laid out the principles that would guide U.S. policy. Baker announced these to include: the right to peaceful self-determination, respect for national boundaries, support for democratic government and the rule of law, support for constitutional guarantees for human rights, and adherence to international law and treaty obligations (Hoffman, 1991). Bush took unilateral steps to order the U.S. military services to eliminate thousands of tactical nuclear weapons and cancel dozens of strategic nuclear modernization programs. His actions included withdrawing nuclear weapons from all U.S. surface ships and removing nuclear weapons from South Korea. In a phone call to Gorbachev on September 27, 1991, Bush explained that he would take these measures in the hope that Gorbachev would reciprocate to move the two countries to reduce nuclear risks. Eight days later, Gorbachev reciprocated on October 5, 1991.

Beyond high-level politics, the academic and non-governmental community played vital roles in developing ideas for nuclear cooperation. These found a receptive home in Congress as Senators Sam Nunn and Richard Lugar spearheaded the passage of the Cooperative Threat Reduction (CTR) Act, appropriately called the Nunn-Lugar legislation, which passed with overwhelming bipartisan support in December 1991.

FROM CONFRONTATION TO COOPERATION: COOPERATIVE THREAT REDUCTION

With the breakup of the Soviet Union, mutually assured destruction was replaced by the realization of mutual nuclear interdependency. The nuclear threat had changed from nuclear weapons in the hands of the Soviet government to nuclear weapons and other nuclear assets getting out of the control of Russia and other successor-state governments. This lesson is important to remember as we think about potential futures on the Korean Peninsula. As dangerous as the nuclear weapons and nuclear assets are in the hands of Kim Jong-un, the risk they pose could be greatly increased if he is incapacitated or dies.

U.S. executive branch leadership continued to be important after the dissolution of the Soviet Union and the 1992 U.S. presidential elections. The Nunn-Lugar program received strong support in the Clinton administration, particularly from Secretary of Defense, William J. Perry, and Deputy Secretary of Energy, Charles Curtis.

The CTR programs housed in the Department of Defense were managed by the Defense Threat Reduction Agency. These efforts focused on supporting the destruction of excess missiles, storage of excess fissile materials, and mitigating the risks from Soviet chemical and biological weapons programs (Harahan, 2014). The State Department managed the International Science and Technology Centers (ISTC) program, one of the key programs to reorient and retrain nuclear workers in Russia and the other states of the former Soviet Union (Weiner, 2011).

Among the most unlikely and eventually most successful proponents of nuclear cooperation were the nuclear laboratories of Russia and the United States. The Los Alamos, Lawrence Livermore and Sandia National Laboratories in the Department of Energy (DOE) developed close collaborations with their three Russian nuclear weapon counterparts (Hecker, 2016). In addition, several other DOE laboratories supported collaboration in areas such as nuclear fuel cycle facilities, nuclear safeguards, nonproliferation, and environmental issues, as well as peaceful nuclear energy. Similar collaborations between North Korean and American nuclear laboratories may be feasible for the scenario of cooperative conversion. Technical cooperation between North Korean nuclear specialists at the Yongbyon nuclear complex and U.S. DOE technical teams occurred during the Agreed Framework and in the 2007-2008 disablement projects.

Implementing the Nunn-Lugar CTR program required a combination of leadership from the executive and legislative branches of the U.S. government, along with support from academic and non-governmental organizations. The Nunn-Lugar legislation defined the threat clearly. The retention of Soviet weapons by three new states (Ukraine, Kazakhstan, and Belarus) along with the bulk of the Soviet arsenal remaining in Russia created a new international danger because of potential instability in these states. The legislation also warned of the threat of the potential seizure, theft, sale or use of nuclear weapons and components, and the threat of proliferation of nuclear weapons, materials, technologies, and know-how. The act stated that President Gorbachev requested Western assistance in dismantling nuclear weapons, and President Bush proposed cooperation on the storage, transportation, dismantling and destruction of Soviet nuclear weapons. The initial funding was directed toward the safe transportation, storage, accounting, and destruction of nuclear and other weapons in the Soviet Union.

The CTR program was not an attempt to denuclearize Russia, which was the legitimate heir of the Soviet nuclear stockpile. Instead, the CTR initiative targeted programs that eliminated the infrastructure that could be used to produce nuclear materials or nuclear weapons that remained in Ukraine, Kazakhstan and Belarus. The program also provided funds for the elimination of chemical and biological weapons and infrastructures in those countries.

During the ten years following the breakup of the Soviet Union, the Nunn-Lugar program supported cooperation in the following areas:

1) Returning nuclear warhead from Ukraine, Kazakhstan, and Belarus to the Russian Federation along with the destruction of missiles stationed in these countries;
2) Improving the safety and security of former Soviet weapons during transport, storage, and disassembly;
3) Improving the safety and security of fissile materials;
4) Disposing of excess fissile materials;
5) Shutting down or converting facilities used for fissile materials production;
6) Improving the security of radiological materials;
7) Preventing the proliferation of nuclear weapons knowledge;
8) Reducing the threat of nuclear terrorism;
9) Assisting in the destruction of chemical weapons and mitigating the danger posed by former biological weapons laboratories and factories (Hecker, 2021).

Although many of the CTR programs made substantial progress in the early and mid-1990s, they continued to face substantial opposition in the U.S. Congress. As Sharon Weiner (2011, p. 4) points out, the budget authority faced strong opposition each time the program came up for re-authorization in the 1990s. Members of Congress complained that the funds helped Russia's own weapons effort, were a waste, or would simply would be better spent at home. Nevertheless, there was strong backing from the Clinton and Yeltsin administrations to make remarkable progress in the 1990s.

RETURN TO CONFRONTATION AND THREATS TO THE GLOBAL NUCLEAR ORDER

That support began to fade at the turn of the century. Russia's economy began to rebound, and its leadership transitioned to President Vladimir Putin. In his 2007 speech at the annual international Munich Security Conference, Putin rejected what he called America's exceptionalism. Although Moscow and Washington agreed to the New Strategic Arms Reduction Treaty (New START) in 2010 (while Dmitry Medvedev was president and Putin was in the role of prime minister), most of the cooperative programs were phased out over the next five years and completely terminated upon Russia's annexation of Crimea and occupation of the Donbas region in eastern Ukraine in February 2014.

Putin's rhetoric became increasingly combative, and Russia's development of increasingly dangerous nuclear armaments did not bode well for resumption of nuclear cooperation. The slight glimmer of hope resulting from the two sides signing a five-year extension of the New START Treaty in February 2021 disappeared quickly with Russia's unprovoked invasion of Ukraine one year later. I shared with the Bulletin of the Atomic Scientists my concern that with the invasion Putin has blown up the global nuclear order established through mutual accommodation during Soviet days and through cooperation after the breakup of the Soviet Union. Under these conditions, prospects for dialogue looked slim and for nuclear cooperation nonexistent. Yet, during the recent Review Conference of the NPT, the American and Russian sides expressed the need to negotiate a follow-on arms control arrangement to New START.

The history of U.S.-Russian cooperation provides many lessons for the prospects of cooperation with North Korea. A critical lesson is the importance of a clear objective. The CTR program emphasized from the beginning that the objective was not to disarm Russia but rather to help it mitigate the dangers resulting from the Soviet breakup and the economic collapse of Russia and the other states of the former Soviet Union. For North Korea, the objective is not to disarm the North but to roll back and eliminate its nuclear weapons to facilitate normalization of the North's relations—political, economic, and diplomatic—with the United States and South Korea.

Another lesson is the importance of support from the executive and legislative branches of the U.S. government. In addition, the academic and NGO (non-governmental organizations) communities contributed essential ideas and contacts in the design and adoption of the CTR program. In the case of North Korea, U.S. executive branch support has differed dramatically with each change in administration and legislative support has been meager to non-existent. It is inconceivable that a cooperative program with North Korea today could achieve the overwhelming 86 to 8 Senate support garnered by the Nunn-Lugar legislation in December 1991. Despite this, academic and NGO community support for cooperation and contact with North Korea historically has been strong but faltered dramatically once Pyongyang cut ties after the Hanoi summit failure. It was further diminished by North Korea sealing its borders during the pandemic. One of the most important lessons for cooperative programs with former adversaries is that such measures require continued governmental attention and coalition-building.

ONE OF THE MOST IMPORTANT LESSONS FOR COOPERATIVE PROGRAMS WITH FORMER ADVERSARIES IS THAT SUCH MEASURES REQUIRE CONTINUED GOVERNMENTAL ATTENTION AND COALITION-BUILDING.

THE FIRST U.S.-NORTH KOREA NUCLEAR DEAL: THE AGREED FRAMEWORK

During the past 30 years, Washington initially turned to nuclear cooperation to keep North Korea from the bomb and subsequently to denuclearize North Korea. Pyongyang, on the other hand, viewed nuclear cooperation to be a step toward the much larger goal of normalizing the relationship with Washington and ending decades of acrimony. Fitful attempts to cooperate between Washington and Pyongyang led to the two sides missing promising opportunities that led to North Korea's possession of a threatening nuclear arsenal today.

It was Kim Il-sung, the country's founder, who decided in the early 1990s to explore a long-term strategic relationship with the United States through diplomacy. He viewed accommodation with Washington as the best path for North Korea to survive the dramatic geopolitical upheavals at the end of the Cold War, a time when North Korea felt abandoned and even threatened by both Russia and China. Kim believed that such accommodation be based on the projection of strength, not weakness. Since by this time, North Korea's economy and conventional military were increasingly falling behind the South, and the North was heavily outmatched by the United States, the only projection of strength would have to come from the North's nuclear program, making it a top priority for the regime. Consequently, Kim decided to simultaneously pursue diplomacy and nuclear weapons, not one or the other.

> FITFUL ATTEMPTS TO COOPERATE BETWEEN WASHINGTON AND PYONGYANG LED TO THE TWO SIDES MISSING PROMISING OPPORTUNITIES THAT LED TO NORTH KOREA'S POSSESSION OF A THREATENING NUCLEAR ARSENAL TODAY

This led Kim Il-sung and, upon his death in 1994, his son, Kim Jong-il, to engage for the first time in nuclear cooperation with the United States. The resulting 1994 Agreed Framework was a diplomatic deal designed to constrain, roll back, and eventually eliminate the North's nuclear weapons program in exchange for energy assistance, the provision of a civilian nuclear energy program in the North, and normalization of U.S.–North Korea relations. To Washington, the Agreed Framework was primarily a nonproliferation document designed to keep North Korea from a nuclear arsenal. To Pyongyang, it was to be a step toward the strategic alignment with Washington envisioned by Kim Il-sung. In effect, the Agreed Framework was a set of guidelines that, if implemented carefully, could provide the time and space necessary to avoid dangerous crises such as those in the spring of 1993 and in May 1994 after international inspectors first gained access to North Korea's nuclear facilities.

The Yongbyon facilities, including its 5MWe gas-graphite plutonium production reactor, were frozen. International inspectors were allowed to monitor the freeze and American technical teams aided the North's efforts to safely store the spent fuel removed from the reactor. The provision of the light water reactors (LWRs) was a big challenge. The reactors were to be financed

and constructed by the Korean Energy Development Organization (KEDO), an international consortium made up of the United States., South Korea, and Japan, later to be joined by the European Union. Though the provision of the LWRs was part of the agreement, Congress refused to join in funding the $2 billion project—that was left to the South Koreans and the Japanese. Nevertheless, by the early 2000s ground had been broken for the reactors at North Korea's Kumho site and components were being built in Japanese and South Korean factories.

During the last few months of the Clinton administration, several key steps were taken to attempt to fundamentally change the relationship between Pyongyang and Washington. After a visit to Washington by the highest ranking North Korean military officer, Marshal Jo Myong-rok, the two sides issued a Joint Communiqué, in which they agreed to fundamentally improve their bilateral relations, that neither government would have hostile intent towards the other, and that they would "make every effort in the future to build a new relationship free from past enmity" (U.S. Department of State, 2000).

The incoming Bush administration, however, did not share that sentiment. The election of George W. Bush brought in hardline conservatives that had been biding their time during the Clinton years. These conservative voices viewed North Korea's approach as a cycle of provocation, crisis, and temporary resolution to buy time for its nuclear program. In the summer of 2002, the intelligence community provided an updated assessment of evidence that Pyongyang had massive procurement efforts for materials and components for a centrifuge program. The briefing and the accompanying intelligence report were sufficient to deal the deathblow to the Agreed Framework. According to John Bolton (2008), the report was "the hammer [he] had been looking for to shatter the Agreed Framework" (p. 106). Hard-line Bush administration officials like Bolton characterized the intelligence as evidence of "cheating" and as a "moral affront" that necessitated punishment. It marked the end of nuclear cooperation (Bolton, 2008).

North Korea had, indeed, hedged its bets. It had continued to follow a dual-track—diplomacy plus nuclearization—approach. The freeze of the Yongbyon nuclear complex was reversible and the uranium enrichment path to the bomb was clandestinely pursued. But once the Bush administration shattered the Agreed Framework, North Korea put the Yongbyon nuclear complex back in operation in 2003 and accelerated its enrichment program. It was the first in a series of "hinge points," moments when Washington may have been able to effectively channel Pyongyang further down the diplomatic road toward the elimination of nuclear weapons at a manageable level of risk, but through its decisions exacerbated the nuclear threat on the Korean Peninsula.[1] By walking away, Washington had traded the long-term threat of Pyongyang developing a centrifuge program to produce highly enriched uranium, which would take another decade to come to fruition, for a free pass to resume operations at Yongbyon and build a plutonium bomb in less than a year.

RETURN TO NUCLEAR COOPERATION IN 2007 AND 2008

During its second term, the Bush administration reached across the political divide to an emboldened but still interested Pyongyang to resume collaboration toward denuclearization. In a China-brokered Joint Statement signed on September 19, 2005, Pyongyang committed to abandon all nuclear weapons and existing nuclear programs and to return at an early date to the NPT and to IAEA safeguards in return for normalized relations and economic assistance. But before the ink had dried on the deal, the White House issued its own unilateral statement that walked back on the major commitments of the deal. Moreover, the U.S. Treasury Department almost concurrently imposed sanctions on the Banco Delta Asia bank in Macao designed to discourage other banks from dealing with North Korea. These decisions convinced Pyongyang to walk away from the deal and its stated denuclearization commitments—resulting in another hinge point.

North Korea continued its nuclear program and conducted its first nuclear test on October 9, 2006. Although only partially successful, the test appeared to have garnered a modicum of diplomatic leverage rather than a military response from Washington. Domestically the test was billed as the North's arrival as a nuclear power. The Bush administration pursued North Korea diplomatically resulting in a return to implementing the 2005 Joint Statement with two agreements in 2007 to pursue the disablement of the Yongbyon nuclear complex. The nuclear facilities were frozen, international inspectors were again given access as was an American technical team. The North Koreans were especially interested in convincing Washington of the seriousness of the disablement actions that they also invited our Stanford University team to visit in 2007 and 2008. We witnessed the disablement actions and held wide-ranging discussions about potential cooperation in civilian nuclear technologies. These helped to inform me that North Korea was serious in pursuing civilian nuclear energy and nuclear medicine.

Diplomatic progress was slowed during the first half of 2008 by bitter division and dysfunction within the Bush administration, which resulted in moving the disablement agreement's verification goalposts that had been negotiated with the North. The death knell for diplomacy came when Kim Jong-il suffered a serious stroke in August 2008. With Kim's life in danger, succession planning drove North Korea's decision-making. The moment for reconciliation had apparently passed, as the North Korea regime put succession planning on a solid track. Pyongyang was no longer willing to deal. North Korea was determined to conduct a second nuclear test to establish the credibility of the

North's nuclear deterrent, leaving a nuclear crisis for the incoming Obama administration.

North Korea greeted U.S. President Obama with an attempted satellite launch on April 5, 2009. The launch was unsuccessful, yet it poisoned the relationship as Obama saw it as a manIFEStation of Pyongyang's "cycle of provocation, extortion, and reward" (Bader, 2011), which he was determined to end. Washington response to the launch was to orchestrate a United Nations (UN) Security Council condemnation of the launch. This was just what Pyongyang expected, paving the way to use the response as a pretext to move its nuclear program forward. It expelled the international and American safeguard teams and restored the disabled Yongbyon facilities to their original state. Six weeks later, Pyongyang detonated its second nuclear device, this one successfully. The only outsiders that have been allowed in North Korea's nuclear facilities since was our Stanford team in November 2010. In the end, as serious as the disablement actions were in 2007 and 2008, they were reversible once diplomacy faltered.

BOTH SIDES DANGLE COOPERATION CARROTS (BUT NEITHER SIDE FOLLOWS THROUGH)

In November 2010, I was invited by the North Koreans for another visit to Yongbyon with our Stanford University team. Instead of convincing us that disablement was serious, this visit was carefully choreographed by Pyongyang to send a message to Washington and the world that they had mastered the uranium centrifuge path to the bomb and that they were no longer waiting for Washington to help build LWRs—North Korea was building their own.

However, in December 2011, Washington and Pyongyang came close to another deal during the last days of Kim Jong-il's life. It appeared that he was probing to see if he could reach a less confrontational relationship with Washington to pave the way for a better leadership transition to his son, Kim Jong-un. The diplomatic effort, interrupted by Kim Jong-il's sudden death in December 2011, resulted in a deal under Kim Jong-un's leadership. On February 29, 2012, the two capitals issued separate press statements of the Leap Day Deal that would have shut down Yongbyon and have placed observers back on the ground at the Yongbyon nuclear complex. It also called for a moratorium on nuclear and long-range missile tests, all for the promise of a couple of hundred thousand tons of U.S. nutritional aid.

Unfortunately, the two sides had different understandings of what constituted a missile test. Two weeks after the Leap Day signing, Pyongyang attempted to launch an Earth observation satellite. Although the launch failed, the launch attempt confirmed the Obama administration's conviction that Pyongyang was an unreliable negotiating partner—a view which lasted throughout the remainder of Obama's time in office. The administration's decision to scupper the deal led yet to another hinge point with Pyongyang's continued buildup of its nuclear and missile capabilities.

With President Trump's ascent to the White House, the year 2017 turned into the most dangerous year on the Korean Peninsula in decades. Trump's 'fire and fury' countered by Kim's equally menacing replies threatened escalation to real conflict. North Korea for the first time successfully test-launched intercontinental ballistic capable missiles (ICBMs). In September, it detonated its sixth nuclear device, likely a hydrogen bomb, with more than ten times the explosive yield of the Hiroshima and Nagasaki bombs. Yet, at the end of the year Kim Jong-un was prepared to pivot to diplomacy, and Trump turned the diplomatic tables by sending a secret message through a UN envoy telling Kim that he was willing to meet.

Trump and Kim met at the Singapore Summit in June 2018. They set the stage through personal diplomacy and through direct diplomatic outreach from South Korean President Moon Jae-in to Kim Jong-un. My Stanford University colleagues and I developed a comprehensive approach to cooperation and denuclearization that we briefed in Washington (Hecker et al., 2018). At Singapore, Trump and Kim signed a joint statement with provisions to work toward normalization and denuclearization in a phased, simultaneous manner. The difficult work of realizing the promise of the Singapore statement was left for another summit, this one in Hanoi at the end of February 2019. However, John Bolton re-entered the stage as Trump's national security advisor. He had helped to kill the Agreed Framework during the Bush administration, and he was determined that no deal would be reached in Hanoi. He succeeded as Trump ultimately walked away from Hanoi without a deal—a final opportunity to cooperate to denuclearize vanished into thin air.

A FAILED SUMMIT, THE PANDEMIC, NEW ADMINISTRATIONS, AND POTENTIAL REALIGNMENT MAKE COOPERATION QUESTIONABLE

Hanoi turned out to be another hinge point, a lost opportunity to turn back the threat of the North's nuclear program. Senior North Korean diplomats publicly warned, "Such an opportunity may not come again" (Hecker, 2023)—and it didn't during the rest of Trump's term. North Korea sealed its borders during most of the Covid-19 pandemic. It rejected dialogue with the Biden administration while continuing to cement its status more convincingly than ever as a state with a nuclear arsenal. It continued to produce enough additional highly enriched uranium for about six nuclear weapons annually. It restarted its nuclear reactor to produce more plutonium and tritium, required for much more destructive hydrogen bombs. At the October 2021 Defense Development Exhibition, Pyongyang rolled out an impressive array of missile

systems followed by a robust testing program in the fall and shifted into high gear in 2022 with dozens of missile tests.

Once Pyongyang began to reengage with the world, it signaled a new strategic alignment with Moscow and Beijing following the February 4, 2022, Xi-Putin agreement of a "partnership with no limits." Pyongyang has since drawn closer to China and has publicly supported Russia in the war on Ukraine. In October, North Korea supported Putin's illegal annexation of four regions in Ukraine. North Korea is also apparently moving to sell millions of rockets and artillery shells—many of them likely from its old stock—to Russia for its war in Ukraine. Pyongyang keeps tens of millions of artillery shells to fortify the demilitarized zone with South Korea. Moreover, North Korea will likely sell older shells since it has likely been replacing them with ones for multiple rocket launch systems or sophisticated missiles in its front-line army bases (Associated Press, 2022).

Pyongyang has augmented the buildup of its nuclear forces with a new law promulgated on September 8, 2022 by the Supreme People's Assembly of the DPRK on the state policy on the nuclear forces (KCNA, 2022). In the law, North Korea takes the high road declaring that the prime mission of its nuclear forces is deterrence and defines what will be done to ensure the safe maintenance, management and protection of nuclear weapons. The law further declares that it will live up to the highest standards of nonproliferation and that it has a robust command and control system. However, the document also clearly outlines that North Korea is prepared to use its nuclear arsenal in case deterrence fails.

In his speech to the Supreme People's Assembly, cited by Yonhap News Agency (Yi and Chae, 2022), Kim Jong-un stated "Our generation will not seek an improved economic life environment by giving up nuclear weapons...in order to seek one's own comfort and pleasure or to avoid today's hardships or by submitting to the enemies' artful preaching..." He went on to say "...a line of no retreat has been drawn so that no more bargains can be made over our nuclear weapons..." These words seemed to reinforce what Kim has been doing since the Xi-Putin statement in February. The statement portends that Kim has possibly given up seeking strategic accommodation with Washington and to develop a reliable balancing force against China, something that has been a central element of the Kim dynasty for the past thirty years. If so, it makes the prospects of future cooperation unlikely.

Although resumption of engagement appears unlikely at this point, it should not be ruled out because the Pyongyang has typically been light on its feet and ready to explore new avenues as situations change. Washington should be prepared to quickly engage Pyongyang in case Beijing and Moscow stumble in their aggressive pursuit of a new international order. It should also be poised to take advantage of potential South-North re-engagement between the two Koreas. South Korea's President Yoon Suk-yeol's Liberation Day speech on August 15, 2022 may present such an opportunity. Although the headlines focused on the economic carrots of what Yoon called an audacious plan that he would offer Pyongyang if it would give up its nuclear weapons and on Kim sister's, Kim Yo-jung, apparent harsh rejection of the plan by calling it "childish," a closer examination shows that the North may have left the door slightly ajar for engagement.

Yoon's proposal contains a sensible three-part approach of economic, security, and improved livelihood measure for North Korea. Moreover, it contains critical elements that have been missing from American negotiations for most of the past twenty years, namely, a step-by-step approach that does not insist on denuclearization beforehand. Although Kim Yo-jung was quite dismissive of Yoon's proposal, Pyongyang may well find it worth another look.

POSSIBILITY OF NUCLEAR COOPERATION: FOUR DIPLOMATIC SCENARIOS

With this background, I now examine what kind of nuclear cooperation with North Korea may be desirable and what may be possible for various diplomatic scenarios. I posit these scenarios to cover the entire spectrum from the current diplomatic stalemate to a breakthrough in relations that leads to the elimination of nuclear weapons on the Korean Peninsula. Between these two extremes, I examine partial steps in that direction that most likely would have to be pursued before a breakthrough is possible.

Diplomatic Stalemate and Continued Expansion of North Korea's Nuclear Program

This is the most likely diplomatic scenario under the present circumstances. It will not be possible for the United States and South Korea to promote peaceful nuclear cooperation while North Korea continues to expand its nuclear arsenal. Nevertheless, dialogue is necessary to avoid misunderstandings or miscalculations that may lead to a nuclear exchange. The North's new law on nuclear policy specifically states that it was made public "to reduce the danger of a nuclear war to the maximum by preventing misjudge among nuclear weapons states and misuse of nuclear weapons." The law outlines a clear command-and-control structure that "the nuclear forces of the DPRK shall obey the monolithic command of the president of the State Affairs of the DPRK"—namely, Kim Jong-un. Yet, it also indicates that Pyongyang has a hair-trigger option. The new law states "In case the command-and-control system over the state nuclear forces is placed in danger owing to an attack by hostile forces, a nuclear strike shall be launched automatically and immediately to destroy the hostile forces including the starting point of provocation and the command according to the operation plan decided in advance" (KCNA, 2022). Washington should establish a hot line with Pyongyang to avoid such situations.

The two sides could also consider forging agreements to avoid or respond to nuclear emergencies. They could agree not to attack nuclear facilities on the Korean Peninsula to avoid potential catastrophic radiological disasters. Such an agreement would require serious negotiations as to what facilities to include, how to declare them, and how to verify. India and Pakistan signed such an agreement in 1988 (NTI, 2022). The India-Pakistan Agreement, which entered into force on January 1, 1991, obligates the two countries to refrain from undertaking, encouraging, or participating in actions aimed at causing destruction or damage to nuclear installations or facilities in each country.

The situation on the Korean Peninsula is more complex than that in South Asia where India and Pakistan both possess civilian and military nuclear facilities and assets. On the Korean Peninsula, the North's nuclear facilities are predominantly military whereas the South has only civilian facilities. That asymmetry would have to be carefully considered so as not to give the North a free pass at its military sites. Whereas such an agreement would not protect South Korea's conventional military sites, protecting South Korea's nuclear power reactors is crucial. A North-South agreement that would protect nuclear energy sites on the Peninsula would avoid regional radiological disasters and potential traumatic shocks to the regional economies. Whereas negotiations toward any such agreement would clearly be contentious, just bringing representative members of North and South Korean leadership (and perhaps the U.S. as well) together around the negotiating table would constitute a positive step.

Diplomatic Opening That Includes a Freeze

Although such a scenario is currently unlikely, it behooves Washington and Seoul to be prepared in case Pyongyang decides to re-engage. A freeze would be a first step in halting the rapid expansion of the North's program since the Hanoi summit. Such a freeze should include halting all operations at all North Korean nuclear facilities and a halt of long- or intermediate-range missile launches. Although a freeze on known nuclear facilities would not halt North Korea's program completely, it would slow it down. The nuclear facilities should include all Yongbyon facilities—that is, stop operations of the 5 MWe reactor, the Radiochemical Laboratory, the Fuel Fabrication Facility, and the Centrifuge Facility. It should also include an agreement not to start operations of the Experimental Light Water Reactor (ELWR) and not to restart operations of various nuclear facilities at the IR-2000 reactor complex. North Korea should also be asked to include at least a temporary freeze of the Pyongsan uranium mining complex.

At this point, it would be too contentious and counterproductive to insist North Korea include its undeclared uranium enrichment facilities and covert nuclear weapons production and assembly sites. These are best addressed in future agreements. Cooperation at this stage would be limited to exploring how to implement the next steps—the disablement of these facilities. The Agreed Framework also featured a freeze, although the North's nuclear capabilities were miniscule compared to today's program. Nevertheless, it brought IAEA inspection teams to Yongbyon and established protocols for their presence as well as for American technical teams that assisted North Korea in conducting the freeze safely and in an environmentally responsible manner. A return of the IAEA and American teams would be desirable but may be more than Pyongyang is willing to do at this point. In that case, verification of a freeze would have to be accomplished remotely.

The Biden and Yoon administrations would have to explore what Pyongyang wants in return for the freeze. It would most likely include some form of sanctions relief and serious discussion on how to address the security environment.

Diplomacy That Includes Disablement of Known Nuclear Facilities

Successful implementation of a freeze and commensurate economic and security concessions should open the door to next steps in a plan to halt, roll back, and eventually eliminate the North's nuclear weapon program. The next logical step would be to begin the disablement process of known DPRK nuclear facilities described in the previous section. This process could follow the 2007-2008 example to include the return of American technical teams and IAEA inspectors to Yongbyon.

In addition to taking concrete disablement steps such as those in the 2007-2008 period, the United States, South Korea, and North Korea could conduct a joint study for the most effective means to produce nuclear electricity in North Korea. Such a study should include the lessons learned from the KEDO project. It should compare the efficacy of nuclear power from Small Modular Reactors (SMRs) to the large LWRs planned through KEDO. It could include a joint study on the future of the IRT-2000 reactor to include the possibility of repurposing the reactor entirely for medical isotope production (including changing the fuel from HEU to LEU). Extending the lifetime of the IR-2000 reactor should be compared to building a new reactor for medical isotope production.

Furthermore, South and North Korea could begin to address what are likely serious safety, security and environmental challenges at the North Korean nuclear sites. They could begin to cooperate on nuclear reactor safety, both the necessary regulatory framework required as well as design and operational practices. The two countries could begin similar cooperation in nuclear security, particularly on physical protection, nuclear safeguards and nuclear materials accounting. Such efforts could involve the IAEA safeguards organizations and South Korea's Korea Institute of Nuclear Nonproliferation and Control (KINAC), a concept further explained in this volume (See Chapter 5). One of the most daunting challenges for nuclear sites such as the Yongbyon Nuclear Complex will be the decontamination, decommissioning, and cleanup of the nuclear facilities. The United States could share its extensive experience in these areas with North Korea. And the two sides could begin cooperation on emergency response and health studies.

On the diplomacy side, disablement by North Korea will have to be accompanied by the United States and South Korea taking concrete steps to address what Pyongyang considers is most pressing needs. That will almost certainly include further sanctions relief, possible economic integration steps between the North and the South, and further improvement of the security environment. However, these areas can only be addressed through dialogue and negotiations.

Cooperative Conversion of Nuclear Weapons and Missiles to Civilian Programs

Although Kim Jong-un clearly stated in his September 8, 2022 speech that North Korea's nuclear arsenal is here to stay, Washington should be prepared with a sensible proposal in case the political landscape changes. Around the time of the Singapore Summit in 2018, my Stanford colleagues and I suggested that Washington offer Pyongyang a grand bargain to achieve the elimination of North Korea's nuclear weapons program by assisting Pyongyang in converting its military nuclear and space programs to civilian use (Hecker et al., 2018). Rather than arguing with Pyongyang about what denuclearization entails, Washington would insist that the North agree to halt, then roll back, and finally eliminate its existing nuclear weapons and its military nuclear and missile programs in return for reciprocal step-wise assistance with civilian programs.

Pyongyang will almost surely insist on maintaining civilian nuclear and space programs. During my visits to North Korea, the country's nuclear specialists and diplomats stressed that these programs are their sovereign right, not one that Washington can choose to grant or withhold. Moreover, both South Korea and Japan enjoy the benefits of civilian nuclear and space programs. The Clinton administration's Agreed Framework was based on the premise that the North trade in its plutonium production reactors for electricity-producing LWRs. The Bush administration was adamantly opposed to Pyongyang retaining anything nuclear because of its belief that it will eventually use such facilities to reconstitute a military program. The Obama administration treated Pyongyang's attempted space launches in 2009 and 2012 as military endeavors, thereby shutting down opportunities for diplomatic solutions and opening the door to Pyongyang enhancing its nuclear arsenal. With the disagreements that emerged at the Hanoi Summit, the Trump administration never seriously addressed North Korea retaining civilian nuclear programs.

The predominant view in Washington has been that North Korea never had civilian nuclear and space programs—rather they were simply a front for its military program. I disagree. The

Soviet Union built North Korea's first nuclear facilities in the 1960s—the IRT-2000 research reactor and ancillary facilities such as hot cells. It did so under its Atoms for Peace program. These facilities were used for civilian nuclear programs, although the dual-use nature of nuclear technologies proved useful to the North Koreans as they initiated a covert military program. The covert program included an indigenously built 5 MWe gas-graphite reactor and a reprocessing facility to be able to extract plutonium from its spent fuel for weapons. Although the reactor was also designed to provide electricity, its total electricity production since its initial operations in 1986 has been an abysmal roughly one-month equivalent operation of a modern light water reactor.

Gas-graphite reactors are good at producing bomb-grade plutonium, they are poor at producing electricity. Pyongyang realized that and requested help from the Soviet Union in the mid-1980s to construct more efficient LWRs. The Soviets agreed under the condition that Pyongyang join the Nonproliferation Treaty, to which it acceded at the end of 1985. The Soviets were not able to follow through as its economy and, in fact, the country collapsed in December 1991. The follow-on Russian Federation had neither the inclination nor the financial wherewithal to help North Korea with light water reactors. In contrast, the Soviet assistance with the North's missile program, however, continued well into Russian times, perhaps even to the present. That kind of assistance provided a source of revenue for Russia.

In the 1990s, Pyongyang turned to Washington for help with LWRs, but in the end, the KEDO project was terminated by the Bush administration before development to the stage of electricity production was ever reached. The North Koreans then decided to build an indigenous LWR. They showed our Stanford University team the construction start in November 2010. Vice Minister of Foreign Affairs, Ri Yong-ho, told me that they had given up on Washington and decided to build their own LWR along with the necessary uranium centrifuge capability. Twelve years later, the Experimental Light Water Reactor that we saw under construction and whose exterior containment shell appeared complete in 2013, is still not operational. It appears the North Koreans will not be able to produce significant nuclear electricity without foreign assistance.

Since North Korea has and continues to be determined to build civilian power reactors, lending a helping hand offers one of the best opportunities for the United States and South Korea to re-engage with the DPRK. Building a civilian nuclear power enterprise introduces long-term bilateral commitments as well as a long-term dependency. It was 50 years ago that Westinghouse began to build the first commercial power reactor for South Korea. For decades, South Korea depended on the United States before it eventually became one of the most successful nuclear reactor constructors in the world. The two nuclear reactors that were to be provided to North Korea by the United States, South Korea and Japan during the Agreed Framework were designed in part with the aim of developing a long-term relationship among the KEDO countries until the Bush administration decided to kill the project. Every administration since has opposed helping North Korea develop a civilian nuclear program. Cooperative military to civilian conversion would change that and replace the decades-old U.S. demand for complete, verifiable, irreversible denuclearization (CVID), which was and continues to be a non-starter for the North Koreans. Alternatively, should Washington continue to refuse engaging on civilian nuclear power, North Korea may turn to a much more willing Russia or China. That would likely end all prospects of future nuclear cooperation between Pyongyang and Washington or Seoul for decades to come.

SINCE NORTH KOREA HAS AND CONTINUES TO BE DETERMINED TO BUILD CIVILIAN POWER REACTORS, LENDING A HELPING HAND OFFERS ONE OF THE BEST OPPORTUNITIES FOR THE UNITED STATES AND SOUTH KOREA TO RE-ENGAGE WITH THE NORTH KOREA.

Cooperative conversion would provide nuclear electricity and nuclear medicine for North Korea's people, instead of bombs. And instead of missiles, North Korea would receive assistance for a peaceful space program to launch satellites for weather prediction and natural disaster relief efforts. Pyongyang may view a stepwise cooperative conversion program as a concrete demonstration of goodwill and a signal of a serious policy change in Washington.

For this to happen, Pyongyang would first have to agree to a plan to halt, roll back, and eventually eliminate its military nuclear and long-range missile programs. Based on what I have seen during my visits to North Korea's Yongbyon nuclear complex, the elimination of military capabilities would be a huge undertaking. In addition to the nuclear weapons it has produced, the North has an extensive nuclear complex to produce plutonium and highly enriched uranium to fuel those bombs, the ability to manufacture the weapons, and a large arsenal of delivery systems that includes intercontinental ballistic missiles. In this vein, much can be learned from the CTR programs with Russia and other former states of the Soviet Union.

In concert with North Korea taking concrete steps to roll back its ability to produce bombs and missiles, Washington and Seoul would similarly take concrete steps to assist Pyongyang with civilian conversion. Such an effort would offer the best chance for the verifiable elimination of North Korea's nuclear weapons program. The magnitude of the North's nuclear and missile programs and the closed nature of the country will make verification of complete denuclearization virtually impossible. It will not be possible for inspectors, especially in an adversarial environment, to get unfettered access to all North Korea's facilities to verify that it has not secretly kept a few nuclear weapons, a few kilograms of plutonium, or one or more covert uranium centrifuge facilities. But working cooperatively with the North's nuclear and missile specialists to convert North Korea's military infrastructure will greatly increase the likelihood of achieving adequate verification measures as was the case for the U.S.-Russia CTR program. With U.S. and South Korean technical personnel on the ground cooperating closely to advance civilian programs, they will be able to learn much about the nature and extent of the North's entire program and see facilities that otherwise might escape notice in the absence of on the ground access.

Cooperative conversion would also offer North Korean personnel connected to the military nuclear and missile programs the opportunity to move to civilian programs. The technical staff currently producing plutonium, highly enriched uranium, bombs, and missiles could instead help to dismantle and decommission the facilities associated with the weapons program while transitioning to civilian activities. The CTR Nuclear Cities Initiative and the multinational International Science and Technology Center (ISTC) programs described in my book, Doomed to Cooperate (Hecker, 2016), could be designed to meet the needs of redirecting some of the DPRK nuclear weapons program personnel.

During previous trips to North Korea, Yongbyon nuclear specialists told me that they are in dire need of medical isotopes, particularly Iodine-131 to treat thyroid cancer in the region but that they have limited ability to produce them because the IRT-2000 reactor has operated only sparingly for the past thirty years due to the lack of fuel. South Korean and American technical experts could work with their North Koreans counterparts to construct a modern HANARO research reactor—regarded as the best-designed in the world—or retrofit the existing small Yongbyon IRT-2000 reactor. The United States and South Korea could also assist North Korea in getting the ELWR operational to produce electricity, although starting over with a western designed Small Modular Reactor is likely a much better choice. Again, the CTR program offers several examples of what can be done cooperatively in replacing or re-purposing old reactors.

The CTR programs managed by the Department of Defense described in With Courage and Persistence assisted Russia and other states such as Ukraine and Kazakhstan to ensure safe and secure transport of Soviet nuclear weapons back to Russia. Some of that experience may be applicable in the case of North Korea as it begins to transport its nuclear warheads for disassembly. In Ukraine, the United States assisted the government in destroying former Soviet missile silos. That experience should be directly applicable for North Korea once the cooperative program reaches that stage. At this point, the North would also have to verifiably inactivate its nuclear test site at Punggye-ri. American experience at the Semipalatinsk Test Site (now in Kazakhstan) is directly applicable, both from a standpoint of making the site unusable for future tests as well as mitigating various security and safety concerns at the test site.

In particular, the U.S. experience in the CTR program related to fissile materials security, safeguards, storage and disposition is also applicable. Collaboration on nuclear materials protection, control and accounting could be initiated early in the DPRK cooperative conversion program. It could be patterned after the highly successful lab-to-lab program described in Doomed to Cooperate (Hecker, 2016). The novel HEU/LEU deal which resulted in 500 metric tons of Russian HEU being down blended and sold to the United States for civilian nuclear

power reactor fuel is a good model for disposing the roughly 1 metric ton that North Korea is believed to possess. Several countries, such as the United States, South Korea, and China, would likely be interested. The DPRK's small inventory of plutonium, believed to be less than 50 kilograms, will not require a plutonium disposition effort such as that attempted for years in the CTR program. The plutonium could be directly sold to the United States or China.

Additionally, North Korea's space programs could be another opportunity for engagement. Cooperation for space programs could range from the either the United States or South Korea providing launch services for North Korean satellites to joint rocket ventures. Similarly, the United States and Russia developed several joint space ventures over the years, but these were not part of the CTR program.

A conversion program will take time but if carried out under the right conditions, a cooperative approach could speed up the timeline for the elimination of nuclear weapons and, if offered early, would also provide a barometer of just how serious Pyongyang is about disarming. Any plan that welcomes civilian nuclear and space programs in North Korea will be highly controversial in the United States. The concerns, not fully unfounded, are that civilian nuclear and space programs would allow North Korea to reconstitute the bomb and long-range missile programs.

A deal that allows North Korea to retain civilian capabilities would reduce the time to break out and rebuild later. However, such attempts would be quickly recognized because the civilian facilities would be under international safeguards and inspection. The risk of breakout could be further mitigated by making the price of breakout—that is, the benefits that North Korea would forfeit if the regime re-militarizes programs—prohibitively costly to the North.

CONCLUDING REMARKS AND RECOMMENDATIONS

Current prospects for nuclear cooperation between North Korea and the United States are slim, particularly considering Kim Jong-un's recent pronouncement that "there can be no more bargaining over our nuclear weapons" (Smith, 2022). But over the years, all three Kim's have shown themselves to be pragmatic as the external environment changed. For example, Trump's first year in office turned out to be the most contentious and the most dangerous with North Korea in decades. Trump and Kim ended the year with threats referring to their nuclear buttons. Yet, by June 2018, the two leaders sat down at Singapore and signed a joint statement that promised to seek denuclearization and normalization of relations.

As one anticipates future turns of events, it is important to remember what kind of nuclear cooperation has been possible with the North, and how and why it ended in failure. As demonstrated in this chapter, much can also be learned by reviewing Washington's experience in cooperating with the former Soviet Union and Russia under changing political environments.

This chapter concludes with several policy recommendations:

1. Washington and Seoul should be prepared to re-engage Pyongyang with serious proposals toward the elimination of nuclear weapons and the normalization of relations. A novel approach, as described above, that recommends the cooperative conversion of North Korea's military nuclear and missile programs to civilian use could be one clear avenue forward.

2. Even under the most likely scenario of a diplomatic stalemate and continued expansion of North Korea's nuclear program, it is essential for Washington to engage Pyongyang to establish a hotline to avoid a nuclear exchange due to miscalculations and misunderstandings. Such a hotline is especially crucial now that the new North Korean nuclear law contains a clause that apparently would allow for the immediate, automatic launch of nuclear weapons should the country's command-and-control system be placed in danger.
3. In this same diplomatic scenario, it is also advised that the both the United States and South Korea establish emergency response procedures with North Korea in case of nuclear accidents. In addition, they should negotiate an agreement that does not allow the targeting of each other's nuclear facilities.

ENDNOTES

[1] Hinge points are the focus of the forthcoming book by Siegfried S. Hecker with Elliot A. Serbin, *Hinge Points: An Inside Look at North Korea's Nuclear Program*, Stanford University Press, January 2023.

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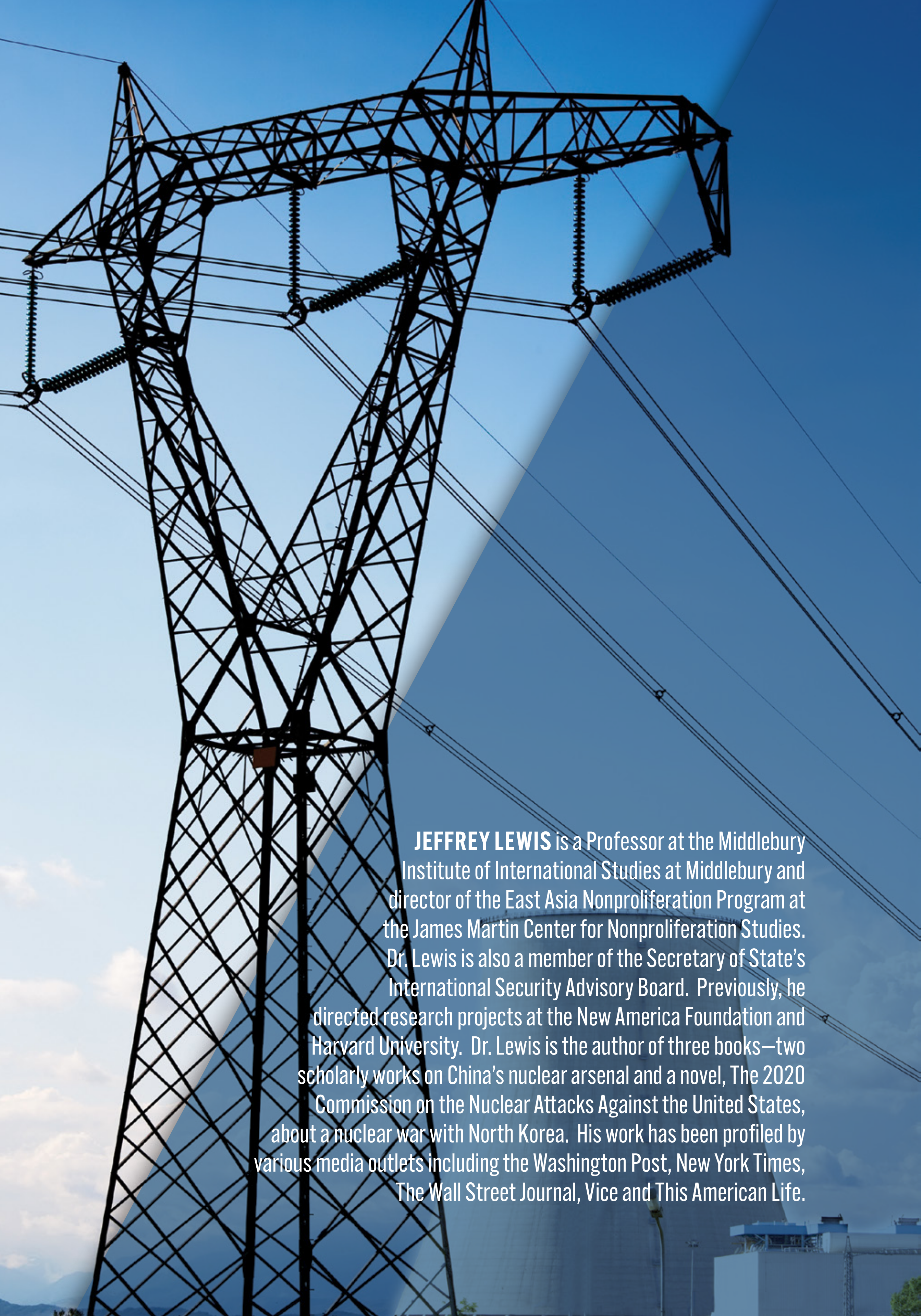

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2 SAFEGUARDING ENERGY-DRIVEN ENGAGEMENT ON THE KOREAN PENINSULA

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INTRODUCTION

The peaceful and military uses of nuclear power have been inextricably intertwined on the Korean Peninsula from the moment that North and South Korea began pursuing nuclear programs. Both Seoul and Pyongyang, at times, have pursued nuclear weapons under the guise of peaceful nuclear energy programs. At the same time, leaders in both Seoul and Pyongyang believed that nuclear energy was an important part of a development strategy, spurred in no small part by the model set by Japan. The civil nuclear programs were every bit as real as the weapons programs. In our public discourse about the risk of nuclear proliferation, we often pay too little attention to motives other than security. Seoul and Pyongyang have both emphasized, to varying degrees of success, economic modernization as a strategy for increasing national power. Each has seen nuclear power at various times as an important industrial or technological capability necessary to this goal.

Over the decades, there was, correspondingly, steady attention paid toward attempting to balance the desire of Seoul and Pyongyang to have access to nuclear energy for power production with the need for reasonable safeguards to prevent proliferation.

The proposals for how to balance these two interests were part of a global conversation about safeguards and other measures. Many of the ideas applied to the Korean Peninsula had developed elsewhere, particularly to suit the challenges in Europe and South America. At the same time, the experience on the Korean Peninsula informed the broader global conversation about safeguards. Our overall impression of the efficacy of strategies like technology denial and safeguards is based on our experiences, many of the most important of which involved the two Koreas.

In general, the United States and much of the rest of the international community have tied two primary strategies to permit the peaceful use of nuclear power. First, the United States and others have tried to encourage technical choices that are relatively proliferation resistant. This includes promoting the availability of light-water reactors (LWRs) and discouraging the development of domestic enrichment and reprocessing capabilities. Second, the United States and others have devised increasingly effective safeguards measures, first to safeguard specific nuclear transfers between states and then broadly to ensure that all nuclear activities in non-nuclear weapons states remain peaceful. These strategies ultimately proved successful in South Korea, but not in North Korea, for reasons that ultimately have much more to do with the broader security context than the efficacy of the strategies themselves.

SEOUL'S NUCLEAR AMBITIONS

For both South and North Korea, the available evidence indicates that interest in nuclear energy preceded interest in nuclear weapons, although both possibilities were apparent to decision-makers in Seoul and Pyongyang. As it happened, Seoul moved first to develop a nuclear energy industry.

OVER THE DECADES, THERE WAS, CORRESPONDINGLY, STEADY ATTENTION PAID TOWARD ATTEMPTING TO BALANCE THE DESIRE OF SEOUL AND PYONGYANG TO HAVE ACCESS TO NUCLEAR ENERGY FOR POWER PRODUCTION WITH THE NEED FOR REASONABLE SAFEGUARDS TO PREVENT PROLIFERATION.

The initial stirrings of South Korea's interest in nuclear energy occurred in the context of the U.S. "Atoms for Peace" proposal. Scholars offer differing perspectives on the importance of U.S. assistance during the 1950s. For Jasanoff and Kim (2009), South Korea made limited progress in this period– enacting an Atomic Energy Act, creating a responsible government agency (The Office of Atomic Energy) and setting up the Atomic Energy Research Institute, which is today the Korea Atomic Energy Research Institute or KAERI. "As yet, however," argue Jasanoff and Kim, "no systematic efforts were made to broaden the scope of South Korea's nuclear activities, which were still significantly constrained by the terms of the South Korea-US agreement." DiMoia (2010), however, argues that U.S. assistance during the Rhee years played an important role in mobilizing the human capital that would serve as the foundation for the South's nuclear industry, concluding that Atoms for Peace assistance, "even if limited in terms of the reactor technology and training it provided, subsidized the livelihood of an emerging scientific community in South Korea, one that would become increasingly significant by the mid-1960s."

Most scholars do agree, however, that South Korea moved much more deliberately to develop a nuclear power industry after the coup that brought Park Chung Hee to power in May 1961. This deliberate effort was consistent with the broader emphasis placed by the Park regime on economic modernization, a strategy that emphasized the development of heavy industry and the promotion of science and technology. This strategy included a strong focus on improving electricity generation, which was seen as an essential component of economic growth. The model for this modernization was that of Japan—rhetorically Park compared his efforts to Japan's Meiji restoration. In practice, however, South Korea's modernization resembled the post-war economic model associated with Nobusuke Kishi's Liberal Democratic Party (Delury, 2015).

Nuclear energy played an important role in how post-war Japanese leaders conceived of industrial modernity. Japan was notably the first country in Asia to build a commercial power reactor, the Tokai reactor which went into operation 1966. The construction of the Tokai reactor was widely documented and publicized as part of a long-standing Japanese government effort to promote nuclear power. The Tokai site was the subject of what Low calls "technical tourism"—at one point in the late 1950s, the site was receiving average of 1,000 visitors a day, with busy days reaching 3,000. The Japanese government also commissioned films documenting construction of the reactor and published 430-page book documenting the achievement. The public education campaign served to mobilize elites and it would be surprising if contemporary Japanese views had no effect in South Korea (Low 2020).

South Korea followed Japan relatively quickly, commencing construction of its first nuclear power reactor, Kori-1, in 1972. South Korea relied heavily on the United States. U.S. assistance to South Korea resulted in the implementation of the first International Atomic Energy Agency (IAEA) safeguards, agreed in 1968 on a trilateral basis among the United States, South Korea, and the IAEA. The 1968 safeguards agreement was an INFCIRC/66-type agreement (U.S. Department of State, TIAS 6435, pp. 4405-4412). INFCIRC/66-type safeguards were rather limited in scope, focused narrowly on ensuring that specific facilities or technology transferred from one country to another were not diverted to any military purpose (Fischer and Szasz, 1985; Sanders, 1975; Schiff, 1983). These safeguards were intended to facilitate technology transfer between states, offering an assurance that technology transferred would not be diverted. What a state did at other facilities was completely outside their scope as there were no international agreements that prohibited the development of nuclear weapons.

Kori-1 was a U.S.-designed Westinghouse reactor supplied by the United States with low-enriched uranium fuel. For the United States to supply this rector, South Korea was required under section 123 of the U.S. Atomic Energy Act, to enter into an agreement with the United States on the peaceful use of nuclear energy. South Korea did so in 1972, prior to the provision of major reactor components. The Agreement was amended in 1974, which is the date usually given. This agreement did not impose significant new safeguards on South Korean nuclear activities. Instead the parties agreed to place under the 1968 safeguards agreement any facilities, technology or material transferred under it.

Park was certainly aware of the potential military application of nuclear technology. It would be wrong, however, to imagine that South Korea's pursuit of nuclear energy was little more than a rationale for nuclear weapons acquisition. Park saw his primary goal as strengthening South Korea's industry and technology, believing that economic modernization would naturally result in greater military power. This is evident in the centerpiece of his economic reform program, the heavy and chemical industrialization (HCI) drive. Park believed that industrialization would come first, and that military power would follow. Park often cited a phrase from Japan's Meiji restoration—"rich nation, strong army"—to describe his strategy. Park directly explained to Kim Chyon-ryom, his then-Minister of Commerce and Industry, that "the power that enabled Japan to declare the Pacific War came from steel mills. Japan could produce tanks, cannons, and naval vessels because it had steel mills" (Moon and Jun, p.118). While Park was certainly aware that nuclear energy program would enable a nuclear option in the future, through the 1960s he seems to have seen nuclear energy in the same light as other heavy industries.

TWO SHOCKS

Even as South Korea was negotiating with the United States for the provision of Kori-1, however, Park's strategy was shaped by two shocks. The first shock came in the form of the Nixon Administration's decision to remove the Seventh Infantry division from South Korea. Park and other Asian leaders allied to the United States had watched with some alarm as the United States grew weary of defending a South Vietnamese regime that seemed unable to reform itself. Their concern was heightened when the new U.S. President, Richard Nixon, gave a speech in Guam in 1969 saying that "the United States would assist in the defense and developments of allies and friends", but would not "undertake all the defense of the free nations of the world." Park interpreted the withdrawal of the Seventh Infantry Division in 1971 as an indication that the so-called Guam Doctrine meant he might soon be on his own, an anxiety that would deepen when the Nixon Administration moved to open relations with China at the expense of Taiwan. For Park, the U.S. decision to abandon authoritarian but anti-communist allies in Saigon and Taipei was extremely worrisome. Whether Park's assessment was correct or not, South Korea was entering what would be an extremely difficult period in its relationship with the United States as many Americans were increasingly uncomfortable about defending a South Korean government that was prospering with an export-led economy, spending little on defense, and committing serious human rights abuses.

According to some accounts—including his daughter and future South Korean President Park Gyun Hee—Park initiated a nuclear weapons program around this time. Other sources dispute this, suggesting that the growing interest in nuclear weapons was not accompanied by the kind of deliberate planning and attention that characterized other projects. Some sources attribute this lack of coordination to a need for secrecy, while others believe that although Park may have begun to lean toward the development of nuclear weapons, he remained uncertain until sometime in 1974. Declassified U.S. intelligence documents express a high-level of confidence that Park's decision was not made until 1974 and, even at that point, was still simply a decision to seek a nuclear option. But without access to South Korean archives—which remain closed to researchers—it is extremely difficult to be sure of the precise timeline as memories of participants can often reorder events into a much tidier narrative than that which occurred.

The second shock was the 1973 Arab oil embargo, which caused oil prices to spike and seriously damaged the export-dependent South Korean economy. The oil shock reinforced the argument that nuclear energy would reduce South Korean dependence on volatile imported oil. Japan and Taiwan interpreted the oil shock in this way. The oil shock, however, did more than simply reinforce the argument for nuclear power. It challenged South Korea's technical choices and offered advocates of nuclear weapons a ready-made justification for a different technical path.

The reactor that the United States was providing South Korea utilized low-enriched uranium as fuel. This reactor design has long been preferred by the United States and other countries for export because it is seen as comparatively proliferation resistant. All reactors produce plutonium, but reactors with low-enriched uranium fuel produce plutonium with an isotopic composition that is undesirable from the perspective of manufacturing nuclear weapons. (It is sometimes wrongly claimed that so-called reactor plutonium cannot be used in a nuclear explosive. This is false. However, it is true that producing a significant explosive yield from reactor plutonium is more technically challenging and there are other issues, including heat generation and radiation, which complicate the process of building nuclear weapons from reactor plutonium.) For the United States, a major strategy for reducing the risk of proliferation has been encouraging the use of rectors that use low-enriched uranium fuel.

This technical fact means that South Korea would be dependent on the United States to supply the enriched uranium fuel for the Kori-1 reactor. While South Korea might be able to import uranium from a variety of countries, only the United States could provide the enrichment services for U.S. supplied reactors. Such a heavy dependence on the United States might have been acceptable in the 1960s, but by the mid-1970s replacing dependence on volatile oil imports with nuclear fuel imported from the United States would have been a case of jumping from the frying pan into the fire.

South Korea, therefore, proposed to purchase a reactor from Canada. The Canadian design, a so-called heavy water reactor, used natural uranium as fuel. While natural uranium does not occur with any abundance in South Korea, it can be imported from a number of countries and does not present the same prospect of dependence on fuel services.

At the same time, reactors fueled with natural uranium are ideal production reactors for significant amounts of weapons-grade plutonium. All of the nuclear weapon states used such reactors to produce plutonium for their nuclear arsenals. As an example, in 1974, India conducted a peaceful nuclear explosion using plutonium produced in a Canadian reactor of the same design that South Korea now sought.

To harvest the plutonium, however, South Korea would need to build a second facility to reprocess the spent fuel and separate the plutonium from it. Such a facility, however, raises immediate concern about the prospect of a nuclear weapons program. The oil shock, however, created an opening for South Korea.

In Japan, the oil shock became a powerful argument for both expanding the country's fleet of nuclear power stations but also for "closing" the nuclear fuel cycle. Japanese nuclear officials argued that the best way for Japan to reduce its dependence on important energy would be to recycle its nuclear fuel—reprocessing the spent fuel to harvest the plutonium, then turning that plutonium into fuel for advanced nuclear reactors (so-called "fast reactors"). Such a scheme, while conceptually straightforward, had proved technically challenging and costly in practice. There have been a number of serious accidents over the decades involving prototype fast-reactors and even today they are seen as technically uncertain ventures. Japanese elites, however, believed deeply in the closed-fuel cycle and invested heavily in developing both a reprocessing capability and fast reactors. South Korea, pointing to Japan, argued that it needed to do the same and attempted to purchase a reprocessing facility from France to separate plutonium that could then be recycled in future reactors.

The U.S. strategy for preventing a South Korean nuclear weapon was to offer limited support for a nuclear energy program in the form of proliferation-resistant LWRs under safeguards, while denying South Korea sensitive fuel cycle capabilities like uranium enrichment or plutonium reprocessing. The potential sale of a Canadian reactor and French reprocessing facility threatened to upend this strategy, even if such facilities were placed under safeguards. The United States, under the Nixon and then Ford Administration, launched a campaign initially aimed at persuading Canada and France to withhold the sale of these technologies.

Canada ultimately played the decisive role (Burr, 2017). Although Canada eventually supplied the reactor, it did so on two conditions. First, Canada insisted that South Korea accede to the Nuclear Nonproliferation Treaty (NPT), which Seoul did in 1975. This had the effect of forcing South Korean to negotiate a new INFCIRC/153-type safeguards agreement with the IAEA. While the INFCRIC/66-type safeguards applied only to specific facilities transferred from one state to another, the INFCRIC/153-type safeguards developed for states that had agreed to the new treaty covered all nuclear activity in the state, with the goal of ensuring that "all source or special fissionable material in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control anywhere … is not diverted to nuclear weapons or other nuclear explosive devices" (IAEA, 1972). This resulted in a significant improvement of IAEA safeguards, although subsequent events would demonstrate the significant limitations that remained even in this strengthened agreement.

Though much improved, the United States government continued to be concerned that the safeguards would be inadequate to ensure that no fissionable material would be diverted from a reprocessing facility. France at this time was also negotiating the export of a similar plant to Pakistan. These two potential sales, as well as the proposed sale of a German enrichment plant to Brazil, resulted in a significant debate about the efficacy of existing safeguards. As it happened, under U.S. pressure, France indicated that it would not object if South Korea canceled the purchase—providing that Seoul compensated the French firm with an appropriate "kill fee".

Again, it fell to Canada to deliver what U.S. officials would call the "knockout blow." Facing domestic political opposition to the sale within Canada, Ottawa ultimately issued Seoul an ultimatum: It would not sell Seoul a nuclear reactor unless Seoul canceled the purchase of the reprocessing facility from France. Seoul had no choice but to accept the terms. (South Korea would a few months later, make a futile effort to revive the contract through a Taiwanese intermediary.) In the end, Seoul received the reactor from Canada—which operated until 2019 as the Wolseong-1 nuclear power plant—but it lacked a viable technical path toward nuclear weapons. Denied this route and under heavy pressure from the United States, Park Chung Hee suspended his nuclear weapons program prior to his assassination. Park's successor, Chun Doo-Hwan, placed much more emphasis on improving relations with the United States. Although South Korea would continue some activities related to nuclear weaponization over the next few decades – activities that we will turn to later – the weapons program never recovered the status and priority it enjoyed under Park.

MULTINATIONAL FUEL CYCLES

As we have seen, the primary approach to safeguarding nuclear activities in this period focused on restricting South Korea's access to certain technologies, especially sensitive nuclear fuel cycle technologies like enrichment and above all reprocessing. While such technologies, in the 1970s, were controlled by a small number of suppliers, it was evident to observers at the time that over time more countries would master the technologies needed to develop domestic capabilities. Japan's embrace of plutonium reprocessing after the 1973 oil shock demonstrated that over time even the most sensitive nuclear technologies would be more widely available and that strategies of technology denial might not succeed indefinitely.

During this period, individuals within the United States, gave serious consideration to an alternative to technology denial—the idea that states might be permitted to access these technologies through multinational fuel cycle facilities. This was the approach taken in Europe, although European arrangements were driven both by a post-war ideology of integration as well as the need to pool limited resources.

The United States, particularly in 1975, sought to persuade South Korea to forgo a national reprocessing capability in favor of a multinational effort, presumably with Japan. Both South Korea and Japan were opposed to this proposal. South Korea rejected it as an infringement of national sovereignty, while Japan was also alarmed at the prospect of hosting such a facility, as it would mean accepting shipments of spent nuclear fuel from other countries (Burr, 2017).

Although Washington did not progress very far with persuading Seoul or Tokyo to embrace such an arrangement, the idea continued to hold sway among nonproliferation practitioners, especially during the Carter Administration. In 1977, the United States conducted the Nonproliferation Alternative Systems Assessment Program (NAS), which was an analysis of nuclear fuel cycle alternatives that was motived, in part, by a sense that national programs for reprocessing would pose an unacceptable danger. Internationally, and at the initiative of the United States, the IAEA conducted the International Fuel Cycle Evaluation (INFCE) between 1977 and 1979. INFCE was a series of technical meetings and studies to consider how best to organize international safeguards in the face of technological change (Scheinman, 1981).

This proposal recurs from time-to-time, largely in the context of efforts to restrict the spread of reprocessing and enrichment technologies. In the face of obvious concern about the proliferation risk of these technologies, states argue that it is unjust that they are denied access to technologies that other countries possess. It is a natural response to observe that these capabilities are costly and technologically challenging. As there is not a large international market for these capabilities, national capabilities are often not a cost-effective commercial option for energy programs. They are much more like national airlines—commercially unviable, but a point of pride or status for countries. And yet, commercially viable or not, many countries have national air carriers. So too, do many countries persist in exploring the nuclear fuel cycle.

NORTH KOREA'S NUCLEAR AMBITIONS

North Korea nearly began its own pursuit of nuclear energy in parallel with South Korea, lagging only slightly behind. The Soviet Union responded to the American "Atoms for Peace" initiative with its own program of assistance, which included North Korea starting in 1959. This assistance, which largely wound down by the mid-1960s, including the construction of a small research reactor, the IRT, near the rural town of Yongbyon (Kaurov, 2000; Zhebin, 2000).

Kim Il Sung had no shortage of inspiration when it came to the desirability of nuclear power—the Soviet Union was actively promoting nuclear power to demonstrate its leadership within the socialist camp; China was rapidly developing its own nuclear capabilities to undermine the dominance of Soviets, Japan was welcoming thousands of tourists a day to Asia's first commercial power reactor, and Park Chung Hee was racing to make sure South Korea did not fall behind. It is impossible to imagine that, in this context, Kim Il Sung would not have asked for what almost every other state in the Warsaw Pact sought and received. The archives of former Warsaw Pact countries, opened after the collapse of Soviet-backed governments, document Kim Il Sung's constant efforts to seek VVER-type nuclear reactors from the Soviet Union and assistance from other pro-Soviet states (Szalontai and Radchenko, 2006).

Moscow's assistance, however, stopped at the IRT. Moscow was unwilling to provide North Korea with a power reactor, a refusal that put North Korea in unusual company. Among Warsaw Pact states, only Romania was singled out for exclusion from nuclear assistance. Most historians believe that the Soviet Union was concerned that Kim would build a nuclear weapon, which does seem to be an accurate assessment. The exclusion of Romania, however, suggests a more complex explanation which perhaps boils down to the same thing. The issue was likely not Kim Il Sung's interest in nuclear weapons per se, but rather his unreliability as an ally—something Moscow also felt about Romania. It was perhaps not that Kim wanted to build a nuclear weapon, but the fact that he was difficult to control. He was the sort of leader who might try to do so, and was thus judged as unreliable. (There is a subtle irony that, after the collapse of the Ceaușescu regime, it emerged that Romania, like North Korea had also initiated a nuclear weapons program. The Soviets were not wrong about their unreliable allies.)

The difference matters because the Soviet Union relied on political control, not technical safeguards, to ensure their allies did not go nuclear. The Soviet Union did not insist on safeguards for the nuclear power plants it supplied to its allies. Moscow, instead, maintained political control over its satellites and was, on general principle, skeptical of Western arguments about the need for inspections (Ginsburgs, 1961). The Soviet-supplied IRT reactor was not, for instance, under IAEA safeguards until North Korea signed an INFCRIC/66 type agreement in 1977.

A larger reactor supplied by the Soviet Union prior to that time simply would not have been safeguarded—and the Soviets did not trust Kim Il Sung.

The Soviet position on safeguards did, over time, evolve in response to the peculiarities of the European context, with Moscow eventually offering the prospect in safeguards on facilities in East Germany, Poland and other central European countries in exchange for West Germany accepting safeguards that went beyond the EURATOM safeguards then in place (Fisher, 1997). The issue was resolved with the accession of the West Germany, as well as many Warsaw Pact states, to the NPT. All were required to negotiate new INFCIRC/153-type safeguards. The situation in Northeast Asia, however, was different. And once the NPT was opened for signature, North Korea resisted signing it.

Like South Korea, North Korea seems to have sought nuclear technology both because its leaders believed that nuclear technology was an important industrial milestone, one that offered clear benefits in terms of energy production as well as military capabilities if it came to that. Like South Korea, North Korea initially sought a relatively proliferation-resistant nuclear reactor from its patron in order to develop its nuclear industry. While Seoul and Pyongyang were ultimately disappointed by their respective patrons for different reasons and in different ways, each turned to reactors fueled by natural uranium for reasons that included national sovereignty, energy security and the possibility of developing nuclear weapons.

North Korea broke ground on its first nuclear research reactor, designed without Soviet assistance, in 1982. The 20MW(th) reactor at Yongbyon was a "gas-graphite" reactor, cooled with CO2 (the "gas") and moderated with graphite. Crucially, it relied on natural uranium, for its fuel. Most sources describe this reactor as having been based on the British Calder Hall reactor design, which was used to produce plutonium for the United Kingdom's nuclear weapons program and to generate electricity. While the Calder Hall design is the original gas-graphite reactor, Japan's Tokai reactor is probably the missing link between the two. Yongbyon bears little physical resemblance to a Calder Hall reactor, but it looks very much like the Japanese reactor at Tokai, which itself was based on the Calder Design.

The Tokai reactor was the first commercial nuclear power reactor in Asia. It was a highly visible demonstration of the importance that Japan placed on nuclear power. It was also highly accessible to North Korea—it was open to visitors, the subject of many films produced by the Japanese government, and even a 430-page book documenting its construction. Japan, with its large community of Korean residents sympathetic to North Korea, was an important source of technology and knowledge for North Korea. There are credible reports of factories in North Korea being modernized with Japanese equipment procured by the General Association of Korean Residents in Japan, a pro-North Korean group of Koreans living in Japan. North Korean defectors have also indicated that Japan was a significant source of technology and equipment for North Korea missile program. North Korea operated a ferry service with Japan that carried both passengers and cargo from 1971 until 2006, when Japanese authorities banned North Korean ships from Japanese waters citing smuggling concerns. For North Korea, facing the prospect of designing a domestic nuclear power reactor, Tokai would have been an obvious and appealing model. North Korean officials have never confirmed this. One visitor to the Yongbyon site once asked a North Korean official why they had chosen the gas-graphite design over Russian reactors. "He looked at me with a puzzled expression," Robert Alvarez (2003) recalled, "and replied that this simple design allowed his country to have an indigenous nuclear power program without relying on Russia or on anyone else".

The construction of a nuclear reactor without Soviet assistance prompted Moscow to reassess its attitude toward Pyongyang. The Soviet Union agreed to supply VVER-type reactors to North Korea. North Korea—in what most observers believe was a quid pro quo—acceded to the Nonproliferation Treaty in 1985.

As we have seen, accession to the NPT requires that a state negotiate an INFCIRC/153-type safeguards agreement. For various reasons, however, North Korea did not do this promptly. The Yongbyon reactor went critical in 1986, reaching full power in late 1987. Still, North Korea stalled.

North Korea's reluctance to accept the safeguards raised less concern within the United States than one might have imagined. Despite what, in hindsight, appears to be several reliable indicators that North Korea was pursuing a nuclear weapons program, U.S. intelligence analysts remained skeptical about the prospected of a North Korea nuclear weapons (Froscher, 2019). Even as late as 1991, U.S. intelligence estimates expressed some hesitation about whether North Korea might be building a nuclear weapon. This was a period of enormous geopolitical volatility, with South Korea's Roh Tae Woo pursing an engagement strategy with North Korea and U.S.-Soviet relations undergoing dramatic changes.

For Roh, removing U.S. nuclear weapons was a significant priority (Bush and Scowcroft, 1998). There was little opposition within the United States military for removing the weapons and many diplomatic advisors believed that it was best to give Roh what he wanted, judging that it was better to remove them of our own accord than under pressure from an allied government. The Bush Administration was extremely reluctant to undertake a withdrawal of nuclear weapons to persuade North Korea to do what it had already committed to do as a state-party to the NPT. The coup against Gorbachev changed the situation dramatically. President Bush sought a number of unilateral measures he could take with regard to nuclear weapons not covered under existing strategic arms control agreements. Bush hoped what his advisors called "The President's Nuclear Initiative"—a series of unilateral steps to draw back—would create the political space for Gorbachev to reciprocate quickly, without a long and drawn-out negotiation. Gorbachev did so, and Russian President Yeltsin made a further step after the collapse of the Soviet Union. As part of a worldwide drawdown in these forces, the United States removed all nuclear weapons from the Korean peninsula.[1]

The South Korean government immediately sought to leverage the withdrawal of U.S. nuclear weapons into an agreement with North Korea, resulting in the January 1992 Joint Declaration on Denuclearization of the Korean Peninsula. This interesting document envisioned very different future for safeguarding nuclear activity on the Korean peninsula. In addition to standard language about, the agreement contained two significant measures. First, both countries agreed they "shall not possess nuclear reprocessing and uranium enrichment facilities" (MOFA, 2018). Second, the two sides agreed to the "inspection of the objects selected by the other side" under a "South-North Joint Nuclear Control Commission" (MOFA, 2018). The model was consciously that of Argentina and Brazil, states that long-refused to join the Non-Proliferation Treaty, only doing so with their own bilateral inspection regime known as Brazilian–Argentine Agency for Accounting and Control of Nuclear Materials or, in its Spanish acronym, ABACC.

In the short-term, the withdrawal of U.S. nuclear weapons and the Joint Declaration seemed to open a path toward preventing nuclear proliferation on the Korean peninsula. North Korea signed a safeguards agreement with the IAEA in April 1992. The good will would be short-lived.

THE NORTH KOREAN NUCLEAR CRISIS

In fact, the signing of the safeguards agreement triggered the North Korean nuclear crisis. North Korea submitted an initial declaration to IAEA in May 1992. One immediate problem was that North Korea had constructed, and operated, a large facility for reprocessing plutonium—not withstanding its agreement in January 1992 that it "shall not possess nuclear reprocessing and uranium enrichment facilities" (MOFA, 2018). North Korea's declaration about the amount of plutonium that had been produced at the facility was inconsistent with information that the IAEA had been able to gather using environmental sampling techniques.

North Korea had stated that it had only separated plutonium once, yielding only a few grams of the material—far less than needed for a nuclear weapon. The isotopic composition of plutonium found in environmental sampling, however, was not uniform as one might expect in a single campaign. It was, as Hans Blix explained, as though North Korea had shown the IAEA a pair of gloves, but one was red and the other was blue (ElBaradei, 2011).

Other evidence soon suggested that North Korea had, in fact, secretly harvested an unknown amount of plutonium. The United States had observe North Korea shut down the reactor for a period, during which North Korea might have covertly unloaded it to supply spent fuel for the secret reprocessing campaign. And there was a building connected by pipes to the reprocessing facility that the U.S. and IAEA suspected of being a camouflaged waste facility. In the face of this evidence, the IAEA requested for the first time in its history a special inspection to resolve the discrepancies. North Korea responded by announcing its withdrawal from the NPT.

The U.S. intelligence community estimated that North Korea had separated as much as six kilograms of plutonium, enough for one, possibly two nuclear weapons. North Korea was also preparing to unload the reactor at Yongbyon which had another 20 kilograms of plutonium in its spent fuel.

In 1994, North Korea and the United States reached the Agreed Framework. North Korea froze its plutonium production infrastructure—shut down its gas-graphite reactor, place the spent fuel in canisters, and freeze construction on two much larger reactors being built—in exchange for the supply, through an international consortium, of proliferation-resistant LWRs. North Korea further agreed, once the reactors were built, to eventually dismantle its facilities at Yongbyon.

Why did North Korea agreed to do this? Even today, we do not know when North Korea made an irreversible decision to seek nuclear weapons. The Soviets believed Kim Il Sung sought nuclear weapons, which is why they denied him the sale of VVER reactor. But it is important to be clear that officials in Moscow and Warsaw Pact capitals made that inference based on the Kim's broader personality. He was the sort of leader, in their opinion, who would seek such a weapon. Certainly by 1988 the evidence is quite strong—the United States detected high-explosives testing at Yongbyon for the development of implosion-type devices. But even then, many outsiders believed that Kim was accumulating leverage rather than racing toward a bomb and that the Agreed Framework provided North Korea under Kim Il Sung, and then Kim Jong Il after the elder Kim's death in 1994, a path out of the isolation created by the collapse of the Soviet Union and the famine that gripped the country.

Verification under the Agreed Framework was left to the IAEA, although there was also a U.S. presence at Yongbyon to help with certain operations such as the canning of spent fuel. The IAEA was not entirely happy with the arrangement. The timetable laid out in the Agreed

Framework meant that it would be many years before the IAEA would be able to resolve the inconsistencies in the DPRK's initial declaration.

SEOUL AND THE ADDITIONAL PROTOCOL

The IAEA's experience with North Korea, as well as its experiences with covert programs in South Africa and Iraq, demonstrated important shortcomings of the existing safeguards infrastructure. Safeguards had, initially, been conceived of as measures to be applied at specific facilities to reduce the risks of international trade in nuclear technologies. With the rise of the NPT, the object of safeguards changed from verifying the non-military use of specific facilities to verifying that all nuclear activities in non-nuclear weapons states remained peaceful. And yet the INFCIRIC/153-type safeguards still relied on a state submitting a declaration of locations. In the case of North Korea and especially Iraq, it was clear that a state could create a parallel program outside of the activities declared to the IAEA.

This challenge led the creation of an enhanced safeguards system, eventually implemented in the form of a supplemental list of safeguards called the "Additional Protocol" to the standard INFCRIC/153-type safeguards agreement. The Additional Protocol would not feature in future negotiations with the DPRK, through it would a central element of the Iran nuclear deal. And the issue of covert facilities for which it was, in part, designed would loom very large.

The Additional Protocol, however, had a much greater impact on South Korea. After Park Chung Hee's assassination in 1979, the new military government of Chun Doo Hwan sought to reduce tension with the United States. To outward appearances, South Korea ended it nuclear and missile programs. The Chun military government eventually relinquished control to a civilian government, allowing South Korea's democratization over the course of the 1990s.

As part of South Korea's emergence as a wealthy industrialized democracy, South Korea entered several international regimes to control the spread of technology relating to nuclear proliferation, including the Nuclear Suppliers Group in 1995 and the Missile Technology Control Regime in 2001. Kang et al (2005) notes that "most nonproliferation analysts held that South Korea's gains from being an internationally certified, squeaky-clean nuclear-powered state meant that the South would adhere stringently to all its nuclear safeguards obligations."

The reality, however, was rather different. South Korea signed the Additional Protocol in 1999, but the agreement did not enter into force until 2004. South Korea dragged its feet, as North Korea had done, largely because its scientists had committed a number of safeguards violations up to the present day and were reluctant to accept the scrutiny from the IAEA empowered by the Additional Protocol. Although South Korea's weapons program had been suspended, a limited amount of covert work had continued. "KAERI officials had been concerned for years that it would be difficult to keep the uranium and earlier plutonium-related experiments secret once the Additional Protocol came into force," explains Kang et al (2005). Even without the Additional Protocol, the IAEA, in November 1997, the IAEA detected small amounts of plutonium in hot cells associated with the TRIGA III research reactor in Seoul. This detection ultimately resulted in South Korea admitting safeguards violations relating to undeclared reprocessing and enrichment activities (Kang et al, 2005).

THE SIX PARTY AGREEMENT AND LEAP DAY DEALS

The 1994 Agreed Framework began to unravel shortly after it was signed. Significant political opposition to the agreement, empowered by a surprising Republican takeover of the House of Representatives in November 1994, resulted in substantial delays to shipments of heavy fuel oil to North Korea and the creation of the international consortium to provide North Korea with LWRs.

The U.S. intelligence community detected, including underground facilities at Hagap and Kumchang-ri that some analysts believed might be related to a covert nuclear weapons program. After the allegation that Kumchang-ri was a covert, underground nuclear reactor The United States publicly accused North Korea of building a cover nuclear reactor at an underground facility near Kumchang-ri. After a protracted negotiation, North Korea allowed a U.S. team—notably not IAEA inspectors—to visit the facility. The team found that the site was not suitable for either an underground reactor or reprocessing facility (Rubin 1999).

The deteriorating political relationship between the United States and North Korea posed a constant challenge during this period, particularly as Washington grew increasingly concerned about North Korea's missile programs. Much of the IAEA's effort in this period focused on persuading North Korea to provide full cooperation despite the increasingly difficult political environment. In 2000, the IAEA determined that it would need another three to four years to complete the activities required to verify the correctness and completeness of the North's initial declaration (ElBaradei, 2000).

Other signs indicated that North Korea had begun to procure equipment for a gas centrifuge program. In the summer of 2001, the profile of these procurements changed in a significant way. North Korea imported a shipment of aluminum tubes that was much larger than it would need for a research and development program. The scale of the purchase led the U.S. intelligence community to conclude that North Korea was constructing a uranium enrichment facility, although the location of the site outside of Kangson would not be identified by U.S. intelligence until 2010 and not publicly disclosed until 2018 (Panda, 2018). U.S. officials, in October 2002, confronted their North Korean counterparts about the covert enrichment program. Although there is a significant dispute about what the DPRK said in response, the effect of the confrontation was the elimination of remaining political will within the United States to continue with the Agreed Framework. The United States suspended its commitments under the agreement, while North Korea expelled inspectors and withdraw from the NPT in 2003. North Korea tested a nuclear explosive device in 2006.

The IAEA would briefly return to North Korea following a Six Party Agreement in 2007, only to be expelled again after Six Party negotiations collapsed in 2008.

CONCLUSION: SAFEGUARDS CHALLENGES

As we have seen, the United States and much of the rest of the international community have tied two primary strategies to permit the peaceful use of nuclear power. First, the United States and others have tried to encourage technical choices that are relatively proliferation resistant. This includes promoting the availability of LWRs and discouraging the development of domestic enrichment and reprocessing capabilities. Second, the United States and others have devised increasingly effective safeguards measures, first to safeguard specific facilities transferred between

states and then broadly to ensure that all nuclear activities in non-nuclear weapons states remain peaceful. These strategies ultimately proved successful in South Korea, but not in North Korea.

Why did these strategies work in South Korea but not North Korea? South Korea was, in some respects, an easier case to solve. Although Seoul's relationship with its superpower patron was often fraught with tension, Seoul was largely able to achieve its energy and security needs within the framework established by the United States. Although we see significant hedging with respect to a nuclear option within South Korea, on the whole Seoul got what it wanted and had a powerful interest in not disrupting its relationship with the United States. North Korea, by contrast, received far less support while its Soviet patron survived and was then left to fend for itself after its Soviet patron's demise.

China never really played a comparable role for North Korea. China had provided no support to North Korea's nuclear program. A tentative effort to transfer a short-range ballistic missile to North Korea in the late 1970s was terminated by Beijing (Lewis and Hua, 1992). This reflected a much more wary alliance than one might have assumed, although it is difficult to understand the dynamics of the relationship between Beijing and Pyongyang. "The truth of the Sino-North Korean alliance under … Kim and Deng," Delury (2022) has argued, "lies somewhere between the ostentatious shows of solidarity and implicit signals of distrust." Chinese officials during the 1980s only grudgingly acquiesced to Kim Il Sung's plan for succession to his son—which ran counter to Deng Xiaoping's campaign to eliminate "feudal" thinking—and made a habit of lecturing the North on the need to implement Chinese-style economic reforms.

When the Soviet Union collapsed, Pyongyang sought energy assistance and security assurances from a coalition centered on the United States not Beijing. This almost certainly made North Korea more likely to hedge with respect to nuclear weapons, while Washington was far less tolerant of such hedging in North Korea than it was in the South. It was simply easier for South Korea to rely on the United States than it was for North Korea to do so.

South Korea, for example, was unable to acquire a heavy water reactor from Canada or a reprocessing plant from France. Faced with this reality, Seoul accepted however grudgingly that persisting would worsen its overall situation. Pyongyang reached the opposite conclusion—that it had little to lose by pressing ahead. Pyongyang's Soviet patron consistently refused to provide a VVER-type reactor until North Korea completed its own domestic reactor. At that point, Moscow was suddenly forthcoming with an offer of assistance. The implication of this observation is that our safeguards and other institutional arrangements, while often far from perfect, have rarely been the problem. The IAEA, in particular, was able to provide significant indications of safeguards violations, first in North Korea, then in South Korea. The problem has been the larger geopolitical context in which Seoul and Pyongyang are making decisions about nuclear energy and nuclear bombs.

What does this mean for future arrangements? The challenges are unlikely to be technical. The IAEA is perfectly capable administering safeguards in both countries if there is a political agreement. Those safeguards could be INFCIRC/153-type arrangements to verify Seoul's compliance with its NPT obligations to bespoke arrangements that might be created for North Korea. The major question is not what safeguards might be imagined, but rather what sort of political arrangement would be acceptable to all parties.

If North Korea were to end its nuclear weapons programs and place its facilities under safeguards, the IAEA could certainly apply measures similar to those that were created in support of the Joint Comprehensive Plan of Action agreed by Iran and the so-called EU/E3+3. That agreement implemented not a "blue book" style INFCIRC/153-type agreement with an Additional Protocol and, instead, went further to contain a number of political commitments to ease the task of monitoring by the IAEA, such as restrictions on where enrichment could be conducted, limitations on research that might be linked to weaponization, and access for the IAEA to centrifuge production workshops and uranium mills. Whatever political objections might be raised to this agreement, there is no dispute that the IAEA was able to implement safeguards effectively until the Trump Administration made a political decision to suspend U.S. participation in the agreement.

Conversely, if there were a political decision to accept the fact of North Korea's nuclear status, much as the Bush Administration did with India in 2004, the IAEA could certainly administer a comparable safeguards agreement. As part of the diplomatic process that led to and India's accession to the Nuclear Suppliers Group, India separated its military and civilian energy facilities, placing the latter under INFCRIC/.66 type safeguards. As in the case of the JCPOA, one might raise political objections to the wisdom of this agreement, but there is no dispute that the IAEA has been able to ensure that facilities placed under safeguards have not been part of India's weapons program.

Nor does the IAEA have to administer all of the safeguards if South and North Korea wish to do so themselves. The IAEA also assists Brazil and Argentina's inspections of one another through the unique safeguards arrangement of ABACC, a model that North and South Korea both found appealing in 1990s. There is no shortage of workable proposals that could safeguard a wide range of diplomatic outcomes on the Korean peninsula.

The nuclear ambitions of both Seoul and Pyongyang were plainly visible to outside powers, which exerted no small amount of pressure on both countries to accept limitations on their nuclear programs. The United States intelligence community had good visibility into nuclear programs in both countries, although policymakers sometimes wanted to close their eyes to inconvenient evidence. That is not to say that intelligence was perfect. But the general direction of things in both Seoul and Pyongyang was certainty clear to anyone who cared to look. And the IAEA detected significant safeguards violations in both North and South Korea, after both dragged their feet in implementing different sorts of safeguards agreements precisely because both knew the detection of clandestine activities was a likely possibility.

What there has been a shortage of, on the other hand, are workable diplomatic outcomes that are acceptable to the major players—first and foremost Pyongyang and Washington, but also Beijing, Moscow, Seoul, and Tokyo.

ENDNOTES

[1] The Bush Administration initially intended to retain aircraft-delivered gravity bombs in South Korea, as it did in some NATO countries, before reconsidering and agreeing to the removal of all such weapons.

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SECTION 2

NUCLEAR ENERGY & SAFETY ON THE KOREAN PENINSULA

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3 NUCLEAR ENERGY IN NORTH KOREA: BENEFITS, RISKS, AND POSSIBILITIES

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INTRODUCTION

North Korea is the only country in the world that has tested nuclear weapons in the 21st century. And, as North Korea's nuclear capabilities increase day by day, its nuclear tactics and threats continue to evolve. The continuous increase in North Korea's nuclear capability disrupts military power balance in the Korean Peninsula and presents mounting challenges to the security of the Republic of Korea, the United States, and Japan.

While the situation reflects historical failures in international efforts to prevent North Korea from acquiring nuclear weapons, the current North Korean nuclear capability is the outcome of the country's long-term resolve to achieve regime security regardless of external conditions or sanctions. The upshot of this observation is that North Korea will only consider the option of denuclearization under the absolutely assured conditions of acquiring regime security, economic prosperity, and international recognition and acceptance of North Korea as a legitimate state.

One of the options on the table regarding North Korea's possible paths for denuclearization is the establishment of a national energy infrastructure in return—providing nuclear energy option to North Korea in exchange for nuclear weapons. In this chapter, possible benefits, risks, and possibilities of such approach is examined.

BENEFITS OF NUCLEAR ENERGY DEVELOPMENT IN NORTH KOREA

Given the current deadlock, the dialogue with North Korea demands new approaches. The new approach must put a premium on devising a process toward confidence-building among the parties involved.

From North Korea's point of view, the United States is unreliable and untrustworthy. This is, obviously, the same observation from the U.S. side. If both the United States and North Korea can agree on starting a very significant step requiring long-term engagement, such agreement itself is a major achievement. Establishing nuclear energy infrastructure requires long-term effort and process. A consensus towards cooperation in nuclear energy development is an expression of will to engage in long-term cooperation.

Also, for any dialogue with North Korea, key factors affecting possible roadblocks must be addressed. These key factors include the perceived impact on national security, the perceived assurance on national prosperity development, and elation of national pride in North Korea. A nuclear energy project can provide a boost in all three areas. Realizing peaceful use of nuclear energy to pursue national prosperity could be viewed as a desirable alternative to nuclear weapons-based national security by the North Korean citizens.

The nature of nuclear energy projects involves high up-front costs, long construction time, and requires international support for plant operations, which present opportunities for continued engagement. Such engagement also opens ways to understand the other side's long-term preferences and vision for the future and verify the commitment of the parties involved. The high-cost investments require risk-taking by the investors (e.g., South Korea, the United States and other allies) which in turn demands political and security arrangements on the peninsula toward the goal of successful project completion (Lawrence, 2019).

ESTABLISHING NUCLEAR ENERGY INFRASTRUCTURE REQUIRES LONG-TERM EFFORT AND PROCESS. A CONSENSUS TOWARDS COOPERATION IN NUCLEAR ENERGY DEVELOPMENT IS AN EXPRESSION OF WILL TO ENGAGE IN LONG-TERM COOPERATION.

Compared to the North Korean light water reactor KEDO project according to the Agreed Framework in 1994, the infrastructure and technical and human capabilities in the nuclear technology field possessed by North Korea have significantly improved, and North Korea is developing the national industry through the nuclear capabilities it has already developed. Therefore, any nuclear power project to be pursued in the future needs to be more extensive and substantive, covering wider spectrum of technology applications. In this regard, the project can be envisioned to include four stages of progressive civil nuclear capability expansion: research reactor development, experimental light water reactor (ELWR) project, small modular reactor (SMR) development, and large light water reactor (LWR) development.

Each stage presents distinctive benefits to North Korea by addressing specific domestic needs. Development of a research nuclear reactor is to produce medical and industrial isotopes for domestic consumption in North Korea. The ELWR project stage would assist in completion of the currently unfinished project in North Korea while equipping the country's engineers with the necessary know-how, materials, and equipment to launch peaceful nuclear power program. The SMR project stage would provide low-carbon energy infrastructure to North Korea—an alternative to large LWR project—while its national electric grids are to be modernized. The large LWR project stage would provide long-term energy security of North Korea while supporting major national industrial development.

The effort for national electric grid refurbishment and upgrade could parallel these stages, depending on the success of respective stage. Therefore, success in each of the phases can lead into more substantive next steps in terms of national energy infrastructure development with large implications for economic and industrial growth in North Korea as a foundation for rapid economic growth moving forward. The proposed stages also represent the nuclear industry growth trajectory in North Korea. Success in each stage must also be defined in terms of progress in confidence-building and achieving major milestones in terms of meeting the expectations among the parties. These expectations include verification of North Korean activities toward denuclearization, providing security guarantee to North Korea, peace development in the Korean peninsula, and normalizing the diplomatic relations between North Korea and the United States and South Korea.

The research reactor development stage should begin with initial agreement and activities freeze within the self-declared areas and facilities inside North Korea. This stage would utilize local North Korean scientists involvement alongside international assistance. The financial and technical support for the project would be arranged by the United States and South Korea through multilateral coalition of countries similar to KEDO. Training of North Korean workforce and related technical assistance can be provided by South Korea, given reduced language and cultural barriers between the two countries. The fuels to be loaded into the research reactor are to come from the down-blending of North Korea's highly enriched uranium (HEU) stockpile, signaling North Korea's commitment to initiate the denuclearization process. Verification of freeze of activities in the self-declared areas and facilities would follow next.

The ELWR project stage, as envisioned, would begin with an activities freeze within all areas and facilities of North Korea, i.e., completely blocking additional nuclear weapons related activities—Effectively capping North Korea's military nuclear program. However, the list of areas and facilities can remain undeclared and undisclosed until the opportune time. The ELWR stage would also be based on utilizing North Korean scientists' involvement and expertise under the financial and technical support of international multilateral coalition with the United States and South Korea co-leading the coalition. Again, South Korea can play a major role in providing technical assistance as in the case of research reactor development. The fuels to be loaded into the ELWR could also come from down-blending of the North's HEU stockpile. Completely consuming all of North Korea's HEU stockpile in the ELWR marks the end of this stage. At the end of the stage, North Korea could release the list of all areas and facilities while applying the highest standard of information security techniques (e.g., blockchain) thus without releasing the list until the opportune time.

The SMR development stage would begin based on verification of self-declared freeze of nuclear activities. The reactor to be built is based on mutual agreement among cooperative parties, including North Korea, the United States, and South Korea. Deployment of SMR on a ship can also be considered depending upon the conditions of the site or the security situations. Funding for this stage could come from U.S. and South Korean industrial consortium as partners in SMR development. North Korea's consent to reveal the list of all areas and facilities of nuclear activities in North Korea would be a necessary condition to complete this stage.

The large LWR development stage would begin with verification of the activities in all of the areas and facilities in North Korea with subsequent dismantling of all of nuclear weapons and components in the North. Any remaining fissile materials and related components will be converted to peaceful use. The reactor to be deployed would be the APR1400+ which is the latest technology of South Korea as a further advanced model of APR1400 which was exported to the United Arab Emirates (UAE). It can be envisioned that this stage is funded solely by South Korea, as inter-Korean new energy initiative on the Korean peninsula.

SMR technology is a potential game changer in nuclear energy development in North Korea. While a nuclear power plant project is typically very big in its physical size, scale, manpower requirement, and funding, while taking long time—up to 7 years, on average—for plant construction, a SMR project is small, takes a relatively short time—only 2 years—to build, and carries low financial risk with a smaller capital involved. A SMR typically refers to a reactor with less than 300 MWe and can be adapted to smaller and weaker grids which is important to North Korea. Lower cooling requirements for SMRs enables their installation at various sites including inland locations. In addition, notable advantages of SMRs include high-level inherent safety virtually eliminating the possibility of large radioactivity release to the environment and built-in nuclear security and safeguards design features against sabotage or misuse. Nuclear security and safeguards benefit of SMR comes from a fact that SMRs, in comparison to large nuclear reactors, have smaller inventory of nuclear materials, higher fuel burnup creating high radiation barriers against misconduct for diversion, and having long cycle length or even unmanned remote operations minimizing the need for human access. SMRs also have much reduced need for the transportation and handling of nuclear material with potential of having both fewer target sets and target set elements.

SMRs also present opportunity for synergistic combined use in energy generation with renewable energies (such as wind and solar power) toward minimizing national carbon emissions. As North Korea's energy system heavily relies on using fossil fuels, such arrangement will be important for North Korea's entry to global economy under the norm of carbon neutrality. Currently, North Korea's nuclear facilities are spread not only near Yongbyon but also in various parts of the country. Through decontamination and environmental restoration activities, these facilities can become important starting points for national energy infrastructure development. For instance, wind or solar power stations can be established at these sites along with SMRs replacing fossil fuel plants. This means North Korea's future energy development, in parallel with denuclearization, presents opportunities for establishing advanced low-carbon energy infrastructure.

The potential SMR types for this deployment include South Korean SMART or i-SMR technology, and U.S. Nuscale designs. SMART and Nuscale are light water reactors (LWR) with existing licensing approval featuring proliferation resistance characteristics acceptable to the international community. Under the once-through fuel cycle system, nuclear materials used in these reactors are always contained inside metallic fuel cladding, never directly weapons-usable, and out-of-system facilities must be utilized before the materials can be converted to weapons-usable form. Other SMR types such as molten salt reactors or high temperature gas cooled reactors (e.g., pebble-bed modular reactors), potential alternatives to LWR-based SMRs, present challenges in nuclear safeguards as these reactors are not suited to conventional approaches of item counting-based nuclear materials accountancy.

As mentioned, fuels for research reactor and ELWR can be manufactured through diluting the HEU of North Korean nuclear arsenal. This represents North Korea version of a small-scale "Megatons to Megawatts" project. Therefore, operation of these reactors carries symbolic significance toward denuclearization and nonproliferation. Along with nuclear weapon materials utilization for peaceful energy generation, the nuclear scientists in North Korea will also need to be transitioned into commercial workforce for peaceful nuclear energy project. These developments represent cooperative conversion of North Korea's nuclear weapons program to a civil nuclear energy program.

As these projects present opportunities to implement latest advances in nuclear technology development, adoption of the so-called safety, security and safeguards, commonly referred to as the 3S in the industry, by-design approaches should be considered to increase the long-term effectiveness and viability of North Korean nuclear power program. In this regard, a novel design concept of fail-safe nuclear safeguards and nuclear security should be considered as part of the reactor design to eliminate the possibility of misuse or sabotage of the reactors.

The progress at the end of each nuclear reactor development stage needs to be examined to distinguish whether the DPRK regime is willing to eventually give up nuclear weapons. Therefore, the engagement activities at each of the stages creates step-by-step progress in confidence-building. Details of each stage can be sequentially and reciprocally implemented contingent upon the success in meeting the desired milestones, eventually opening a tangible path for political situation change (Lawrence, 2019).

Additional provision necessary to realize the North's nuclear energy development is the introduction of nuclear liability insurance in North Korea against possible nuclear accidents. Such introduction is important for public health protection in North Korea as well as in neighboring countries and requires government policy support by the participating parties. A possible approach to be utilized is a guarantee of indemnity from another party (including South Korea or other members of the international coalition for North Korea's denuclearization) to assume the national responsibility for indemnification, over and above the insurance level North Korea could be provided. Alternatively, an arrangement can be pursued for North Korea to join the International Atomic Energy Agency's (IAEA) Convention on Supplementary Compensation for Nuclear Damage (which entered into force as of April 2015). In this case, North Korea would have to contribute to a financial pool on the basis of installed nuclear capacity. Given the financial situation of North Korea, an international fund could be set up as part of the denuclearization support package for North Korea to make such contribution.

Ultimately, success in providing nuclear energy to North Korea opens up the possibility of developing market-based economy in North Korea through its industrial development and access to global economy. This development may enable implementation of Northeast Asia Common Market as envisioned by Harvard Korea Project (Park, 2021).

RISKS OF NUCLEAR ENERGY DEVELOPMENT IN NORTH KOREA

Even with the succession of national leadership through three generations, North Korea fundamentally has not changed. North Korea may repeat the same behavior as in the past by resorting to the tactics of deceit and brinkmanship as the needs, motivations, and conditions of the country have not fundamentally changed.

North Korea's nuclear capability is at a mature technical level with highly skilled workforce built over several decades. Even if North Korea commits to denuclearization, its nuclear competence will remain among its human capital regardless of physical elimination of facilities. Therefore, the latent capabilities of North Korea will enable post-denuclearization rebuilding of its nuclear program should the need for such development arises. This is, in particular, highly salient as North Kore successfully indigenized and even revolutionized its own nuclear enterprise (Montgomery, 2020) supported by its own illicit trade networks (Hastings, 2016).

North Korea may partially give up nuclear weapons program as this possibility was indicated during the negotiations between Trump and Kim Jong-Un. But there is no guarantee that North Korea will open and dismantle its entire infrastructure as there is no physical possibility of verifiably identifying and eliminating all aspects of its nuclear weapons capability. There is also no way of finding out the true intentions of North Korea in terms of whether they will indeed give up their nuclear weapons program. History also tells that engagement with North Korea regarding denuclearization provides pretty much unilateral advantages to North Korea, with no achievements on the side of the United States or South Korea after long hours of diplomatic work. (Park, CH 2018)

In this regard, designing the steps of denuclearization in sequential manner is essential as part of nuclear energy project. Progress in nuclear energy project should commensurate to denuclearization progress and the success and significance of respective processes achieved by the participating parties. Accordingly, as part of the nuclear energy project roadmap, the measures of denuclearization and the corresponding reward measures should be designed based on the principle of exchanging equivalent values. Depending upon the achievement of a given step in realizing denuclearization measures, the United States can take tailored sanctions waivers or limited sanctions-relief steps. The goals, activities, and schedule for the subsequent stages can be defined based on consensus on the corresponding reward measures.

PROGRESS IN NUCLEAR ENERGY PROJECT SHOULD COMMENSURATE TO DENUCLEARIZATION PROGRESS AND THE SUCCESS AND SIGNIFICANCE OF RESPECTIVE PROCESSES ACHIEVED BY THE PARTICIPATING PARTIES.

Denuclearization measures that have been discussed in the past, include but are not limited to the following summarized by C. K. Park (2018): 1) Freeze nuclear and long-range missile tests, 2) Freeze all nuclear programs, 3) Monitor and inspect nuclear program activities, 4) Declare the end of pursuit of nuclear programs and policies, 5) Shutdown the Yongbyun nuclear facility, 6)

Deactivate and dismantle HEU facilities, 7) Disclose information regarding all nuclear activities and programs, 8) Scrap all nuclear facilities and materials, 9) Destroy long-range missiles and relevant programs, 10) Safely store nuclear weapons and missiles under international monitoring, 11) Execute complete dismantlement of nuclear weapons and missiles (with verification), 12) Transition nuclear program personnel to different job sectors, and 13) Return to NPT and follow international norms on the peaceful use of nuclear energy.

To support the implementation of these measures, technologies to verify the success of each milestone should be identified and effectively utilized. Technologies in demand include the methods to verify presence or absence of uranium enrichment and spent fuel reprocessing, disarmament verification technologies, and the techniques to find hidden nuclear materials.

For verification of activity freeze, probabilistic verification method (MacDonald, 2021) or a nodal monitoring system (Garcia, 2021) could be used while access to the facilities remains limited or unavailable due to low level confidence among the parties. In probabilistic method, all information available from monitoring systems is combined with contextual information and expert analysis to reach a decision on compliance of the system. Judgement on probability of noncompliance in each case is also utilized in the analysis. A nodal monitoring system is a continuous monitoring portal approach based on using one or multiple portals around the restricted area to determine the movements of items in and out of the area.

Additionally, through environmental sampling or facility operation monitoring to detect the presence of signature isotopes such 235U and 239Pu and their quantities, determining the presence of uranium enrichment or spent fuel reprocessing operations is also possible. Finding hidden nuclear materials can be pursued by using active (i.e., based on projecting neutrons) interrogation techniques such as dual energy radiography with accelerator or using mono-energetic sources, nuclear resonance fluoroscopy, differential die-away, and micro-calorimeter (Medalia, 2010). However, if the location of a facility is unknown, as is the case with North Korea's clandestine uranium enrichment program, there is no proven method of finding secret uranium enrichment facilities. Also, determining how long a uranium enrichment facility has been on operation and how much enriched uranium has been produced remains a near impossible task at the moment. Recent studies on uranium chemistry investigating morphological characteristics and environmental degradation of uranium ore concentrates or UF4 (Pastoor, 2021) may present possibilities in this regard.

Advanced technologies applicable for disarmament verification include blockchain and a physically encrypted warhead verification system. A blockchain is a distributed database or ledger to store information electronically in cryptographic digital format that is shared among the nodes of a computer network. The record cannot be altered retroactively without the alteration of all subsequent blocks and the consensus of the network. The verification data can be created in blockchain and when sufficient progress in confidence-building has been made, the declaration can be shared with the relevant parties. This application would allow for step-by-step verification of the correctness and completeness of the initial declaration so that the information release and supporting inspections can keep pace with parallel diplomatic and political processes as part of the confidence-building process. A physically encrypted warhead verification system is based on using neutron induced nuclear resonances that are sensitive to the combination of isotopics and geometry and uses physical encryption of the data to prevent the leakage of sensitive information.

The specifics of verification programs in North Korea need to be tailored or varied depending upon the acceptability of gaining access to the facilities and items. In this regard, partial coverage over space, facilities, and a range of nuclear activities and materials could be applied during the early phase verification. Exchanges of personnel to enable the proposed activities should be pursued through political and security arrangements as confidence-building progresses.

Depending upon the progress and success in taking steps toward denuclearization, various additional rewards to North Korea can be implemented. These rewards could include the following (Park, C. K., 2018): 1) Lift international sanctions (partial until the due time for complete lift), 2) Provide limited social and economic aid, 3) Sign a non-aggression pact, 4) Provide additional energy support, 5) Provide technology, equipment, cost support for dismantling the nuclear program and decontamination of the site, 6) Improve and normalize relations with the U.S. and the international community, 7) Expand inter-Korean relations, 8) De-escalate military tensions and build trust between the two Koreas, 9) Adjust ROK-U.S. combined exercises, 10) Adjust the size of U.S. forces on the Korean Peninsula, and 11) Sign a peace treaty and build a peace regime.

In particular, expanding inter-Korean relations with regards to contacts, exchanges, investments including the utilization of Gaesung Industrial Complex, Mt. Geumgang tours, and train link-ups can be considered. Other confidence-building steps can also include humanitarian aid within the parameter of UN sanction resolutions, personal exchanges such as inviting North Korean elite bureaucrats or students to South Korean, or even American, universities or participation in international human capacity building programs, conducting exploratory collaborative research. Inviting North Korea to international institutions like the International Monetary Fund, World Bank, World Trade Organization, or World Health Organization could also be arranged.

POSSIBILITIES OF NUCLEAR ENERGY DEVELOPMENT IN NORTH KOREA

Currently, North Korea is in a difficult situation due to the Covid-19 pandemic on top of prolonged international sanctions. While the ongoing Ukraine war is providing opportunities to North Korea to earn cash through supplying weapons to Russia, North Korea would still want stable revenue to eventually sustain its economy. In particular, North Korea is in dire situation in terms of its national energy supply. According to the 2019 CIA World Factbook, only 26% of North Korean population has access to electricity. Many households are restricted to 2 hours of power per day as priority is given to manufacturing plants. Its chronic energy crisis threatens the quality of life of its people as well as sustainability of its domestic industry. In this regards, North Korea carries a need to make a concession with the international community to find ways to improve its national energy supply. Given its symbolic meaning of technical prowess and prestige, nuclear energy will be on top of North Korea's future energy planning. If the timing is right, North Korea will be interested in starting a dialogue for domestic nuclear energy development.

One of the key difficulties in denuclearization dialogues with North Korea lies with disclosing the list of nuclear facilities. Advances in information security technology opens new possibilities to address the challenge. North Korea can declare its nuclear facilities list only in encrypted form in a shared database. Based on sequential progresses demonstrated, individual facility locations can be identified sequentially through decryption-verification steps. This gives North Korea time to deliberate on their decision on disclosing the list while checking the progress in achieving their strategic goals. Once a facility location is declared, inspection of the respective facility can be followed to determine the genuineness of the declaration.

Until recently, political circles in the United States have shown very negative reactions to the proposal of providing North Korea with nuclear energy to address its energy supply challenge. There are, however, signs of change. A recent report from Harvard Kennedy School (Lawrence, 2019) argues that technical discussions to support North Korea's nuclear energy infrastructure construction should be part of diplomatic discussions for denuclearization of North Korea. Also, a recent report from Nuclear Threat Initiative (Rusten, 2019) said that cooperation is needed to create opportunities for North Korean nuclear scientists to work in the civilian nuclear sector for the denuclearization of North Korea. At 2021 NEREC conference hosted by the KAIST Center for Nuclear Non-Proliferation Education and Research (August 3-5, 2021), Dr. Toby Dalton of the Carnegie Endowment for International Peace and Professor Sharon Squassoni of George Washington University both mentioned that the idea of North Korea having nuclear power may be feasible and necessary to achieve denuclearization of North Korea (Dalton, 2021; Squassoni, 2021).

The Republic of Korea possesses world-class nuclear technology and can support conversion of North Korea's military nuclear weapons program into a peaceful program while contributing to decontamination and dismantling of the North's nuclear facilities. As mentioned earlier, South Korea is in a position to play a major role in providing technical assistance to North Korea in all stages of nuclear power development. Utilizing these capabilities, South Korea could develop major technical cooperation with North Korean scientists in the area of designing nuclear reactors, performing analysis for nuclear safety and environmental impact of nuclear power, management of radioactive waste and spent nuclear fuel, and environmental cleanup and restorations. Also, the United States, who has successfully conducted cooperative threat reduction project on nuclear facilities and the related workforce conversion in the former Soviet Union, can play a key role in technical cooperation with North Korea utilizing the lessons from the Russian cooperation experiences (see Chapter 1).

Lessons from the KEDO project indicate that success of North Korea nuclear power development hinges upon the financial viability of the project (Kartman, 2012). In this regard, it is suggested that the stages of initial research reactor development as well as ELWR development, the least costly stages of the project, should be funded by international coalition similar to the KEDO membership. The third stage of the project, namely, SMR development, can be funded jointly by the United States and South Korea, mainly through industrial consortium partnership. Such funding arrangement can be justified if the industrial consortium can earn the right under government approval to build the future SMR units in North Korea at the market price as North Korea economically grows in the ensuing years. The final stage of LWR development may be covered solely by South Korea both technically and financially as long as North Korea agrees. In this case, large LWRs to be built can become part of an integrated energy infrastructure in the Korean peninsula with electric grid connection between the South and North.

Another important lesson from the KEDO project is that political commitment of the U.S. government to North Korean nuclear power program is essential. The U.S. government can assign major milestones into each respective stage of North Korean nuclear power development with progressive moves toward complete normalization of the diplomatic relation with North Korea. Such moves can also paralleled developments towards peaceful relations between South and North Korea. The nuclear energy project in North Korea led by the United States and South

Korea opens an avenue for establishing stable human exchange mechanism for collaboration and mutual understanding. Such exchanges would prove to be a catalyst toward North Korea denuclearization. All four stages of nuclear power development as elaborated earlier can take advantage of these exchanges.

In terms of timeline projection, the author envisioned that the first and second stage of the nuclear project would each take up to five years. To support the ELWR development, North Korea is expected to make efforts to connect the newly built plant with the local electric grid. Experiences gained from this approximately ten year period and the mutual confidence become the basis of the next SMR development stage. Such development signals the beginning of North Korea's energy infrastructure makeover. During this period, all of the HEU stockpile in North Korea would be used up through the operation of the newly built research reactor and ELWR. This SMR stage is expected to continue over ten years with further electric grid improvements near the region of the SMR site. Along with SMR construction, the supplemental energy infrastructure development using wind and solar energy is to take place. The final stage of large LWR development is expected to take another ten years during which period a parallel national electric grid improvement project is conducted to establish a modern national energy system in North Korea.

Nuclear energy project in North Korea also opens opportunities for North Korean workforce to be directly involved in decommissioning and decontaminating nuclear facilities. Such environmental restoration work will be essential to minimize the spread of radioactive contamination and potential adverse human health impacts on the people in the nearby region.

POLICY RECOMMENDATIONS

The experiences gained from the KEDO project between 1994 and 2006 should be collected and carefully scrutinized with deriving lessons. Details of necessary preparations, confidence-building, conducting communications, site preparations and any necessary arrangements, and project implementation should be derived based on reviewing KEDO history (Kartman, 2019) to serve as guidance for the newly proposed process. Financial and political commitment of the United States and South Korea in agreement with North Korea at the highest level must be developed and maintained throughout the entire project.

In order for North Korea nuclear energy development to be accepted by the political and diplomatic circles in the United States, various diplomatic and political communication efforts should be made and maintained among institutions in the United States and South Korea throughout the project period.

Goals and activities of the phased nuclear energy project as elaborated in this paper should be further examined and defined to lay out the details of success paths toward denuclearization. The types and designs of the nuclear reactors (e.g., research reactor) to be employed as part of North Korea nuclear energy project should be further investigated. The Jordan Research Reactor, recently exported by South Korea to Jordan, could serve as an important candidate.

Successful implementation of nuclear energy project in North Korea requires careful plans for conducting verification and decommissioning and environmental restoration of nuclear weapons complex facilities. The U.S. experiences from environmental cleanup and restoration of nuclear weapons complex are to be maximally utilized. Verification effort in terms of gradually increasing the requirement for comprehensiveness and correctness can proceed step by step along with the progress in confidence-building among the parties. The project also needs to be paralleled with development of next generation human resources in North Korea as well as in South Korea, the U.S., and other neighborhood countries. They will become important agents of change for cooperation in nuclear energy development, denuclearization verification, environmental restoration, and even in other energy sectors and economic development projects.

It will be important and necessary for South Korea and the United States to closely cooperate together for maximum utilization of each country's respective strengths in North Korea nuclear energy project. The proposed nuclear energy project as part of North Korea denuclearization effort needs to be examined within the grand scheme of rebuilding North Korea toward achieving peace and prosperity in the Korean Peninsula.

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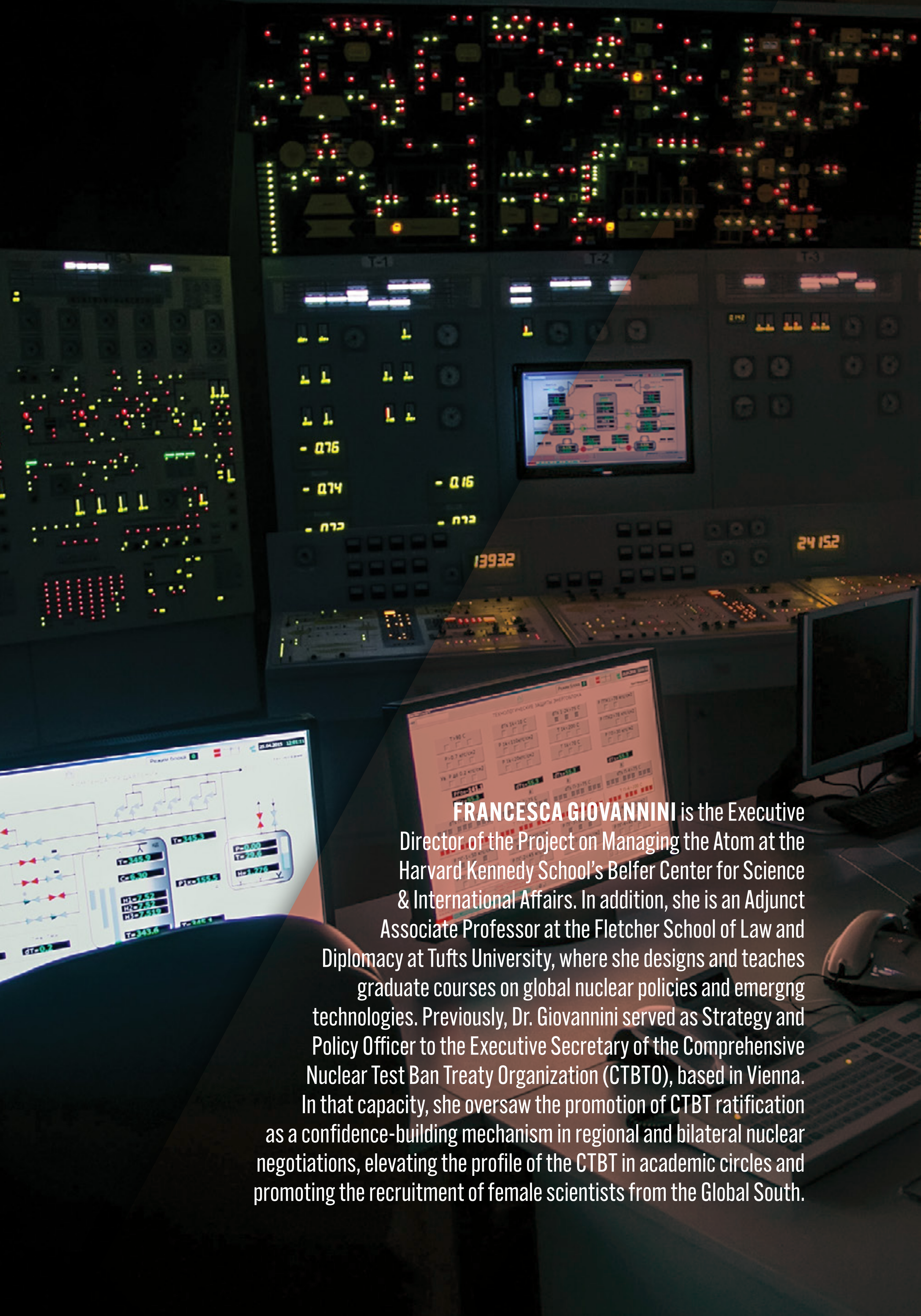

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4 A DISASTER IN WAITING OR SIMPLE PARANOIA? EXAMINING THE STATUS OF NUCLEAR SAFETY IN NORTH KOREA AND THE FACTORS THAT MIGHT STRENGTHEN IT

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"SAFETY FIRST—NOT ONE ACCIDENT CAN OCCUR!"

(Safety sign at the entrance of what could be the first indigenously fabricated Light Water Reactor of North Korea)

INTRODUCTION

The development of North Korea's nuclear program has been accompanied by a spectrum of emotions, from fear to anxiety, from resentment to amazement. Despite its isolation, North Korea has continued its relentless pursuit of nuclear capabilities. While angering neighboring countries, North Korea has equally demonstrated an unparalleled resolve, unwavering commitment to its security ambitions, and extraordinary ingenuity in overcoming the international sanction regime's technical challenges.

Whereas the debate over North Korea, especially in the West, has been predominantly confined to the discussion over its nuclear arsenal, its delivery system, and its ill-formed nuclear posture, much less has been discussed over the nuclear safety culture that ultimately rules over the management of an ever-extending nuclear infrastructure. And in the debate that does exist in this regard, diverging views have emerged. For some commentators, the fact that North Korea has never witnessed a major nuclear accident is simply a miracle. For others, the depiction of North Korea as a "walking nuclear disaster in waiting" is not only exaggerated but also merely inaccurate.

Whereas studying the nuclear safety culture of North Korea presents a significant research challenge, such a task has become perhaps crucial in today's debate, primarily characterized by a fundamental contradiction. On the one hand, we posit that the nuclear program is vital to the security and survival of the North Korean regime. On the other, we argue that the safety standards in the country are so abysmal and primitive that an accident is not a matter of if but a matter of when.

How can these two statements be factual at the same time? To challenge what I perceive to be a contradiction in how we represent the actual state of North Korea's nuclear safety culture, I have embarked on a rather comprehensive yet incomplete review of existing literature, ranging from field visit reports to technical assessments and historical accounts. This study ultimately reveals a more balanced and far less alarmist assessment. The paper makes two interrelated arguments. First, where safety weaknesses and vulnerabilities persist, the North

Korean nuclear community and its leadership have four meaningful drivers that provide crucial incentives to avoid a nuclear accident at all costs. The small scale of the North Korean nuclear complex, coupled with domestic prestige and safety calculations, will help reduce the probability of a nuclear accident of significant proportions. Second, international, and regional cooperation on nuclear safety and disaster preparedness might help North Korea strengthen its national capacity to manage dangerous accidents. Yet any offer for collaboration—even purely technical—will undoubtedly be politically costly for the United States and South Korea. Given the unprecedented tension and confrontation with the West, North Korea might read any cooperation proposal to collect intel on and interfere with its nuclear ambitions. Hence, the expected benefits from any such cooperation effort could be potentially negligible and marginal.

NORTH KOREA: A WALKING NUCLEAR DISASTER?

In 2017, an article on 38 North opened with the following statement:

> *The ability of North Korea to safely operate its nuclear reactors according to many experts is increasingly being called into question given the North's isolation and lack of safety culture. Pyongyang's ability to respond to a nuclear accident in a timely fashion will make the difference between a small-scale event and a catastrophic disaster. And while the actual contamination would be localized the lack of transparency from North Korea is likely to cause political panic in the region. (Korda, 2017, para. 1)*

The assessment came in the wake of a string of extraordinary events that led many to believe North Korea's nuclear program was simply out of control. In July 2013, North Korea's 5 MWe plutonium production reactor had to be briefly shut down following a flood near the Yongbyon facility. In September 2017, an alleged series of tunnels collapsed immediately following North Korea's sixth nuclear test.[1] It was reported that the accident killed approximately 200 workers and triggered some alarm along the Chinese border about potential radiation leakage. And following the test, a series of earthquakes shook the area for days. Finally, released reports from defectors recount stories of radiation and contamination in the surrounding regions and unconfirmed stories of children with defections at birth.

WHEREAS THE DEBATE OVER NORTH KOREA, ESPECIALLY IN THE WEST, HAS BEEN PREDOMINANTLY CONFINED TO THE DISCUSSION OVER ITS NUCLEAR ARSENAL, ITS DELIVERY SYSTEM, AND ITS ILL-FORMED NUCLEAR POSTURE, MUCH LESS HAS BEEN DISCUSSED OVER THE NUCLEAR SAFETY CULTURE THAT ULTIMATELY RULES OVER THE MANAGEMENT OF AN EVER-EXTENDING NUCLEAR INFRASTRUCTURE.

The situation prompted a few South Korean officials to comment on the concerning situation.[2] At the March 2014 Nuclear Summit in The Hague, for instance, then-South Korea President Park Geun-Hye claimed that:

> *As noted in a recent report by an international research institute, North Korea's nuclear facilities generate serious safety concerns. North Korea's Yongbyon is home to such a dense concentration of nuclear facilities that a fire in a single building could lead to a disaster potentially worse than Chornobyl, according to the report. By any measure,—whether nonproliferation, nuclear security, or safety—North Korea's nuclear programs are cause for enormous concern. The peace and security of the world demand no less than their dismantlement. (MOFA, 2014)*

Yet, the nuclear safety record of North Korea remains impressive at present, defies expectations, and elicits surprise. The country, despite its isolation, has not had one major accident in its long nuclear history. Most importantly, the reports of the American scientists who visited the facilities are an essential counterbalance to media alarmism depicting North Korea's nuclear management as ineffectual, even erratic, and irresponsible.[3] Such inaccurate analyses reinforce the belief among several American politicians that "dealing with North Korea" is reckless and a lost cause and that the only option is to induce regime collapse through maximum pressure and overwhelming forced economic isolation. Luckily, the scientific accounts we have today help us build a more nuanced and sophisticated understanding of the technical capabilities, challenges, and values underpinning North Korea's impressive nuclear development. They offer invaluable insight into North Korea's facilities but equally provide an opportunity to investigate the factors that maintain North Korea as a functioning nuclear state.

NORTH KOREA'S NUCLEAR SAFETY RECORD: BETWEEN ALARMISM AND CAUTIOUS OPTIMISM

Nuclear safety culture is generally defined as the core values and behaviors resulting from a collective commitment by leaders and individuals to prioritize safety over competing goals to protect people and the environment (Mosey, 2006).

It must be noted that nuclear safety does not only refer to the technical requirements and the design specifications that might make a nuclear reactor safer to operate. It relates equally to intangible cultural and social features that compound individuals within complex organizations to perform at the highest level of accountability, competence, and transparency. Those soft-security elements are the most difficult to evaluate and assess.

This paper presents a typology of safety risks posed by North Korea's nuclear infrastructure. By offering a broad overview of the risks, more than a specific examination of each nuclear facility, I hope to provide a clear and comprehensive review of North Korea's nuclear infrastructure status.

1. Risks of Reactor Overheating Due to Cooling System Challenges

Yongbyon nuclear complex sits adjacent to the Kuryn River, the indispensable but somewhat unreliable stream of water vital for the cooling system[4] of the whole complex, which includes, among others, a 5 MWe graphite-moderated reactor and a 30 MWe experimental light water reactor. Two main cooling challenges related to water management have been currently identified. First, the Kuryn River is subjected to freezing in the winter and significant drought in the summer. And, with the progression of global warming, water scarcity in the basin will only become more acute. To prevent this problem, North Koreans built an impressive system of dams that should help them manage the river flow. In 2018, they completed the first earthen dam, while two more are now being constructed to further stabilize the water intake. According to Frank Pabian, et al (2021):

> *These additional dams would also reduce the amount of gravel and silt getting to the reactor cooling water intakes during floods through decantation. The third dam or causeway downstream of the reactor complex appears to be intended to ensure there is sufficient water to meet the needs of the Radiochemical Laboratory (RCL) and the Uranium Enrichment Plant (UEP) areas adjacent to it. (para. 9)*

The second problem relates to flooding of the river. According to reports, in July 2013, catastrophic rainfalls and subsequent flooding filled channels and ponds with sand, and the cisterns for the 5 MWe and the Experimental Light Water Reactor (ELWR) were equally buried in the sand. Hence, the 5 MWe reactor had to be briefly shut down following a flood that destroyed part of the cooling system. In July 2022, rising waters from recent rains flooded part of the Yongbyon Nuclear Research Center, but fortunately none of the buildings within the center were damaged. The North Koreans have compensated at least temporarily by installing pipes for the 5 MWe reactor, but given flooding risks, much more comprehensive solutions will have to be explored, especially if the country is seriously committed to the construction and operation of a 100 MWe Light water reactor.

Experts are skeptical about the North Koreans' ability to handle the area's cooling problems once and for all. Nick Hansen (2014) noted that "Kuryn River may not be able to provide a reliable and adequate source of water and that could in turn damage one or both reactors as well as a possible release of radioactive material. In addition, if a major flood cuts off the cooling water supply to the reactors before they can be shut down, a major safety problem could occur."[5] Similarly, Niko Milonopolous and Edward Blandford (2014) wrote, "a sudden fault in North Korea's outdated power grid could prevent the Yongbyon reactors from being adequately cooled and could potentially trigger a meltdown. A similar situation could also occur because of a natural disaster."

The third cooling challenge that North Korea faces is related to its outdated domestic power grid. The North Korean energy grid is obsolete and often unreliable. A power-generating reactor demands an active safety system to operate adequately; onsite power must be constantly supplied to pump the water required to cool the reactor core. To prevent overheating of the reactor, emergency generators are also needed to offset any grid blackout or failure. Yet, examinations of images from the Yongbyon do not show any presence of emergency generators, thereby increasing safety risks at the site.

The challenges that North Korean scientists are facing in designing and running a reliable cooling system for their 5 MWe are worrisomely comparable to those that ultimately caused the Fukushima meltdown in Japan. Hence, the Japanese story of nuclear mismanagement and complacency should be particularly instructive to North Korea to avoid similar pitfalls.

In the case of Japan, two main vulnerabilities in the nuclear safety culture led to the catastrophic reactor meltdown. First, the plant's owner, Tokyo Electric Power Company (TEPCO), designed nuclear safety systems that could withstand plausible accidents but failed to test the system against non-plausible yet non-impossible scenarios. The height of the Tsunami wave that ultimately struck the plant was considered so unlikely that no preparation had been made for the plant to face this eventuality. "Yet large evidence existed of large Tsunamis inundating the region surrounding the plan about once every thousand years" (Acton and Fitzpatrick, 2012). Second, diesel emergency generators—in noncompliance with international safety standards had been placed in the basement of the power plant. Hence, the flooding caused by the Tsunami took out both the main and the emergency electrical systems leaving the cooling system inoperable.

The challenges that North Korea faces today to ensure a reliable and stable cooling system might not be dissimilar from those that the Japanese had to handle in a time of natural disaster and devastation. The Fukushima case with its many lessons learned could prove an indispensable learning opportunity for North Korea in strengthening its system resilience and designing safety measures that are both flexible and adaptable to the natural risks that the country faces.

2. Environmental Damages & Contamination Leakages

Jeffrey Knopf (2002) correctly points out that nuclear weapons production not only creates hazards for workers but also endangers people beyond side boundaries. The possible environmental damages resulting from the six nuclear tests conducted by the North Korean government have been explored and analyzed by scientific communities worldwide, especially in neighboring countries such as China and South Korea. In addition, with its vast monitoring system, the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) has disclosed essential data on the blast's yield and the nature of the nuclear weapon tested. Such data helped analysts conclude the potential environmental impact of North Korea's nuclear tests.

According to satellite, seismic, and radionuclide measurements, for example, the scientific team at CTBTO concluded that the 2017 nuclear test—which unleashed a powerful 6.3-magnitude tremor also caused four large unplanned events. The powerful blast deformed visibly the surface of the mountain which housed the nuclear test site. Several aftershocks later followed prompting scientists to conclude that the cavity of the mountain had collapsed thereby rendering the nuclear test site useless for further testing. In addition, powerful landslides were set in motion prompting several Chinese scientists, including Wang Naiyan, the former chairman of the China Nuclear Society, to raise the spectrum of a major environmental disaster.

Generally speaking, two major concerns have been reported in relation to nuclear testing activities: (1) radiation contamination of the neighboring communities to the complex and (2) deforestation and inducted earthquakes. According to several unconfirmed reports, nuclear tests have led to the destruction of 80% of greenery and soil fertility, around the regions of Punggye-Ri. And according to North Korean defectors, "the groundwater table also dropped, thereby causing the wells to dry up. Nukes involve a heavy discharge of radioactive particulates which if mixed with air, soil and water will endanger human lives" (Gaebler, et al., 2018). Other reports—yet unverified—have disclosed details of local villagers suffering from cancers related to exposure to radiation and of countless children being born with radiation-induced congenital disabilities

(Hansen, 2014). Suh Kyun-ryul, Professor of Nuclear Engineering at Seoul University, has argued that while the reports have not been verified, "If North Koreans continue to test similarly heavy nuclear bombs on the same site, sooner or later they will lead to a premature collapse where radioactive material could reach and contaminate both the groundwater and the surface of the earth" (Kretschmer, 2017; also see Saplakoglu, 2018).

Induced earthquakes have also sparked significant fear in North Korean and Chinese towns around the nuclear complex. In 2017, after the sixth and most powerful test, a series of tunnels collapsed, reportedly killing 200 workers, and triggering alarms along the Chinese borders about potential radiation leakages. Shortly after the test, "Chinese authorities closed part of the tourist park on their side of the border because of rockslides. The explosion registered as a 6.3 magnitude earthquake and was blamed for water bottles rolling off tables and furniture toppling in China, and apartment buildings rattling all the way to the Russian port city of Vladivostok" (Demick, 2017). Chinese authorities would not say definitively whether the nuclear test was to blame, but seismologists think it is likely.

Finally, experts using Google Earth have observed and studied signs of deforestation at the nuclear test site and in adjacent areas. Junghoon Ki, Minki Sung, and Choongik Cho (2019) compared Google Earth images after each of the six tests conducted by North Korea and drew the following conclusions:

> *After the 1st-3rd nuclear tests, green spaces were found to be considerably reduced. When comparing the Google Earth images before and after the second nuclear test, some ground subsidence was observed. Such subsidence can cause tunnels on the mountainsides and cracks in rocks around the mountains, leading to the release of radioactive materials and contaminating groundwater. After the 4th-6th nuclear tests, decay and deforestation were observed not in the nuclear test sites, but in their surrounding areas. Especially after the 5th and 6th nuclear tests, the topography and the forests of the surrounding areas were severely damaged. (Ki, et al., 2019, pp. 563-573)*

Similarly, to South Korea, the Chinese scientific community has been increasingly concerned over the possibility of radiation leakage from North Korean nuclear testing activities. As noted by Anny Boc (2018):

> *Nuclear security has become a great concern for Beijing, especially after Pyongyang conducted its fourth nuclear test in January 2016. Over the years, China has expanded its monitoring stations near North Korea to detect possible radiation. Though so far, the Chinese government says that no abnormalities in radiation levels have been recorded, some Chinese scientists have warned of a possible implosion at the mountainous nuclear facility which would cover the northeastern part of China in radioactive fallout. (p. 53)*

Yet, prominent Chinese scientists have started sounding the alarm. Zhang Liangui an expert on North Korea at the Central Party School of the Communist Party has openly discussed the risks of severe environmental damage from erratic and uncontrolled nuclear testing. Additional concerns over contamination and radiation leakages beyond nuclear testing have been reported by analysts throughout the history of the North Korean nuclear program development. In an article published in 1994, at the dawn of North Korea's nuclear weapons development program, American scientist David Albright claimed the North Koreans were using a corrosive fuel capable of inducing major leakages and posing severe environmental risks. Albright (1994) wrote:

> *The irradiated or spent magnox fuel rods discharged from North Korea reactor cannot be stored safely for long under the current conditions in the ponds near the reactor. The magnesium metal alloy jacket around the uranium metal fuel is corroding and radionuclides in the uranium fuel may escape into the environment. (p. 89)*

This risk has been acknowledged by North Korean scientists, who have adopted mitigation measures to prevent the so-called corrosion processes of fuel cladding. For example, they began reducing the reactor's temperature from 350 C to 300 C, a process that might ultimately help fuel cladding failures (Braum, et al., 2016).

3. Primitive Regulatory Infrastructure and Isolation from International Know-How

North Korea has a long-standing State Nuclear Safety Regulatory Commission (SNSRC) responsible for the country's nuclear safety and radiation protection. The Commission is tasked with conducting inspections and issuing licensing for all related nuclear projects. After the negotiations of the Agreed Framework in 1994, SNSRC had the opportunity to cooperate and collaborate with a wide array of institutions, thereby gaining critical expertise and knowledge. Today it is unclear what kind of international cooperation the commission still enjoys and what level of international expertise it can access. In addition, it isn't easy to assess the actual degree of independence the Commission enjoys outside of the political leadership. Given the nuclear program's centrality to the regime's survival and prestige—an argument that I will elaborate on more in the paper—it is doubtful that such a Commission has been designed to function as a genuinely independent oversight agency.

In addition, given the small scale of the nuclear program, North Korea's nuclear scientists and regulators have virtually no hands-on experience in operating, managing, and maintaining any type of nuclear reactor other than the gas-graphite reactor. Constructing, regulating, and performing light water reactors, for instance, that the regime aspires to develop would prove a steep learning curve for the nuclear scientists cut off from any international learning experience or any forum where lessons learned, and information sharing is facilitated. The indigenous learning-by-doing model that North Korea has been forced to pursue exposes the country to significant risks, given the complexity of nuclear technology and the sophistication of the know-how required to manage it.

Sig Hecker, one of the few American scientists who visited the North Korean nuclear complex of Yongbyon, recounted having concerns over the ability of North Korea to operate an ELWR safely. He wrote:

> *Given that this is a completely new design not yet operated in North Korea, with limited operator training and lack of experience in the operation of the safety regulatory system operations imply that even if the reactor start-up is successful, it is no guarantee of sustained long-term safe operations of the ELWR (Braum, et al., 2017).*

Inexperience, coupled with the lack of access to international peers and best practices, has been one of the factors that the Russian nuclear scientists attributed to the Chornobyl disaster

(Korda, 2017). Albeit not in scale, the safety concerns over North Korea might appear like the ones existing in the Soviet Union before the Chornobyl accident.

Similarly, Niko Milonopoulos and Edward Blandford (2014) discussed the lack of competence6 of the North Korea regulatory agency. In their assessment, they cite "the employees of the SNSRC, while university graduates, probably only have practical experience working at Pyongyang's and have never licensed an LWR. This lack of experience is a significant problem."7

On the other hand, the North Korean government has striven to make progress on the institutional front to show its commitment to behave as a responsible nuclear power. After Chornobyl, and with its program still nascent, North Korea signed two International Atomic Energy Agency (IAEA) conventions on early notification of a nuclear accident and assistance in the case of a nuclear accident or radiological emergency.

And most recently, in April 2013, North Korean Supreme People's Assembly adopted a law stating, "the DPRK shall strictly observe the rules on safekeeping and management of nukes and ensuring the stability of nuclear tests" in addition "the DPRK shall cooperate in the international efforts for nuclear nonproliferation and safe management of nuclear substance on the principle of mutual respect and equality, depending on the improvement of relations with hostile nuclear weapons states" (KCNA, 2013).

4. Possible Flawed Reactor Safety Design and Inadequate Quality of Construction

Reports from field visits to Yongbyon by international scientists describe the North Korean nuclear program as rudimentary and unsafe because of the lack of advanced safety and monitoring technologies and basic electro-mechanical systems, which forces the country to rely overly on hands-on human interventions. Robert Alvarez (2020) notes:

> *The 5 MWe requires a significant amount of hands-on operations, relying less on the advanced remote controls used in other countries. Hands-on operations are more prone to spill leaks and chemical failures. These problems can lead to extended downtime and a significant amount of plutonium going into the waste stream, lowering the overall efficiency of the operation. (p. 408)*

David von Hippel and Peter Hayes (2010, 10) argue that "North Korea can almost certainly build a pilot 25 MWe LWR albeit of unknown safety and that such an indigenous design would likely incorporate crude electro-mechanical systems rather than modern technologies."

As North Korea's nuclear ambitions grow, the country will be required to develop more advanced manufacturing and acquire more in-depth know-how. It's, however unclear whether it will be able to do so. For instance, the construction of LWR generally requires "active safety systems" and advanced computer-based systems embedded in a nuclear installation to support instrumentation and control (I&C) functions essential to safety. Over the past decades, as LWRs grow in popularity and dissemination, a multitude of studies and tests were carried out to test the design and address possible vulnerabilities. Safety requirements grew together with the sophistication of the monitoring system. Most specifically, design solutions to strengthen the inner and outer containment of LWRs (indispensable to prevent a radiation leakage in case of an accident) had been also accompanied by state-of-the-art technological advancements including ultrasonic surveillance, automated control and shutdown systems, and emergency cooling systems.

Yet, the ability of North Koreans to fabricate specialized safety-related equipment and components is questionable and problematic. Everything in the reactor, from the piping to the pressure and containment vessel to the concrete used for the containment building, requires specialized materials and quality-assured fabrication to prevent radiological leaks.

At present, the North Koreans remain remarkably distant from achieving the know-how and expertise necessary to operate an ELWR or any equally advanced nuclear power plant. Even the simple construction of the plant seemed to have raised safety concerns. Sig Hecker et al. (2011) recounts:

> *The construction of the light water reactor that was visible did not come close to reactor-grade concrete work for the containment structure. From what little we saw, it also appeared that construction practices are not commensurate with international reactors safety standards and practices.*

Yet also, in this case, the safety record of North Korea is mixed but potentially improving. In the construction of the experimental 25 to 30 MWe LWR, which should serve as a predecessor to the 100 MWe LWR that North Korea aims to build, the integration of high technologies was visible during the last field visit of Professor Hecker. He noted:

The control room was astonishingly modern. Unlike the reprocessing facility and the reactor control room which looked like the 1950 US or 1980 soviet instrumentation, this control room would fit into any modern American processing facility. They had five large panels in the back that had numerous LED displays of operating parameters. They had computers and four flat-screen monitors. The monitors had flow diagrams and a lot of numbers displayed (Hecker, 2010).

5. Hazards Related to Plutonium Reprocessing and the Management of Nuclear Waste

The management of nuclear waste by North Korea has also been a source of concern. Robert Alvarez (2020) describes in a rather poignant way how management practices that the North Koreans adopted had ultimately led to risky developments. He writes:

> *Because of the sunlight and seasonal temperatures, there was a layer of algae on top of the water. We could barely see several rods not so neatly tumbled into the metal baskets, which were staked two or three upon each other… attempts to clean the water and reduce the erosion of the cladding had clogged the filter equipment; it was broken and heavily contaminated. The North Koreans had used sodium hydroxide to retard the erosion, but doing so also heightened the risks of corrosion and eventual release of contaminated water. (p. 406)*

Another concern originates from the management of the plutonium reprocessing plant. Describing how the Soviets were forced to relocate a large population from an area due to an explosion in a tank of liquid high-level waste at a Soviet reprocessing plant in 1957 (von Hippel and Takubo, 2019), Professor Jungmin Kang (2022) during an interview told me that "A similar accident can happen at Yongbyon reprocessing plant because North Korea has dumped its liquid HLW into an underground space after reprocessing the spent fuel so far. To prevent the accident, the dumped liquid HLW should be immobilized in the glass. However, North Korea is not ready to prevent (i.e., no technology) or manage a disaster at all."

From the picture presented above, the overall conclusion about nuclear safety concerns at North Korea's nuclear facilities is a mixed record of problems and risks and promising changes. And as we continue to explore North Korea's safety culture and prospects for international cooperation, we ought to consider one important factor.

All nuclear weapons states have incurred either minor or major accidents. Producing nuclear weapons is risky, and no state—either developed or emerging—has been spared from facing safety issues related to their operation. Nuclear technology is complex and to be managed and requires an extraordinary amount of expertise, dedication, and commitment to the highest standards of excellence.

It is, therefore, quite remarkable that North Korea has thus far managed to avoid catastrophic accidents and, for the most part, relatively minor ones. The record of North Korea is more striking if we consider that the program is almost entirely indigenous and is expanding in complete international isolation and with enormous supply-chain constraints due to a pervasive sanction regime.

North Korea has had no catastrophic accidents in its long nuclear history while mastering all the most sensitive steps in developing a nuclear weapon program. Most specifically, we should highlight the following points:

- North Korea has refueled its 5MWe reactor at least three times since the start of the operation, and it did so safely and without significant accidents.
- It has conducted six nuclear tests—all relatively successful—and without any launch or system failure.

- It has also reprocessed plutonium and enriched uranium without any substantial disruption, catastrophic leakage, fires, or mishandling.

In addition, the North Koreans have demonstrated caution in managing their 5 MWe graphite reactor and designing and constructing the ELWR. It must be noted that in any instance where the water stream was unreliable, the North Koreans acted rapidly to shut down the reactor and prevent any overheating of the core. They have also consistently assessed any chance in the environment surrounding the complex of Yongbyon and adapted promptly by constructing new cooling mechanisms. Finally, despite the importance of the ELWR project and its national symbolism, the North Koreans have displayed a remarkable degree of professional caution by proceeding slowly in the reactor's construction while integrating new technologies necessary to achieve an even higher degree of safety.

NORTH KOREA'S INCENTIVES TO AVOID NUCLEAR ACCIDENTS

While several nuclear safety issues indeed remain (and might worsen over time), the attitude of North Korea vis-a-vis nuclear safety is promising. It is primarily grounded in four critical drivers.

First, nuclear energy is vital in mitigating North Korea's catastrophic energy insecurity. A catastrophic failure during a nuclear weapon test or a major accident at one of the nuclear facilities would have unacceptable reputational costs domestically and internationally. A nuclear accident would have enormous consequences beyond environmental or human costs. Second, the legitimacy of the Kim Jong-un regime has been largely built around North Korea as a credible nuclear-weapon state.

Third, North Korea—different from conventional beliefs—has had several opportunities to engage with international safety experts and learn from some of the world's most advanced nuclear technology countries. The creation of the Korea Energy Development Organization (KEDO) provided the government with extraordinary learning opportunities, KEDO also helped DPRK develop norms and regulations that might still be in force to date. Finally, concerns over transnational environmental damages to China's neighboring villages and towns might further incentivize North Korea's nuclear scientists to add an extra layer of cautiousness to their operations. I analyze these four factors in turn below.

1. Nuclear Energy Is Vital, and Failing Is Not an Option

Energy insecurity is almost endemic in North Korea. Kent Calder (2005) remarked:

> *Since the collapse of the Soviet Union, its last consistent ally, at the end of 1991, North Korea's energy infrastructure, like its national economy more generally, has decayed sharply. Limited domestic energy resources compounded by political isolation and scarce buying capabilities have forced the country to make energy one of its most urgent priorities. No foreign energy assistance, other than heavy oil supplied under the Agreed Framework between 1995 and 2002, has come to the country's aid.... nuclear power has a certain natural logic in energy terms, political-military issues aside.*

And throughout its history, the country has aspired to achieve energy security. In mid-1980, the then North Korean leader Kim Il-sung noted that "without electricity, we cannot produce anything, either in peacetime or wartime" (Ahn, 2003, 118). The collapse of the Soviet Union brought an additional hurdle. The drop in oil import from Moscow and the inability to pay for crude oil at the market price have forced North Korea to consider indigenous nuclear energy development as an in-dispersible path. The pursuit of reliable energy has become central also to the current regime of Kim Jong-un, especially since power outages and the current volatility of the operating grid, among other problems, have become increasingly pronounced over the past decade as North Korea's electric power grid, which dates back in unified national form to 1958, becomes increasingly obsolescent.

Seen in this context, investing in power-generating nuclear reactors such as light water reactors (LWRs) is understandable. Yet, if a major accident ought to occur, this would significantly reduce the nuclear program. A radiation spillover would not only force North Korea to relocate elsewhere, but most importantly, it would impose additional financial costs (decontamination, repairing of tools and instrumentation, and relocation of communities) that the regime might not be able to honor.

2. Unacceptable Reputational and Audience Costs in Case of an Accident

The nuclear weapon program is central to the North Korean regime's domestic security and legitimacy. On the international level, it has been used to extrapolate and coerce the international community to provide aid or assurances to the country.

But even more importantly, at the domestic level, it has proven indispensable to consolidating Kim Jong Il's regime and Kim Jong-un's. Jongseok Woo (2015) observed:

> *North Korea's nuclear provocations have served domestic political purposes by promoting national pride and patriotism among key elites as well as ordinary people and mobilizing international threats to mute ay domestic political opposition. In this respect, the intended audience for the nuclear tests is not just the international community but also north Korea's own people (p. 73).*

Hence, an accident-free, well-managed nuclear program is an indispensable asset for the regime to garner and maintain support, project competence, and ideologically compete with its more advanced neighbor.

The construction of North Korea's narrative as an advanced responsible nuclear power has been furthered by a wide range of governments' investment in other technological and scientific sectors seen as complementary to the nuclear enterprise. In fact, since 1952, when North Korea established its Academy of Sciences, nuclear efforts also became a vital driver of the creation and expansion of a vast network of research institutes.8 And from rocket science9 to AI and cyber, technology coupled with the North Korea nuclear program is seen as the triumph of the self-reliance policy of North Korea against a malign international landscape. Rian Jensen (2009) observed:

Policy pronouncements by Kim Jong Il and official discourse in newspapers and journals characterize science and technology policy as a matter of high politics and an instrument to achieve various national goals. This discursive linkage of science and technology to classical

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objectives is complemented by the parallel strategy of elevating scientists and technicians to more prominent levels within the national hagiography.

Indeed, scientific and technological developments have emerged as a distinct national strategy for North Korea over the last decade and a mighty instrument of national power and prestige. Facing external security challenges, domestic economic stagnation, and rising political uncertainty stemming from the succession issue, North Korea seems to have singled out science and technology as an instrument for national revival.

Under Kim Jong-un, who assumed power in late 2011, scientists have become an increasingly visible and privileged class, receiving public honors, awards, and special favors such as new housing developments near their workplaces. Scientists, as opposed to Party or military officials—or any other group besides the Kims—have been credited with the country's achievements in developing missiles and nuclear weapons.

Finally, the launch in 2012 of the concept of kangsong taeguk, meaning rich nation strong army, clearly marked the prominence of science and technology not only in the economic domain but also especially in the military sphere. By developing key technologies indigenously, North Korea seeks to reduce its need to import sensitive goods that might otherwise be denied to it through export controls, sanctions enforcement, or lack of funds. Direct collaboration between North Korean and foreign scientists is playing an expanding role in the regime's pursuit of technological advancement.

3. The Critical Legacy of KEDO

As part of the Agreed Framework in 1994, the United States and North Korea signed an agreement that committed the former to provide two light water reactor units to North Korea in return for the North Korean regime's commitment to shut down its graphite moderated reactor, its related facilities, and remain a member to the Nuclear Non-Proliferation Review Treaty (NPT). To oversee the implementation of the agreement and the construction of the American EWLRs, the Korean Peninsula Energy Development Organization (KEDO) was established. In the long history of North Korea's nuclear program development, KEDO has probably served one of the most influential and critical roles in promoting and implementing a nuclear safety culture that has remained with the country even after the end of the Agreed Framework and the dismantlement of KEDO itself.

KEDO worked with the North Korean government on critical nuclear safety, liability, and management aspects. By the time KEDO ceased its mandate, the organization had negotiated and agreed with North Korea on critical protocols, including:

- Protocols on Transportation, Communications, and on Juridical Status to protect KEDO persons who travel to North Korea for the LWR project
- Protocol on Quality Assurances and Warranties that detailed and regulated North Korean participation in the quality assurance program, turnover of quality assurance documents to North Korea, warranties on major equipment and components,
- Protocol on Training for North Korean operations and maintenance personnel
- Protocol on nuclear liability legislation and indemnification obligated North Korea to establish legal and financial means to meet claims arising from nuclear damage, develop

and adopt an indemnity agreement and secure adequate insurance or other financial security to protect KEDO operations.

- Protocol on Supply Agreement required North Korea to provide a stable and reliable supply of off-site electrical power for commissioning the LWR plants.
- Protocol on Delivery Schedule and Steps to be Performed ensured that North Korea complied with its nonproliferation milestones of achieving full compliance with the IAEA safeguards agreement.

The primary mandate of KEDO was to build, in cooperation with North Korea, a nuclear regulatory infrastructure and a level of technical competence adequate for the country to operate the LWR following all the highest standards of nonproliferation, safety, and security. To do so, KEDO also established an extraordinary and unparalleled network of institutes and centers of excellence to bring the highest expertise to North Korea.

It is difficult and rather improbable to believe that KEDO efforts had not influenced the safety culture of North Korea. Many of the scientists who were involved in KEDO training have continued to be involved in North Korea's nuclear program. Most of them have been exposed and, even more so, trained on IAEA international standards. Such training and know-how have undoubtedly been transferred to other nuclear experts who have later joined the nuclear program.

4. Trans-boundary Environmental Damages to China's Neighboring Towns and Villages

The last driver underpinning North Korea's commitment to safety culture (albeit imperfect and flawed in some respects) is the concern over what might be transboundary environmental damages to China's towns and villages bordering North Korea and the impact that could have on trading between the two countries. Although the relationship between North Korea and China is marked by significant differences and tension, the two countries' complex interdependence remains strong.

On the economic front, China accounts for more than 90% of North Korea's total reported imports and exports. China provides North Korea with raw materials, production equipment, and foreign currency brought into the country by individuals. In turn, China expects from North Korea loyalty and predictability. In 2017 and 2018, during the direct negotiations between the United States and North Korea, many analysts reported on China's concern over a possible loss of influence of Beijing over North Korea because of a possible agreement with Washington. Albeit unpredictable, Beijing, at least for now, continues to work to secure North Korea as its sphere of influence. Many Chinese analysts see this strategy necessary to ensure that North Korea will not undermine or impact China's relationship with the United States.

In addition, economically, China has invested significant resources in developing towns along the North Korean borders. Accounts of government investments in the ever-expanding industrial city of Dandong in Liaoning Province abound. This plan began to take shape when Dandong was included in the 'Five Points One Line' development strategy in 2009, which envisioned well-connected industrial zones along the northeast coast of China. With major highway and road constructions linking Dandong to large nearby cities of Dalian and Shenyang, the city began building a new district south of the current metropolitan center. Recently, China made extensive investments to expand the railway system (into North Korea) and to expand transnational business investments.

The fear and mass panic that especially the last North Korea nuclear test has elicited among China's citizens living along the border is something that Beijing struggles to tolerate. Statements from China's ministry of foreign affairs have stated Beijing's rejection of North Korea's nuclear weapons program and condemned it as a threat to international peace and security.10 Several officials have publicly complained to North Korea over the panic caused by the test and the environmental damages that Chinese communities have reported on the border.

CAN NUCLEAR SAFETY BE THE AVENUE FOR ENGAGEMENT WITH NORTH KOREA?

Technical safety cooperation is often discussed as an avenue where partnership could thrive even among countries locked in strategic rivalry. The argument is simple. Nuclear safety is indispensable; accidents have devastating effects. Given the complexity of nuclear technology, cooperation is vital for countries to learn from past accidents, adopt best practices from cooperating countries and access the most advanced safety technology and expertise.

The argument is valid, yet it fails to acknowledge that while indispensable, nuclear safety cooperation is as political as it is technical. The view that scientific engagement on safety can occur despite ideological and political faultiness is simplistic. Quite the contrary, given the centrality of nuclear safety, cooperation requires countries to disclose internal vulnerabilities that might be too politically sensitive or dangerous as adversaries might manipulate them.

To achieve nuclear safety cooperation successfully, the interested parties ought to recognize the politics underpinning safety and accept that cooperation might be limited.

Policymakers who must decide whether to propose or engage in nuclear safety cooperation will decide their course of action based on three specific questions:

1. What vulnerabilities will this cooperation reveal about the program, and can such vulnerabilities be strategically used against me?
2. How much data about my nuclear capabilities will this cooperation require me to disclose? And how can such data be used to undermine me?
3. How will nuclear safety cooperation be perceived domestically? What benefits will it bring me? And what costs will it impose on me?

Furthermore, it is essential to realize that not all nuclear safety issues and concerns matter equally to countries. Yet the risk tolerance of countries differs widely. Environmental or health problems might factor prominently in one culture but might be overlooked in a different context. For this reason, successful cooperation requires an alignment of interests and priorities, which can be challenging to reach.

Finally, prospects for nuclear safety cooperation can be enhanced or reduced depending on who is leading the negotiations. Some countries have greater faith and trust in engaging with international organizations, while others prefer bilateral or trilateral relations. Understanding the diplomatic cultures of the nations is key in proposing nuclear safety collaboration that these countries would be willing to accept.

A NUCLEAR SAFETY ENGAGEMENT FRAMEWORK WITH NORTH KOREA

To provide analytical clarity and a framework for policy recommendations, I suggest creating a typology of nuclear safety cooperation interventions that might be possible.

SAFETY CONCERN	LEVEL OF RISK	DATA TO BE DISCLOSED (TECHNICAL FEATURE OF THE REACTOR?)	PROPONENT	RECOMMENDATION
COOLING CHALLENGES				
Lack of reliable water sources	High	Low data (the issue is well known and does not require disclosure of technical features of the reactor)	Coalition of countries that have experience in managing unreliable water streams for cooling system	Environmental assessment and impact study and possible technological solutions to provide more stable water -intake
Flooding	High	Low data	IAEA	Training on best practices and lessons learned from Fukushima reactor (how to prepare for the unthinkable)
Obsolete power grid	High	High (it would require a proper evaluation of energy needs and energy capacities for the whole grid)	Gulf Countries	Discussions on energy needs and requirements for modernizing the energy grid
ENVIRONMENTAL CONTAMINATION				
Radiation leakages	Low	High	China/South Korea	Both governments could launch an integrated approach in cooperation with North Korea to clean contaminated areas, repair and replace radioactive infrastructure and discuss further steps
Earthquakes (induced)	Low	High (it would require North Korea to disclose data over nuclear testing infrastructure)	China /South Korea	Conduct a joint environmental and seismic assessment of the area and propose investments in anti-seismic critical infrastructures. Discuss the need to halt nuclear testing as a severe environmental concern

SAFETY CONCERN	LEVEL OF RISK	DATA TO BE DISCLOSED (TECHNICAL FEATURE OF THE REACTOR?)	PROPONENT	RECOMMENDATION
INADEQUATE KNOWLEDGE OF NUCLEAR SAFETY REGULATIONS AND CULTURE				
Current regulatory agency is cut off from best practice on nuclear safety	High	High	EURATOM/ United States/ China/Russia	Training for nuclear regulators on nuclear safety and emergency preparedness in case of a nuclear disaster
CONSTRUCTION AND DESIGN FLAWS				
Lack of know-how and advanced material for construction	High	Low	South Korea (KEPCO)	Possible dialogue on material needed for construction of the ELWR
PLUTONIUM REPROSESSING AND SPENT FUEL				
Management of spent fuel	Low	Low	South Korea/ Taiwan	Possible dialogue on disposal and reprocessing of spent fuel

UNDERSTANDING THE TYPOLOGY OF NUCLEAR SAFETY AGREEMENTS AND THEIR IMPLICATIONS FOR POLICYMAKERS

The nuclear safety challenges of the North Korean nuclear program are many, but they vary in urgency, priority, and addressability. In general, the following areas should be considered.

1. **Nuclear safety challenges that demand a limited disclosure of more sensitive data are more straightforward to address than those whose management requires the country to expose critical vulnerabilities.** For instance, North Korea might be inclined to engage in cooperation to clean the environment surrounding the Yongbyon complex. Yet a successful collaboration on this front would not automatically lead the country to seek cooperation on addressing design flaws for its indigenously constructed ELWR. The latter would require the government to reveal the level of knowledge its scientific possess, thereby giving adversaries a critical insight into its nuclear know-how.
2. **Bilateral cooperation has a limited role but can succeed based on the alignment of priorities and common causes.** For example, China is interested in preventing further landslides, induced earthquakes, and potential radiation leakage to its land. Hence, technical cooperation between China and North Korea can be established based on mutual vulnerability and the transnational nature of the risk. Mutual vulnerability helps countries establish an equal bargaining position that North Korea might welcome. Similarly, cooperation on nuclear waste and spent fuel might bring the two Koreas to an avenue of common interest. South Korea has struggled to articulate a solution for nuclear waste and has resorted to controversial pyro-processing. North Korea might be interested in learning how to store nuclear waste and improve safety on plutonium reprocessing safely.
3. **Bringing new countries into the mix will help North Korea benefit from a greater diversity of expertise.** The engagement of more countries will also challenge the narrative of North Korea as an American problem and offer a more significant role to the international community. For example, the Gulf Cooperation Council and the United Arab Emirates (UAE), in particular, have done impressive work on developing technologies that would make water streams more reliable and, therefore, safer for reactor cooling systems. New technology could interest North Korea as it battles devastating flooding and increasing water scarcity.
4. **The United States has a limited yet indispensable role:** For the United States, cooperating directly with North Korea might prove too politically risky (domestically) as the results of such cooperation might likely be mild at best. Yet, the United States is indispensable in enabling other countries to get involved. Any signal that nuclear safety cooperation with North Korea would be an acceptable policy for the United States might prompt revived momentum and activism within the international community. Only a little progress would be feasible without an explicit endorsement from the United States.
5. **International institutions have a specific role to play but traditional international organizations might not be the right choice.** North Korea has had a troubled relation with international organizations. The contested exist from the NPT followed by the dramatic and unwise decision of expelling IAEA international inspectors granted North Korea the reputation of a rogue state, fundamentally unwilling and incapable

of behaving as a responsible stakeholder on the international stage. While such reputation is grounded in many realities, North Korea's relation with international organizations is—as usual—more sophisticated than depicted. For example: North Korea is an active player at the United Nations General Assembly First Committee, also known as the Disarmament and international security committee. In addition, in recent times, the government of Pyongyang has sent delegates and participants to several forums including the Moscow Nuclear Non Proliferation Conference where in 2019, a delegate from North Korea participated in a panel on promoting the entry into force of the CTBT. In addition, and perhaps most visibly, through the famous annual New Year's Eve speech, North Korean supreme leader aims at indicating the country's priorities to both a domestic and international audience. Although these participations might be sporadic and selective, they nonetheless indicate the country's eagerness to shape and partially contribute to the global nuclear discussions. Yet, at least for the foreseeable future, the most promising engagement with North Korea will come not from traditional international watchdogs such as the IAEA, the CTBTO or UNODA, but from coalition of countries interested in partnering and cooperating with North Korea on more specific and limited goals. Whereas North Korea will continue to reject the monitoring and verification mission of many IOS, it might however welcome more functional and pragmatic partnership with regional organizations like the Gulf Cooperation Council, or ASEAN or new forums on the model of the six party talks.

CONCLUSIONS: COOPERATING TO WHAT END?

Reviving cooperation with North Korea on nuclear safety issues is not unthinkable. The history of North Korea's engagement with the international community tells us that cooperation is possible, however limited. But to what end? And is such an end worth the risks and the costs? The obvious answer is: it depends. In my view, the belief that nuclear safety cooperation will lead to further and deeper cooperation on denuclearization and disarmament is wildly misplaced. Nuclear safety helps address vulnerabilities within a given nuclear program but does not address the critical security deficit North Korea perceives to characterize its regional backyard.

Nuclear safety is important but is not sufficiently important to be traded for nuclear disarmament concessions. For nuclear safety cooperation to serve as a confidence-building mechanism, it also requires extensive engagement and deep involvement at high political levels, resources, and time. In this sense, North Korea has demonstrated through its action that international engagement is an expendable commodity in protecting its nuclear weapons program. The payoff is uncertain and unclear. Finally, cooperating with North Korea on nuclear safety issues could also be read by other nuclear aspirant countries as enabling further proliferation. U.S. allies, in particular Japan, would most certainly reject any attempt to engage with the regime of Pyongyang unless clear concessions on the military program are made.

Despite the critical dilemmas that nuclear safety cooperation with North Korea raises, two additional considerations have to be brought to the forefront. The first is the responsibility that the international community must avoid at all costs any nuclear accident in any part of the world—independently of politics and ideologies. Preventing nuclear accidents is fundamental responsibility we all owe to communities worldwide and future generations who will inherit our countries and lands. The second is that the history of successful nuclear cooperation has always occurred amid tremendous challenges. Scientist-to-scientist cooperation has been the key to U.S.-Soviet engagement for decades during the Cold War (as shown in Chapter 1). And our most productive dialogues with the North Korean have ultimately been challenged by scientists who share a passion for physics, engineering, and chemistry.

Giving scientists a platform to engage with their North Korean counterparts might open new avenues that are today unthinkable and unseen. And if this could bring us closer to greater safety and dialogue in the Korean Peninsula, it might be worth a shot.

ENDNOTES

[1] 1 See Saplakoglu, (2018). The ground around the test site continued to rumble after the nuclear test. Seismologists were particularly stumped by a tremor recorded on September 23 that appeared to be a 3.4 magnitude earthquake under Mt. Mantap, an area that does not ordinarily experience earthquakes. A joint report published by the Chinese Academy of Sciences and UC Santa Cruz concluded that tunnels in the test site collapsed. "It was the mountain collapsing into the cavity created by the explosion … hundreds of meters below the surface," said Thorne Lay, a professor at UC Santa Cruz.

[2] 2 Already in 2011, South Korean officials sounded the alarm. Min Dong-seok, Vice Minister of Foreign Affairs and Trade of Republic of Korea at the Kiev Summit on Safe and Innovative Use of Nuclear Energy (April 2011): Aside from nuclear capabilities, we are also concerned about the safety of North Korea's nuclear facilities. Pyongyang's failure to comply with international standards and practices in constructing nuclear facilities spells high vulnerabilities for the region in the event of a natural disaster. And Won Sei-hoon, Former Director of the National Intelligence Service of the Republic of Korea, at the Congressional Hearing (April 2011): "North Korea's Yongbyon nuclear facility is considered to be poorly managed, but it cannot be confirmed of where exactly the facility is vulnerable."

[3] 3 For example, see Matt Korda (2017), who writes on December 14, that "a video of Kim Jong-un smoking next to an untested liquid-fueled missile tells you everything you need to know about North Korea's nuclear safety culture. The remarkable 14-second clip shows the Supreme Leader taking a puff while a Hwasong-14 intercontinental ballistic missile is erected on the launch pad mere feet away—prompting a torrent of snarky Twitter commentary expressing regret that Kim's lit cigarette had not "solved the problem for us." Kim's recklessness is certainly notable, and it hints at an underemphasized and potentially devastating possibility: the threat of a nuclear accident in North Korea." The depiction of the regime as incompetent and erratic in handling nuclear safety risks does not match the accounts provided by several American scientists who have regularly visited North Korea's nuclear facilities.

[4] 4 See Pabian, et al (2021). The cooling challenges that North Korea faces at its Yongbyon complex are not exclusively related to water management. Frank Pabian, Olli Heinonen, Jack Liu, and Peter Makowsky noted, "Problems with the cooling system have been noted previously, demonstrated by the replacement and repositioning of three of the units in late 2014, and the removal of one of the cooling units last year (2020), which has yet to be replaced."

[5] 5 According to Vision of North Korea, a South Korean NGOs disaster may have already occurred with over 21 North Korean defectors recounting numerous babies suffering from deformations at birth.

[6] 6 It is interesting to note that the lack of competence of the North Korea Regulatory Agency in certifying a prospective ELWR was also noted by KEDO. According to historical accounts, KEDO negotiated with North Korea a supply agreement that entrusted the DPRK regulatory authority to issue all the permits for the construction, commissioning, and operating of the LWR project. Yet, upon the recognition by KEDO that DPRK regulatory authority lacked the experience and nuclear regulatory infrastructure required, KEDO decided to assume responsibility while bringing DPRK regulatory commission up to speed for the job at hand.

[7] 7 See Milonopoulos and Blandford (2014). To substantiate the concerns over the lack of competence of the SNSRC, Niko Milonopoulos and Edward Blandford equally noted that "The SNSRC accepted the preliminary safety analysis report for the ELWR and a construction permit was issued despite the fact that many details

of the reactor were not decided until after construction began. As a result, this analysis was likely done piecemeal without a broad, comprehensive safety analysis of the plant's entire system until late in the construction phase. Experienced nuclear engineers would have conducted this analysis before concrete was ever poured. Not doing so early in the design phase could lead to significant gaps in the reactor's safety system."

[8] 8 For example, the Joint Institute for Nuclear Research (JINR) in Dubna was created with the support of the USSR, in 1956 and was subsequently followed by the establishment of.

[9] 9 Speaking at North Korea's General Satellite Control and Command Center in April 2009, Kim Jong Il called the launch of the kangmyongsong-2 (Lodestar-2) rocket a "striking demonstration of the might of our Juche-oriented science and technology.

[10] 10 In 2017 for instance China's Ministry of Foreign Affairs declared, "We strongly urge (the) North Korea side to face up to the firm will of the international community on the denuclearization of the peninsula, abide by relevant resolutions of the UN Security Council, stop taking wrong actions that exacerbate the situation and are not in its own interest, and return to the track of resolving the issue through dialogue."

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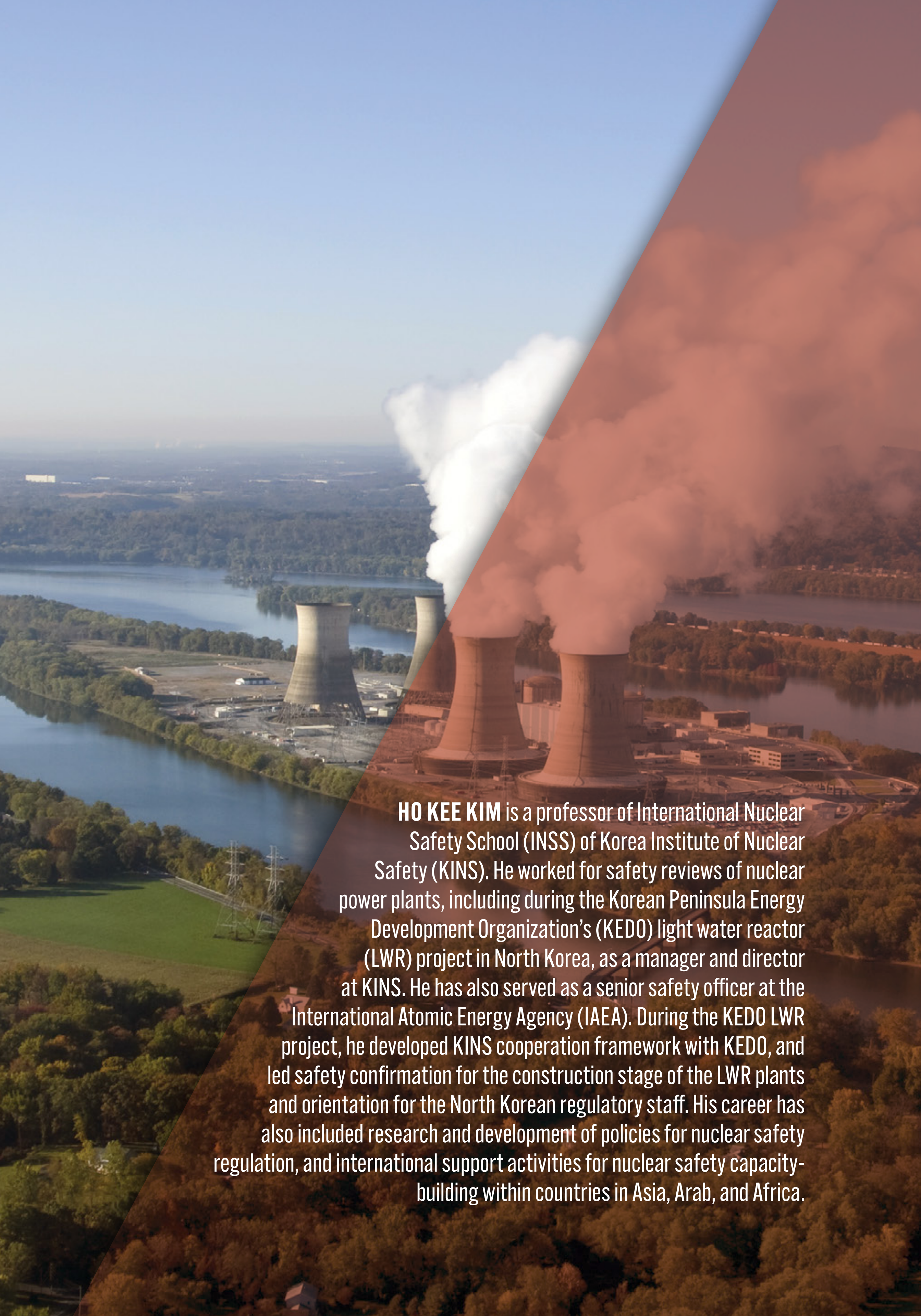

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5 SOUTH KOREA'S NUCLEAR SAFETY COLLABORATION: WHAT LESSONS CAN BE LEARNED FROM ONE OF THE WORLD'S LEADING NUCLEAR ENERGY DEVELOPERS

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INTRODUCTION: NUCLEAR POWER AND THE SAFETY

Currently, nuclear safety is a common global concern to be dealt with by a global normative framework. Even in the divided Korean Peninsula, this topic should be a point of collaboration, not only responding to international interests but also contributing to widening the window of collaboration to bridge the gap between the two Koreas.

As a modern component of human civilization, nuclear power requires a high-level of safety capacity to handle it strictly in consideration of the inherent nature of the risks coupled with radiation and large-scale energy. The global framework for nuclear safety aims to achieve global nuclear safety and security harmonization, and the key to this is ensuring that each country has a high-level of safety capacity. The past three major nuclear accidents at Three Mile Island (TMI), Chernobyl, and Fukushima Daiichi are cases in point. These accidents have also shown that an infrastructure with sound institutions and environment in sociocultural terms is necessary for nuclear safety. In each case, the common root causes were a lack of a safety culture at that time, which points out that even countries with high levels of technology should continue to strive for enhanced safety management capacity.

In nuclear safety capacity, there is a very large gap between the countries that possess safety frameworks and those that do not. At the global level, it could be said that the current nuclear reactor and radiation technology and their safety technology are mature. New innovative nuclear reactors with higher accident resistance are also being developed. Nevertheless, there is no change in the inherent risk associated with nuclear power. Therefore, in terms of various science and technology fields and their depth related to the use of nuclear power and the socio-cultural infrastructure that supports safe use, the gap between the countries with and without safety capacity is a matter of consideration not only whether they have sufficient knowledge, but also whether they have practical experience. North Korea's withdrawal from the IAEA in June 1994, outright refusing the special inspection of their nuclear facilities, was self-defeating, blocking the North's own opportunities to develop capacity for the peaceful use of nuclear power and safety management (IAEA, 2022).

At the center of international politics surrounding the Korean Peninsula is North Korea's nuclear issue. For decades, South and North Korea have developed different paths in the use of nuclear power, with South Korea focusing on the peaceful use of nuclear power and North Korea focusing on military purposes for the sake of regime security (See Chapter 2).

Nuclear safety is an important topic on which the two Koreas will collaborate in terms of real capacity, transcending the current status-quo of the divided Korean Peninsula. Given that a safe life is a basic human right, this is a topic that needs to be dealt with from the perspective of safety in the entire Korean Peninsula, included among other forms of inter-Korean exchanges in culture and sports and the reunion of separated families, for which the two Koreas have been collaborating. Through collaborative inter-Korean engagement on safety, it will be possible to share with North Korea the safety capacity that South Korea has accumulated over the past several decades, covering all areas of the use of nuclear power and radiation. Such engagement will also contribute to global nuclear safety and security harmonization.

There have been many ups and downs in various attempts to achieve peace in the Korean Peninsula (and there may still be), but nuclear safety will remain a major topic of inter-Korean engagement. Regardless of whether the peaceful use of nuclear power is used as an alternative means to resolve the North Korean nuclear issue, as once attempted by the Korean Peninsula Energy Development Organization's (KEDO) light-water reactor (LWR) project of the 1990s, or whether nuclear safety itself is the focal point following the alleviation of international tensions, the nuclear safety capacity of North Korea should be considered. However, it is undeniable that the actual collaboration between the two Koreas is inextricably linked with the international politics surrounding the nuclear issue.

Within this chapter, how to utilize or handle the topic of nuclear safety will be reviewed in order to prepare for or open the way for collaboration between the two Koreas. This is underpinned by summarizing both sides' nuclear power and their safety capacity with respect to the relevant infrastructure and experience to show the necessity of inter-Korean engagement. First, I present the background of inter-Korean engagement for nuclear safety capacity building. Second, I describe the capacity and competency of nuclear power and safety management in South Korea. The Korea Institute of Nuclear Safety (KINS) experience of the KEDO LWR project is discussed in the follow section. Additionally, I offer a review of North Korea's nuclear-related laws and present the details of the how the two Koreas' have historically worked towards nuclear safety. In conclusion, I list several areas for policy recommendations based on the insights provided in this chapter.

REGARDLESS OF WHETHER THE PEACEFUL USE OF NUCLEAR POWER IS USED AS AN ALTERNATIVE MEANS TO RESOLVE THE NORTH KOREAN NUCLEAR ISSUE, OR WHETHER NUCLEAR SAFETY ITSELF IS THE FOCAL POINT FOLLOWING THE ALLEVIATION OF INTERNATIONAL TENSIONS, THE NUCLEAR SAFETY CAPACITY OF NORTH KOREA SHOULD BE CONSIDERED.

SOUTH KOREA'S NUCLEAR CAPACITY BUILDING

Consistent Policies and Ample Experience: Capacity for Nuclear Power

South Korea has secured its own nuclear reactor technologies and become self-reliant through long-term efforts since the early days of the U.S. "Atoms for Peace" project, when the world began to develop technologies for the peaceful use of nuclear power (KAERI, 2007). Currently, South Korea designs, constructs, operates, or decommissions about 40 NPPs and research reactors, and numerous institutions in industry, academia, and research use radiation. The technology development for the use of nuclear power and radiation in South Korea dates back to the 1950s, when global society started promoting peaceful use under the banner of Atoms for Peace. In March 1958, the Atomic Energy Act was enacted for the research, development, production, use, and management of nuclear energy amid the ruins of the post-Korean War. In the 1960s, research reactors of TRIGA Mark II and III were introduced in Korea, research on the use of radioactive isotopes began, and the first nuclear power plant (NPP) development projects were initiated. In the 1970s, the first two NPPs were introduced from the United States and Canada in accordance with the strategy of well-proven engineering technology and turnkey contract. In the 1980s, seven NPPs projects were initiated with designs from the United States, France, and Canada in accordance with non-turnkey contracts for self-reliance of construction, and, additionally, a multi-purpose research reactor was constructed. In the 1990s and 2000s, technologies for the 1000 MWe and its improved 1400 MWe pressurized water reactors (PWR) were developed, and eleven NPPs were built, including three 700 MWe Canadian Deuterium Uranium (CANDU) plants. After 2010, ten additional NPPs are in operation or under construction, and the projects for two research reactors and two small modular reactors (SMRs) are in progress. In the 2010s, four NPPs and a research reactor were also exported to the United Arab Emirate (UAE) and Jordan, respectively.

South Korea's self-reliance in nuclear technology will play an important role for the future development of the Korean Peninsula. South Korea's history of securing energy for post-war national reconstruction, lessons learned from the 1970s oil shock on the importance of energy security, and the benefit of energy that depends on science and technology rather than natural resources, drove the development of nuclear technology. The nuclear industry in South Korea will continue growing in the future, given the advancement of climate change, the contribution of the nuclear industry to sustainable economic development, the increase in consumption of clean energy, and scarcity of natural resources. Furthermore, considering the situation of North Korea and the expansion of inter-Korean collaboration or re-unification to come, the use of nuclear power and radiation for peaceful purposes on the Korean Peninsula will lead to a rapid expansion in all sectors of society.

Consistent Policies and Ample Experience: Capacity for Nuclear Safety Regulation

South Korea has set up a comprehensive regulatory infrastructure for nuclear safety, which has continuously evolved the competency through feedback from increased regulatory demands and international and domestic movements on nuclear safety. In this way, South Korea has ensured safety strategies for the development and expansion of the peaceful use of nuclear power. Prior to the 1970s, during South Korea's early stage of nuclear power development, the Atomic Energy Act was enacted, and a safety regulatory infrastructure for the initial stage was established to support the introduction of research reactors and NPPs. The Atomic Energy Act of 1958 stipulated both the promotion of peaceful use of nuclear power and safety management simultaneously. The Act required the establishment of the Office of Atomic Energy under the authority of the President to control and manage the entirety and also stipulated permits for nuclear facilities, standards for radiation protection, and licenses for the handlers. The Office was composed of a five-member Atomic Energy Committee, the secretariat, and the Atomic Energy Research Institute, and played a key role in developing technology for peaceful use of nuclear power as well as safety management. In 1967, the Agency of Atomic Energy, which was the external agency of the Ministry of Science and Technology, took charge of both promotion and safety management tasks. The Atomic Energy Act, amended in 1973, specifically stipulated the regulation of nuclear fuel materials and reactors as one of the tasks of the Committee. During this time, the Agency of Atomic Energy issued licenses for the first two NPPs in South Korea. The issuance of these licenses referenced safety reviews by the Safety Review Committee of Nuclear Reactor Facilities and its affiliated specialized subcommittees, which utilized safety standards of vendor countries.

In the 1980s, in the wake of the TMI Unit 2 accident in 1979, South Korea implemented substantial changes, including the establishment of the Nuclear Safety Center attached to the Atomic Energy Research Institute as a nuclear safety expert organization in 1981. The Atomic Energy Act was amended in 1982 to establish the Atomic Energy Commission (AEC) and introduced a two-step licensing system of Construction Permit (CP) and Operating License (OL) for nuclear reactor facilities. Additionally, to build competency in nuclear safety regulations, the government began to develop regulatory requirements and the cultivation of regulatory personnel.

In the 1990s and 2000s, following the Chernobyl accident in the former Soviet Russia in 1986, the Korea Institute of Nuclear Safety (KINS) was installed by the Special Act in 1990 as the nuclear safety expert organization, succeeding to the duties of the Nuclear Safety Center. The establishment of KINS was in a clear attempt to strengthen the independence and capacity of nuclear safety regulation. Moreover, the Nuclear Safety Committee (NSC) was established in 1996, dividing the safety functions of the AEC. During this period, there were increased regulatory demands for CPs for 17 NPPs and OLs for 13 NPPs, which also included safety confirmation for the construction of two KEDO LWR plants. It was through the cooperation frameworks that contributions to global society were largely expanded.

LICENSING FOR NUCLEAR FACILITIES IN SOUTH KOREA (as of September 2022)

NAME		RX TYPE	CAPACITY (MWE)	AUTHORIZATION		PERMANENT SHUTDOWN?
SITE	UNIT/VENDOR			CP	OL	
KORI	1/USA	PWR	587	May 1972		Y
	2/ USA		650	Nov. 1978	Aug. 1983	-
	3/ USA		950	Dec. 1979	Sep. 1984	-
	4/ USA		950	Dec. 1979	Aug. 1985	-
SHIN-KORI	1/ROK		1,000	Jul. 2005	May 2010	-
	2/ROK		1,000	Jul. 2005	Dec. 2011	-
	3/ROK		1,400	Apr. 2008	Oct. 2015	-
	4/ROK		1,400	Apr. 2008	Feb. 2019	-
	5/ROK		1,400	Jun. 2016	Under safety review for OL	
	6/ROK		1,400	Jun. 2016	Under safety review for OL	
WOLSONG	1/Canada	PHWR	678.7	Feb. 1978		Y
	2/ Canada		700	Aug. 1992	Nov. 1996	-
	3/ Canada		700	Feb. 1994	Dec. 1997	-
	4/ Canada		700	Feb. 1994	Feb. 1999	-
SHIN-WOLSONG	1/ROK	PWR	1,000	Jun. 2007	Dec.2011	-
	2/ROK		1,000	Jun. 2007	Nov. 2014	-
HANBIT	1/USA		950	Dec. 1981	Dec. 1985	-
	2/USA		950	Dec. 1981	Sep. 1986	-
	3/ROK		1,000	Dec. 1989	Sep. 1994	-
	4/ROK		1,000	Dec. 1989	Jun. 1995	-
	5/ROK		1,000	Jun. 1997	Oct. 2001	-
	6/ROK		1,000	Jun. 1997	Jul. 2002	-
HANUL	1/France		950	Jan. 1983	Dec. 1987	-
	2/France		950	Jan. 1983	Dec. 1988	-
	3/ROK		1,000	Jul. 1993	Nov. 1997	-
	4/ROK		1,000	Jul. 1993	Oct. 1998	-
	5/ROK		1,000	May 1999	Oct. 2003	-
	6/ROK		1,000	May 1999	Nov. 2004	-
SHIN-HANUL	1/ROK		1,400	Dec. 2011	Jul. 2021	-
	2/ROK		1,400	Dec. 2011	Under safety review for OL	
RESEARCH RX	HANARO/ROK	LWR	30 MWt	Dec. 1987		
	KJRR/ROK		15 MWt	May 2019	-	-
	ARA/ROK		65.5 MWt	Under safety review for CP		
SMR	SMART/ROK	PWR	330 MWt	Approved standard design in Jul. 2012		
	SMART 100/ROK		365 MWt	Under safety review of standard design		

Since 2011, following the Fukushima Daiichi NPPs accidents in neighboring Japan, there has been a rapid paradigm shift in nuclear safety regulation in South Korea. Reflecting the public's high concern about nuclear safety and environmental radiation, the Atomic Energy Act of 1958 was subdivided into the Nuclear Safety Act, the Nuclear Energy Promotion Act, and the Nuclear Safety and Security Commission (NSSC), which as the competent regulatory authority, was established to further strengthen independence of nuclear safety regulation. Post-Fukushima, South Korea's nuclear safety regulation is now systematically separated from nuclear promotion functions, which is an enhancement upon the original functional separation maintained since the beginning of the nuclear age. As highlighted in international conventions like the Convention on Nuclear Safety (IAEA, 1994), effective separation of regulatory authority is key to the global normative framework for nuclear safety, alongside the concept of the prime responsibility of licensees for nuclear facilities. With establishment of the NSSC, institutional independence of South Korea's regulatory authorities has become clearer to the public as well as global society.

South Korea has maintained a dual system separating administrative enforcement and technical expertise since the early stages of nuclear safety regulation. This has limited the impact of changes in government organization and resulted in preserving the coherence of regulatory expertise and its developing efforts. South Korea's governmental organization has undergone changes in keeping with alterations of political power and times, including implementation of key legislature and organization development such as the Division of Atomic Energy (1956) and the Office of Atomic Energy of the Ministry of Education & Culture (1958); the Agency of Atomic Energy of the Ministry of Science and Technology (1967); the Bureau of Atomic Energy of the Ministry of Science and Technology (1973) and, later, the Ministry of Education, Science and Technology (2008); and the present NSSC (2011). Regarding nuclear safety expertise, in the early stage of nuclear power development, the Agency of Atomic Energy issued the licenses in reference to the review results of the Safety Review Committee of Nuclear Facilities. However, currently, KINS is in charge of the entire expertise's work, which succeeded the mission of the Nuclear Safety Center in 1981.

Consistent and continuous national policy, as mandated by the Act, has led to strong capacity building for the development, use, and safety management of nuclear power. South Korea has been focusing on building capacity in the nuclear field from the beginning and stipulated basic plans, policies, and manpower cultivation as matters of the resolution of the five-member Atomic Energy Commission established by the first Atomic Energy Act in 1958 (Ministry of Education & Culture, 1958).

For structured capacity building, the Act (Ministry of Science & Technology, 1995), revised in 1995, stipulated the establishment of a Comprehensive Nuclear Energy Promotion Plan and a Sectoral Implementation Plan in a 5-year interval, and an Annual Detailed Implementation Plan for nuclear power use and safety management. This government policy emphasizing capacity building has been maintained even after the Atomic Energy Act was divided into the Nuclear Safety Act and the Promotion Act in 2011. The current Nuclear Safety Act also stipulates that the Comprehensive Nuclear Safety Plan, Sectoral Implementation Plan, and Annual Detailed Implementation Plan should be established every five years for safety management in the use of nuclear power (Nuclear Safety Commission, 2011). The plan should include five main points: 1) current status and prospects for nuclear safety management, 2) policy goals and basic directions, 3) tasks for each sector and its implementation, 4) required financial resources and the financing methods, and 5) other matters necessary for safety management. As of 2022, the third Comprehensive Nuclear Safety Plan (2022–2026) is being implemented. The plan presents four policy directions with 12 implementation strategies towards the desirable future of nuclear safety regulations, which focus on public participation in the process of nuclear safety regulations and on innovation of regulatory infrastructure for better practicality.

Increased demand for safety regulations, as well as public concerns due to overseas nuclear accidents, have enhanced the independence of regulatory infrastructure and promoted regulatory competency building. In the early stages of nuclear development, licensing and regulatory activities for NPPs were based on vendor country standards in accordance with well-proven engineering technology and turn-key contracts, as well as the support of the IAEA. But responding to the policy to expand the use of nuclear power and develop independent reactor technology, a technology-neutral regulatory system covering all types of reactors has been established, and the expansion of construction of NPPs, which continues even today, has promoted the development of regulatory competency. In addition to this, public concerns about nuclear safety, which increased periodically due to the accidents in overseas NPPs such as TMI in 1979, Chernobyl in 1986, and Fukushima Daiichi in 2011, have not only led to changes in the administrative system that enhanced independence of nuclear safety regulation but also pushed forward the strengthening of regulatory expertise in South Korea.

In particular, there was a stronger public reaction to the NPP accident in neighboring Japan. Immediately after the Fukushima nuclear accident, South Korea conducted special safety inspections at all domestic NPPs and reinforced safety-relevant facilities, as needed. Also, stress tests for all NPPs were conducted in accordance with the mid-term plan and legislated the establishment of an accident management plan, ranging up to the level of hypothetical severe accidents. The emergency planning zone of NPPs was expanded from 8 to 10 km to 20 to 30 km around the reactor, and emergency response capacity was strengthened. National policies aimed at expanding the peaceful use of nuclear power and achieving self-reliance in reactor technology have also triggered workplace learning in nuclear safety regulation.

The role of benefactors to share safety technology with global society has expanded in order to lead the achievement of global safety and security harmonization and to assist latecomer countries in building regulatory capacity. In the 1990s, KINS began to provide international training, and in July 2002, with orientation for 25 North Korean regulators, KINS expanded its global contributions to increased levels. In order to further promote global contribution and cooperation, the International Nuclear Safety School (INSS) was established in 2008 at KINS, which launched projects for international regional nuclear safety networks, bilateral agreements, and an international nuclear safety master's degree program. Support for regional safety networks began in 2008 when KINS signed an agreement with the IAEA to regularly provide training and financial resources for participating countries in Asian Nuclear Safety Network (ANSN). Since then, KINS has successfully expanded its activities to include various training projects, which have been conducted for nearly ninety member countries of three regional safety networks such as the Arab and African regions through the Arab Network of Nuclear Regulators (ANNuR) and Forum of Nuclear Regulatory Bodies in Africa (FNRBA) organizations. Up to now, about 150 workshops, including more than 2,000 participants, have been implemented, jointly with the IAEA.

In accordance with bilateral agreements, KINS has supported nuclear safety confirmations for the construction of NPPs in the UAE and the research reactor in Jordan, and provided orientation workshops for Saudi Arabia, Vietnam, and Egypt in order to support of establishing each country's own nuclear safety regulation systems and developing human resources. In 2009, the International Nuclear Safety Master's Degree Program was launched, jointly with Korea Advanced Institute of Science and Technology (KAIST), to educate the international next generation about nuclear safety.

Beyond identities and values shared by people, collaboration between the two Koreas is the most optimal way to improve the nuclear safety regulatory system and build the safety capacity of North Korea. In order to promote global nuclear safety and security harmonization and induce capacity building of member countries, the IAEA has enacted international legal instruments such as conventions or codes of conduct and developed the supporting safety standards, which together constitute the global normative framework for nuclear safety. Various cooperation channels and opportunities are also available to latecomer countries to utilize the experiences of leading countries under the global nuclear safety and security network. Additionally, other international organizations such as the Organisation for Economic Co-operation and Development's (OECD) Nuclear Energy Agency (NEA), the World Association of Nuclear Operators (WANO), and the Institute of Nuclear Power Operations (INPO) define safety capacity in a variety of ways and present varied standards. Advanced knowledge and information technologies also help with easy access to such global resources. As in the cases of the UAE, Jordan, Saudi Arabia, and Egypt, international business contracts could be used to lay the foundation for securing nuclear safety capacity. Therefore, in order for latecomer nuclear energy producers to improve nuclear safety infrastructure and build safety capacity, it is necessary to, first, assimilate into the global environment and to establish a cooperative mechanism with appropriate experienced transferors.

Basic nuclear safety capacity involves establishing legal and institutional infrastructure in line with the concept of society and culture. Such processes also require the development of regulatory standards necessary for safety regulations on the use of nuclear power and radiation, the securing of related facilities and equipment, and the development of human resources. Since nuclear safety regulation is a highly intellectual activity, the most essential among them is to cultivate regulatory personnel with knowledge and experience. Moreover, long-term experience is required based on academic knowledge so as to nurture manpower with sufficient regulatory competency.

Various methods, such as the utilization of international safety infrastructure and cooperation, the conduct of in-house R&D, and the practice of regulations, could be utilized to accumulate experience. As such, it requires a lot of effort over a long period of time to develop safety capacity, and considering current international cases of seeking the use of external assistance, North Korea also needs to seek effective and efficient measures.

THE KEDO LWR PROJECT FOR NORTH KOREA

When bringing up nuclear safety collaboration between the two Koreas, it is worth recalling the KEDO LWR project, which was terminated in 2006 despite in-progress construction of two Korean Standard NPPs (KSNP) in the Kumho district of North Korea. The KEDO project was implemented on the bases of the Geneva Agreement of October 1994, signed by the United

States and North Korea, to freeze North Korea's nuclear weapon program in exchange for financial and diplomatic incentives (KEDO, 1994). In compensation for freezing the program toward ultimate dismantling of the program and relevant facilities, the Agreement was to construct two KSNPs and provide 500,000 tons of heavy fuel oil annually until the first NPP came online. In March 1995, Executive Board member countries, consisting of South Korea, the United States, and Japan established KEDO[1] as their secretariat for implementing the Agreement and started the project. In December 1995, KEDO signed the Supply Agreement with North Korea began to carry out its mission (KEDO, 1995).

After KINS's presentation workshop in August 2001 on the results of their 14-month safety review for the construction stage, construction of the NPPs began at full scale with the CP by North Korea on September 1, 2001. In July 2002, 25 North Korean regulators participated in the orientation regarding the fundamentals of nuclear safety regulation for NPPs at KINS for about a month. However, due to the re-emergence of North Korea's nuclear issue, the KEDO Board decided to suspend construction at the end of 2003 and concluded the termination agreement at the end of 2006. Based on KEDO's project management system, only 34.5% of construction had been completed.

KEDO had a special position as both a supplier to North Korea and an interim owner before the turn-over of the NPPs. According to the Supply Agreement, while providing two 1000MWe LWRs to North Korea on a turnkey basis, KEDO was to enact the following: implement a quality assurance program in accordance with the Agreement's codes and standards, and guarantee the NPP's generating capacity; design and implement training programs for North Korea's operation and maintenance of NPPs; ensure that the NPPs comply with nuclear safety and regulatory codes and standards in the Agreement; and, provide the results of nuclear commissioning tests and operator training records to assist North Korean operator in obtaining an operating license.

To satisfy the Supply Agreement and fulfill the role of an interim owner, KEDO established the Nuclear Safety Confirmation System (NSCS) and signed the Cooperation Agreement with KINS to perform design and safety reviews of the NPPs. Although KEDO established the NSCS, the organization was designed to fulfill the same responsibilities as that of other countries' regulatory systems in terms of independence and expertise for nuclear safety. Until the NPPs were delivered to North Korea, this organization was to confirm nuclear safety in accordance with international practice. The NSCS was composed of KINS, Nuclear Safety Advisory Group (NSAG), and the IAEA. Within this structure, each member organization held complimentary responsibilities: KINS for safety confirmation; NSAG, nine member-country experts, for advice regarding safety policy and safety; and the IAEA for peer review.

The services of the KINS-KEDO Cooperation Agreement included the development and implementation of training programs for North Korean regulators as well as safety confirmation for the construction of the LWR plants. But the Supply Agreement did not include training for North Korean regulators. During the negotiation with KEDO, KINS emphasized the need for external support so that North Korea, which has no regulatory experience for commercial NPPs, would secure in advance necessary knowledge for the operational safety of NPPs. The international community, including NSAG, also expressed similar concerns. As a task in the first year of the Agreement in 1999, KINS developed the orientation program, benchmarking their nuclear safety regulatory duties. The planned program was to conduct a total of 18 courses throughout the entire construction period in the form of classroom and on-the-job field orientation. The KINS orientation was aimed at building the regulatory expertise of North Korean regulatory staff for safety reviews and inspections of their nuclear facilities and activities. In 2000, a set of orientation materials for 11 courses regarding the fundamentals of nuclear safety regulation were developed.

After the CP in September 2001, in July 2002, the first orientation for North Korean regulators was conducted at KINS with 25 participants for about one month regarding nuclear safety regulatory fundamentals. Preferably, the orientation was to start with the involvement of North Korean regulators in the KINS safety review of the LWR plants. For the practical experience of regulators, it is desirable to start orientation from the beginning to facilitate understanding of the design and safety characteristics of NPPs. KEDO and KINS, alongside other supportive international organizations, together emphasized this point to the North Korean regulatory body and the importance of participating in KINS orientation. However, it was not until the end of December 2001, after KINS safety review and the CP by North Korea in September 2001, that North Korea notified KINS of its intention to participate in orientation. Even after the issuance of the CP, KEDO and international organizations unanimously stressed that North Korea needs sufficient regulatory capacity to operate the NPPs safely and that an early start is the most effective.

North Korea's delay in participation was most likely due to political considerations less than fundamental disinterest. Because this orientation was the first working-level event in the South since the division of the Korean Peninsula, it would not have been an easy situation for the North Korean regulatory body to receive approval of participation under their regime. Despite North Korea's likely recognition of the need for safety training, it took a considerable time to change the perception of competent authorities and obtain their approval. Although there is a difference in degree, it seems to be due to the characteristics of North Korean regime along with the priority of national policy that puts use and development ahead of safety management, which latecomer nuclear energy countries have generally shown in the early stages of nuclear power development. Whether due to political circumstances or regime structure, it is important to acknowledge North Korea's decision-making process and the status of its regulatory body when it comes to nuclear safety.

The first orientation was conducted in a very tense situation in inter-Korean relations in July 2002, shortly after the second Battle of Yeonpyeong in the West Sea on June 29, 2002, which resulted in a number of casualties. However, despite this, inter-Korean participation through the safety orientations continued, emphasizing that dialogue and cooperation were necessary under any circumstances. Since then, until the termination of the LWR project in 2006, KINS jointly performed safety inspections of the NPP construction process with North Korean regulatory authorities and shared its experience.

The plan for developing North Korea's regulatory capacity through the construction process of the LWR plants was aimed at resolving global concerns about the operational safety of the NPPs in North Korea. Fundamentally, it was to confirm the safety of nuclear power on the Korean Peninsula, and establish a coherent regulatory infrastructure between the two Koreas in preparation for reunification.

Assuming the environment and reality faced by North Korean regulatory authorities, various forms of external support and cooperation would still be needed to develop their regulatory capacity. Even though construction of the LWR plants was terminated at the initial stage, the State Nuclear Safety Regulatory Commission (SNSRC), the safety regulatory authorities in North Korea, would have acquired an overall understanding of nuclear safety regulation. However, nuclear safety regulation is underpinned by the public's acceptability of the risk of nuclear power, and fundamental infrastructure is shaped by sharing global norms. In addition, nuclear safety regulations are a sort of intellectual activity to ensure the safety of the use of radiation and nuclear power. Given the characteristics and environment of the North Korean regime, in order for the SNSRC to actually exercise its authority as a nuclear regulatory body, it would still be necessary to make various efforts to secure its reasonable authority and prestige necessary for technical decisions intervening in the development and use of nuclear power.

NORTH KOREA'S NUCLEAR CAPACITY: FOR PEACEFUL USE

Economic Development and Energy in North Korea

North Korea's infrastructure is severely underdeveloped, representative of the country's poor economic situation. However, if North Korea participated as a responsible member in the international community, opportunities for rapid economic development would follow and there would be a surge in energy demand, especially electricity. Moreover, North Korea has been constantly interested in the development of NPPs since the establishment of their regime, and their hope remains as the leader's legacy. In some ways, since the peaceful use of nuclear energy requires enormous national resources, it is likely that they were obsessed with military purposes to maintain their regime, which, in contrast, could be achieved with a relatively small investment. Given the opportunity, it is not hard to envision a future North Korean economy requiring the same level of energy as South Korea and, provided changes in the global environment occur, North Korea's use of nuclear power and radiation for peaceful purposes could greatly expand. In the process, the experience of the KEDO LWR project and the site left after termination could play a role again.

Nuclear-Related Acts and Safety Capacity

There is still much to understand about North Korea's legal and institutional infrastructure and nuclear safety system. The current North Korean law of each social sector describes the purpose, method, and organization in charge of the law in a declarative and concise manner. On the other hand, detailed standards and methods for implementing laws are entrusted to administrative organizations designated by the law to develop and implement them as detailed regulations. Therefore, it is possible to understand the upper laws but difficult to grasp the detailed regulations for actual implementation due to limited information.

At the legal level, North Korea stipulates both nuclear armament and the peaceful use of nuclear power. Regarding nuclear armament, their constitution declares that they are a nuclear state. For the peaceful use of nuclear power, promotion of use and safety management are separated. North Korea's Atomic Energy Act provides a basic direction focusing on the development and promotion of nuclear power while in principle using nuclear power for peaceful purposes.[2]

The Act on the Prevention of Radioactive Contamination, newly enacted in 2011, provides the basis for nuclear safety management. It aims to prevent radioactive contamination and protect the public and environment through the safety management of radioactive materials and nuclear facilities, treatment of radioactive waste, and monitoring of environmental radiation. Prevention of radioactive contamination, scientification and modernization, and international exchange and cooperation are suggested as basic directions of the Act. For safety management of radioactive materials, it stipulates the process of production and use, the authorization of the SNSRC, and its authority to request data for this. For safety management of nuclear facilities, the Act requires environmental impact assessment for construction; preparation of preliminary and final safety analysis reports for construction and operation, respectively; safety reviews of the SNSRC for the reports; and radiation monitoring around the facilities. Both nuclear-related Acts stipulate that the state cultivates manpower and strengthens R&D, but do not provide a system or method for the implementation, such as a comprehensive plan.

Although it is difficult to grasp the details of North Korea's nuclear power use and safety management, even declarative at the level of the Acts, it has a minimum framework. In particular, it appears that the Act on the Prevention of Radioactive Contamination reflects experiences from the KEDO LWR project and orientation at KINS. However, the detailed regulations enacted by the SNSRC under the mandate of the Act should be understood in the future since the orientation focused on the fundamentals of nuclear safety regulation.

A little imagination is necessary to understand North Korea's nuclear safety capacity only at the level of the Act. North Korea mainly focuses on developing nuclear weapons for military purposes, and safety management of related facilities and activities seems to be at the level of applying basic science. The use of radiation and nuclear power in the civil sector and regulatory demand for it may be limited. Even if it is difficult to distinguish between military and civilian uses, North Korea is likely to have a considerable number of radiation and nuclear related facilities. Therefore, in order for regulatory authorities to exert practical authority over the use of nuclear power and radiation, it is necessary to harmonize with the global normative framework. Regulatory authorities should secure effective independence and professional expertise. This could be confirmed from the perspective of the completeness of the regulatory system, including the scope and level of safety standards; the appropriateness of human resources; and the accumulation and use of regulatory experience.

Given North Korea's centralized authority of extreme line-organization in decision-making structure and their nuclear-related policy prioritizing development and use, the international community will need to cooperate so that North Korea's regulatory authorities have official status and authority to enter the arena of international cooperation for the purpose of building capacity and harmonizing with the global normative framework on nuclear energy and safety. This is to create the necessary environment at the North Korean government level for regulatory authorities to engage in various international activities related to nuclear safety. These include opportunities for not only information exchange but also mutual benchmarking of safety capacity at a practical level. In the political and diplomatic sectors of the two Koreas and global society, a common perception should be created to make nuclear safety and regulatory capacity one of the topics of mutual cooperation with North Korea to facilitate changes in North Korea's internal environment.

IN REALITY, WITHOUT A MAJOR SHIFT IN THINKING, IT IS DIFFICULT TO EXPECT INTER-KOREAN ENGAGEMENT FOR NUCLEAR SAFETY BEYOND THE NORTH KOREAN NUCLEAR WEAPON ISSUE AND WITHIN THE CURRENT GLOBAL SANCTIONS REGIME.

Cooperation for building North Korea's safety capacity should be effective and efficient, taking both reality and the unified peninsula into account. Considering the complexity of international politics and diplomacy surrounding the North Korean nuclear issue, it is difficult to choose any specific method at this time. However, the international community would also agree that the end result of the discussion is to utilize the advantages of collaboration between the two Koreas. This would be a part of the process military to civilian use transition, including converting or dismantling facilities and reassigning personnel involved in the weapons program, increasing civilian use and cooperation following their return to the global society, developing measures to ensure nuclear safety in the Korean Peninsula, and reducing tensions between the two Koreas.

These matters are broadly classified into two categories in accordance with progress in changes of circumstance surrounding North Korea. In the event of an unexpected situation that leads to rapid integration of the two Koreas, the ultimate process of converting or dismantling is carried out while managing the safety of North Korea's existing nuclear facilities. Safety regulations and standards of South Korea that are in line with global norms could be utilized for safety management in the process. North Korea's nuclear-related personnel can also participate in safety management, promoting smooth relocation of personnel.

When a situation allows for expanding inter-Korean collaboration or international cooperation, the two sides could prepare for integration with sufficient mutual understanding. The matters that the two Koreas collaborate on together with the support of the international community are summarized as follows, and these points will need to be incorporated into the process of political and diplomatic activities surrounding North Korea's nuclear issue.

- The role of the international community should be to assist North Korea's nuclear regulator so that it can have independence and regulatory authority that is in accordance with global norms. Attention and support from global society would help ensure that regulatory authorities have their own status in North Korea's power regime even under the environment of military purpose development, while strengthening the global normative framework for nuclear safety. This allows them to engage in various global activities for nuclear safety to develop safety capacity and achieve harmony.
- Joint research should be conducted between the two Koreas to promote the establishment of an infrastructure for nuclear safety regulation in the unified Korean Peninsula. A step-by-step plan should be established to compare and review the safety-related legal systems and standards of both sides and to accept global norms.
- A safety management plan that satisfies international standards should also be developed for North Korea's nuclear facilities, test sites, and other facilities utilizing radiation and nuclear power. After investigating and analyzing the status of all nuclear-related facilities, a plan for use or disposal should be established, and a management system and standards for safely managing the process needs to be developed. Additionally, these plans should also include a site management plan which examines the geology, ground, and contamination level of the nuclear test site, secures facilities and equipment for environmental radiation monitoring and environmental laboratories, and prepares those operational management measures.
- In preparation for North Korea's nuclear program participants to be reassigned to the field of nuclear power use for peace purposes or its safety management, capacity

building of re-assigned personnel should be promoted. This process could develop strategies, organizational systems, and human resource utilization and training plans for the unified Korean peninsula's future nuclear development, implementation, as well as safety management.

At the practical level of nuclear safety regulation, it is believed that the North Korean regulator has built up the confidence necessary to promote these mutual activities throughout the process of the KEDO LWR project of KINS. Some evidence for the North Korean regulator's trust in the South's regulatory procedures could be found in the preceding sections. However, it is important to add that confidence in the political or diplomatic factors of addressing North Korea is yet to be confirmed.

POLICY RECOMMENDATIONS FOR INTER-KOREA ENGAGEMENT: NUCLEAR SAFETY MANAGEMENT

The ultimate goal of inter-Korean engagement for nuclear safety is to establish a collaborative framework on the Korean Peninsula. For consistent and comprehensive nuclear safety management within such a framework, it is necessary for the two Koreas to take forward-leaning steps towards collaboration, including establishing an interconnected legal or institutional system, developing organizational and human capacity for nuclear safety regulation, and seeking ways to secure, operate, and manage facilities and equipment for radiation safety

The ways to cooperate with or support North Korea are summarized from the perspective of three categories: 1) capacity building within North Korea through its own change and collaboration with South Korea, 2) international community's role in the process of seeking gradual improvement in the situation surrounding North Korea, and 3) the role of inter-Korean relations in the process. Cooperation and support from global society at any higher level or framework to deal with North Korea's nuclear issue could facilitate these processes, which will contribute to strengthening the global normative framework for nuclear safety.

The approaches below, assuming gradual changes in North Korea, could also be utilized as a countermeasure against sudden changes in their situation.

Of course, it is preferable for North Korea to take the lead in developing their own capacity, and global resources could readily be useful to assist them at any time in accordance with their own resolution.

- The best way is for North Korea to join the global society as a responsible member, cooperate under the global normative framework, and develop safety capacity. It is not unimaginable that North Korea, like other states, have access to and development for nuclear power; however, it would require North Korea to integrate into the international community's global frameworks for nuclear safety and security harmonization.
- With North Korea itself lacking natural resources and being one of the poorest countries in the world, it would be necessary to expand the use of nuclear power for peaceful purposes and build safety capacity to promote economic development and national welfare. This is a shift in policy from the military use of nuclear power, which has been the focus so far, to the use for peaceful purposes.
- During the process, South Korea will be the most effective and efficient partner. Their

high competency could be extensively utilized for the nuclear safety capacity building of North Korea. South Korea has established a comprehensive safety infrastructure and accumulated ample experience in all areas of nuclear and radiation use over a long period of time and also has the policy of promoting global contributions.

In reality, without a major shift in thinking, it is difficult to expect inter-Korean engagement for nuclear safety beyond the North Korean nuclear weapon issue and within the current global sanctions regime. Since nuclear safety management is rooted in the basic human rights of securing safety for the pursuit of happiness, there is a possibility of humanitarian engagement on energy development. Although it should be cautiously enacted, such engagement could be considered as a subject of inter-Korean engagement or international cooperation of North Korea apart from the international situation. This open approach toward global nuclear safety raises expectations that it could also contribute to the formation of internal deterrence, albeit limited, in the context of North Korea's military use of nuclear power and be another leverage in talking with them.

- Although North Korea is a non-member state, a method to create and allow an international atmosphere in which North Korea can utilize the IAEA's nuclear safety infrastructure and participate in related activities needs to be discussed and options deliberated. It could be a forward-looking approach in that it will happen in a yet to be defined future, although the international political and diplomatic conditions necessary for expansive engagement with North Korea are yet to be seen.
- Additionally, international politics and diplomacy deal with nuclear safety as a topic of inter-Korean collaboration or international cooperation with North Korea.

Considering the tendency of authority concentration toward the upper level in the North Korean regime, in order for the North's nuclear safety regulatory authority, the SNSRC, to have authority to actually cooperate with the outside world, global society needs to work together to emphasize the importance of its independence and empowerment—in addition to the voices about North Korea's nuclear weapon program.

- Global society, while interacting with North Korea on the nuclear issues, should take an interest in North Korea's nuclear safety and urge cooperative interaction with the North's regulatory authorities.
- When the time comes that North Korea joins the international community as a responsible member, it will also be necessary to support the SNSRC to develop its own capacity while cooperating with South Korea and global society.

In a future opportunity, when the two Koreas may move forward on the path of expanding collaboration, they could jointly study, establish an integration strategy, and systematically prepare the details accordingly.

- Collaboration for nuclear safety with North Korea requires effective and efficient sharing of practical experience. It is also important to consider the location and size of North Korean nuclear-related facilities, safety management that complies with global norms, and the practicality and advantage of inter-Korean direct engagement.
- The purpose of inter-Korean engagement should be to support securing the independence and authority of North Korean regulatory authorities, build nuclear safety infrastructure in the Korean Peninsula, promote conversion or disposal of nuclear weapon-related facilities, and meet international safety standards at facilities and test sites. It is also important to promote the redeployment and capacity-building of nuclear

weapon program participants.
- The results from these efforts could contribute to the establishment of alternatives in the process of resolving the North Korean nuclear issue, such as handling existing nuclear facilities and test sites, relocating personnel, and resuming the KEDO LWR project, which was terminated in 2006. If done successfully, North Korea may be able establish a nuclear safety infrastructure that facilitates the peaceful use of nuclear power and radiation.

ENDNOTES

1 Prior to termination of the project, KEDO consisted of a total of 13 member countries, and the EU joined as a board member in September 1997.

2 North Korea's constitution and acts are available in the Database on a Unified Korea's legal system: https://www.unilaw.go.kr/bbs/selectBoardList.do?bbsId=BBSMSTR_000000000021.

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CONCLUSION

In exploring potential avenues for U.S.-ROK-DPRK engagement on nuclear energy and safety, this volume has offered in-depth analysis, covering historical background, current conditions, and insights into future challenges and opportunities. In summary, the volume highlighted the follow insights:

- International support to expand nuclear power for peaceful purposes in North Korea has the potential to improve energy access for North Korean citizens and promote economic development and national welfare in one of the most energy deficit countries in the world.
- Preventing nuclear accidents is fundamentally a global responsibility, and it is the responsibility of the international community to consider avenues for cooperation on nuclear safety and security, even in the case of North Korea.
- Much can be learned from previous nuclear nonproliferation and energy engagement frameworks, such as U.S.-Soviet CTR initiatives and the KEDO LWR project—both serve as invaluable legacies for future discussion on nuclear energy, safety, and security on the Korean Peninsula.
- Given South Korea's established comprehensive safety infrastructure and accumulated experience in peaceful nuclear and radiation use, South Korea would be a most effective and efficient partner in North Korean nuclear energy engagement.
- Though desirable, any future diplomatic engagement will be contingent on workable diplomatic framework and desired outcomes that are acceptable to the major players—first and foremost Pyongyang, Washington, and Seoul but also Beijing, Moscow, and Tokyo.
- It is vitally important for the United States and South Korea to cooperate closely on future North Korean energy and safety engagement, particularly in the nuclear field. Through cooperation, both country's respective strengths in the nuclear technology, safeguards, and security could be maximally utilized towards the common goal of denuclearization and transference of North Korea's nuclear military program to civil nuclear use.

From these observations, the varied policy recommendations can be gleaned. While each chapter presents individual perspectives and policy arguments, a few key recommendations are listed below:

- Washington and Seoul should be prepared to re-engage Pyongyang with serious proposals towards the elimination of nuclear weapons and the normalization of relations should the opportunity arise.
- Clear lines of communication should be established by Washington and Seoul with Pyongyang to avoid misunderstandings or miscalculations that may lead to a nuclear exchange. Even under continued diplomatic stalemate, Washington and Seoul should consider the establishment of a diplomatic hotline.
- As North Korea's nuclear technical experience grows, its intent to access and development nuclear power is not unimaginable. To ensure local and regional safety, North Korea should be required to integrate into the international community's global framework for nuclear safety and security.

- The international community, while interacting with North Korea on the nuclear issues, should take an interest in North Korea's nuclear safety and urge cooperative interaction with the North's nuclear regulatory authorities (i.e. SNSRC).
- The United States and South Korea (alongside other regional neighbors) should explore options to establish emergency response procedures with North Korea in the case of nuclear accidents either in North Korea or on the Korean Peninsula more broadly.
- In the event of successful implementation of a freeze, halt, and rollback of North Korea's nuclear weapons program, the United States, South Korea, and North Korea could conduct a joint study for the most effective means to produce nuclear electricity in North Korea. Considerations of lessons learned from KEDO, efficacy of small modular reactors (SMRs) to larger LWRs, and the future of the IRT-2000 reactor could be explored.
- Only after considerable progress towards rollback and elimination of North Korea's military nuclear and long-range missile programs were agreed upon might the United States and South Korea take measured steps to assist North Korea with civilian conversion of its nuclear program.

Clearly, while this report lists specific policy suggestions, future refinement and clarification will be needed based on international factors, such as the progression of U.S.-China strategic competition, future conditions of ROK-DPRK relations, and changes in political leadership in South Korea and the United States, among others.

Whether opportunity for cooperative efforts are presented—serving as confidence-building stepping-stones, strengthening trust, and helping to prevent a dangerous escalation of tensions on the Korean Peninsula—or, as may be expected, North Korean tensions continue reducing the likelihood of diplomatic engagement, in either scenario, Washington and Seoul will need to work together to address the future of global nuclear energy and safety, avoiding meltdowns and blackouts on the Korean Peninsula and beyond.

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