Fukushima's Implications for Korea's Nuclear Dilemmas

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The cascade of events starting with the November 2010 unveiling of the DPRK's enrichment and small light water reactor program that culminated with the Fukushima meltdowns after the 3.11 earthquake-tsunami has redefined the nuclear issue in the region, and especially in Korea.[1]

The nuclear event in Japan is not yet over. That will only happen when the reactors that suffered partial meltdowns at Fukushima achieve some kind of cold shutdown status, and the spent fuel ponds are stabilized. It will take at least a year to achieve this status;[2] and then between 1 and 3 decades to dismantle and cleanup the site and surrounding area.[3]

Thus, it is still premature to speculate on the exact scope of the event and its implications both for nuclear power and nuclear proliferation in the region.

Nonetheless, certain tentative broad conclusions may be drawn already from the impacts already observed at Fukushima and its aftermath.

First, in the narrowest sense of where nuclear reactors may be built safely in the future, the Fukushima disaster exposed the folly of co-locating reactors (so that one may make it impossible to work in an adjacent reactor), and of locating reactors in coastal zones subject to tsunamis. Already, countries such as Vietnam are revisiting their design criteria for nuclear plants, especially the risk posed by tsunamis higher than 4 or 5 meters assumed to be the worst case in planning for nuclear plants in that country.[4]

Second, locating spent fuel ponds in the vicinity of the reactor cores, inside reactor secondary containment buildings, let alone suspended high in the reactor building, has been exposed as a

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[1] See P. Hayes, D.von Hippel, R. Tanter, T.Kae, J. Kang, B. Wen, G.Thompson, K. Yi Kiho, A. Imhoff, S. Bruce J. Diamond, *After the Deluge: Short and Medium-term Impacts of the Reactor Damage Caused by the Japan Earthquake and Tsunami*, NAPSNet Special Report, March 17, 2011, at: http://www.nautilus.org/publications/essays/napsnet/reports/SRJapanReactors.pdf

[2] See TEPCO, "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station," April 17, 2011 at: http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110417e12.pdf

[3] Mariko Yasu and Maki Shiraki, "Hitachi, GE Submit Proposal to Dismantle Crippled Fukushima Nuclear Plant," April 12, 2011, at: http://www.bloomberg.com/news/2011-04-13/hitachi-ge-file-proposal-to-scrap-fukushima-dai-ichi-plant.html

[4] Le Dai Dien, "Overview on Tsunami Risk Evaluation and NPP Project in Vietnam," presentation at 1st Kashiwazaki International Symposium on Seismic Safety of Nuclear Installations, November 24-26, 2010, Niigata, at: http://www.jnes.go.jp/seismic-symposium10/presentationdata/3_sessionB/B-09.pdf

design flaw of enormous significance. Spent fuel ponds contain the fuel from scores of reactor years of operation, and represent a greater radiological threat per se than the reactors themselves. Problems at the spent fuel pond implicate the reactor building and operations, and vice versa. With hindsight, it's hard to believe that the designers and regulators did not realize that this was a dumb idea that created the possibility of a common failure mode to the spent fuel pond and to the reactor core cooling systems. Remarkably, however, this was the case in the early years of the GE boiling water reactors, and TEPCO proved unable to respond to recent advice that it faced an overwhelming tsunami threat.[5]

In the future, spent fuel ponds should be located away from reactors, and likely should also be underground, especially in warzones such as Korea. Moreover, for the short period that spent fuel is kept on-site in a pond, that structure be built to cool the contents passively, and viewed as a container for possible meltdown and sub-critical fission events. It should be transferred as soon as possible into dry cask storage and then transported to a surface or subterranean storage facility, to reduce the risk of damage from earthquake, tsunami, fire, or terrorist attack. Furthermore, a distributed strategy rather than a centralized spent fuel facility may reduce overall risk of catastrophic release.[6]

Third, the Fukushima event has exposed the need for already demanding nuclear reactor technology to build in new features, including off-site, shielded duplicate control centers, standby back-up power, via diesel generator and battery power, at a minimal elevation safe from tsunamis, pressure relief valves that work manually in case of loss of on-site battery backup power, color coding of key components so that robots and drones can identify scattered and broken equipment, and stores of boron and other critical materials should be pre-positioned at all facilities.

Fourth, the Fukushima event confirms, yet again, the centrality of the human contribution to the operation of high technology subject to low probability but extreme failure events. The range of issues that need to be revisited based on the Fukushima experience to date includes setting international standards for nuclear accident site stabilization and recovery operations, rather than *ad hoc* adjustments to domestic standards based on expediency; an international response capacity that is standing in organization and rapidly deployable (similar to that in operation already for earthquakes) rather than organized ad hoc and only after significant delay (three weeks in the case of Fukushima); and a complete review and likely massive strengthening of the obligations of states under the Convention on Nuclear Safety to share information with neighboring states as well as domestic populations.

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[5] K. Krolicki, S. DiSavino, T. Fuse, Special Report: Japan engineers knew tsunami could overrun plant, March 29, 2011, at: http://www.reuters.com/article/2011/03/29/us-japa-nuclear-risks-idUSTRE72S2UA20110329

[6] Akira T. Tokuhiro, "Early lessons from Fukushima Daiichi nuclear power plant crisis," abstract of paper submitted to Nuclear Exchange, April 14, 2011, at: http://www.powergenworldwide.com/index/display/articledisplay/2206353516/articles/powergenworldwide/nuclear/reactors/2011/04/early-lessons-from-Fukushima-Daiichi.html?cmpid=EnlPEApril152011

The impression was unmistakable that the Japanese government strove mightily in the first weeks of the nuclear crisis to share massively the information that it had at hand, but equally strongly, avoided any revelations about the range of possible response requirements based on forecasting due to uncertainty—leaving the impression that much knowledge about the potential threat was denied to the public and neighbors, as distinct from information being shared.

Fifth, the shattering of the Fukushima nuclear complex in the midst of an enormous earthquake and tsunami exposed the plant operator, TEPCO, to enormous stress. At one point, TEPCO's CEO Masataka Shimizu reportedly was hospitalized due to exhaustion caused by the overwhelming flood of information, the press of responsibility, and the weight of decisions.[7] The nuclear workers exposed to terrible conditions at the site are depressed and exhausted. As the emergency became protracted, criticism of the monopolistic practices of the nuclear utilities in Japan, and their immunity from past criticism and demands to be more accountable to municipal and provincial authorities, let alone local communities, has flooded into the mainstream daily and weekly newspapers in Japan.

Sixth, the event has been framed as one in which the victim—the Japanese people—faced a villain—the tsunami, as if this event were natural in origin, supplemented by the notion of TEPCO's "culture of complicity."[8] In reality, the roots of Fukushima plant and liability for its failures are found not only in Japan's domestic political economy and institutional structure of the power sector, but also in the US Eximbank financing and nuclear export program used by General Electric to sell reactors to TEPCO in the first place, including those at Fukushima. In this convenient arrangement, General Electric received sovereign immunity against liability arising from accidents and malfunctions at the plants that it sold to and built in Japan. To date, General Electric has managed to stay out of the limelight. I predict that situation will change as enquiries are held as to what went wrong at Fukushima, and how a plant could be constructed to fail so monumentally. Liability for major nuclear accidents will certainly be an issue faced by nuclear exporters in the future; and it is possible that old indemnity agreements may be challenged legally should the accident investigation show negligence on the part of reactor suppliers and architect-engineering firms. This issue is also salient in Korea.

Seventh, the Japanese government will almost certainly need to request that an international official enquiry be convened, in addition to whatever domestic investigation of the causes of the failure is undertaken.[9] Whether the international enquiry is convened by Japan itself, or at its request by the International Atomic Energy Agency is immaterial. What is important is to recognize that this

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[7] A. Higgins. "Vanishing act by Japanese executive during nuclear crisis raises questions," *Washington Post*, March 28, 2011, at: http://www.washingtonpost.com/world/vanishing-act-by-japanese-executive-during-nuclear-crisis-raises-questions/2011/03/28/AFDnHNpB_print.html

[8] N. Onishi and K. Belson, "Culture of Complicity Tied to Stricken Nuclear Plant," *New York Times*, April 26, 2011, at: http://www.nytimes.com/2011/04/27/world/asia/27collusion.html?_r=1&hp=&pagewanted=print

[9] As called for by Richard Lester, head of the Nuclear Science and Engineering Department of MIT (where the light water reactor was originally designed) speaking on nuclear leadership challenges after Fukushima at the Symposium on Nuclear Energy in 2050, in an audio podcast, Center for Advanced Nuclear Energy Systems, March 30, 2011, at: http://techtv.mit.edu/collections/nse/videos/11797-richard-lester-audio-podcast

accident exceeded the bounds of the imagination of these who promoted nuclear power, and was a truly global event—within weeks, radiation had not only circled the entire northern hemisphere, but had also spread across the inter-tropical convergence zone into the southern hemisphere.[10]

Relatedly, not only is the event not simply the responsibility of TEPCO and the nuclear bureaucrats of the central government; it is also the responsibility of those who promoted nuclear power in the first place. The GE television advertisement in Japan that said of its boiling water reactors "We bring good things to life" looks surreal today.[11]

Eighth, the Fukushima event prefigured the risk that a state or a non-state actor may select a nuclear fuel cycle facility, especially reactors and spent fuel ponds, as targets for radiological warfare (as against a war in which nuclear warheads are used).[12] The relatively low levels of security at most nuclear facilities is not capable of withstanding a well organized terrorist attack using modern light arms and missiles.[13] No doubt this issue will be a major theme at the 2012 Global Nuclear Security Summit in Seoul, but Fukushima has made the issue of radiological terror immediate and urgent.

Ninth, an unexpected discovery in response to the earthquake-tsunami's impact on central power stations, fossil fuelled as well as nuclear powered, and on the transmission and distribution grid, is that a combination of rapid deployment of modular, small renewable combined with a massive program of efficiency in household, commercial, and industrial end use, may provide faster and cheaper resilience in large-scale collapse or destruction of critical power infrastructure than conventional power systems.[14] This is because central power stations take at least 2 years to build, whereas photovoltaics, windpower, and end use efficiency can be installed very quickly, provided the supply infrastructure exists—and once installed, will continue to operate locally even when the central grid is down. The economics of such a massive response are much improved by the existence of an integrated, national smart grid, which is almost completely lacking in Japan today, but such a grid would further enable intermittent renewable to add resilience to power systems in a faster, more reliable manner than central power stations.

Tenth, Fukushima has stalled the nuclear renaissance in Asia. China is revisiting its nuclear expansion plans; the Philippines put starting its long-completed but never operated reactor on the side of a volcano back onto indefinite hold; opponents to nuclear sites have erupted in Muria in Indonesia (led by the local Islamic community), and in India, long thought to be immune to nuclear

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[10] Comprehensive Nuclear-Test-Ban Treaty Organization, "Update 13 April: radioactivity also measured in the southern hemisphere," April 26, 2011, at: http://www.ctbto.org/press-centre/highlights/2011/fukushima-related-measurements-by-the-ctbto/fukushima-related-measurements-by-the-ctbto-page-1/

[11] See: http://www.culturepub.fr/videos/la-pub-radieuse-de-general-electric

[12] See B. Ramberg, *Nuclear Power Plants as Weapons for the Enemy, an Unrecognized Military Peril*, University of California Press, Berkeley, 1980.

[13] G. Thompson, *Robust Storage of Spent Nuclear Fuel: A Neglected Issue of Homeland Security*, Institute for Resource and Security Studies, January 2003, at: http://www.nirs.org/reactorwatch/security/sechossrpt012003.pdf

[14] D. von Hippel, K. Takase, P. Hayes, R. Tanter, *The Path from Fukushima: Short and Medium-term Impacts of the Reactor Damage Caused by the Japan Earthquake and Tsunami on Japan's Electricity Systems*, NAPSNet Special Report, April 11, 2011, at: http://www.nautilus.org/publications/essays/napsnet/reports/SRJapanEnergy.pdf

critics. Germany and Italy are bowing out of nuclear power altogether, and reactors begun but not completed in Texas have been simply terminated.

Which brings us to Korea, a tiny nation festooned with reactors in the South and with big aspirations to export its standardized pressurized water reactors, and with one small light water reactor under construction in the North.

In reality, South Korea not only must revisit all the issues outlined above, and retrofit its existing fleet of reactors in many cases. This alone will take much time and money. Now, however, South Korea's ambitious reactor expansion plan faces a more demanding siting constraint. Co-location of reactors will certainly be re-examined, and the idea of simply increasing the density of fuel rods stored in spent fuel ponds is unarguably a bad idea—as was reinforced by an authoritative MIT report issued on April 26, 2011 on the future of the nuclear fuel cycle.[15] In effect, South Korea can only increase the reactors in its expansion plan by building more on existing sites and running the risk of common failure modes between reactors, and across reactors and spent fuel ponds. In addition, the pressure to separate spent fuel storage from reactor sites increases the urgency of identifying a safe and reliable set of distributed spent fuel sites—already a politically gridlocked issue due to local community resistance.

The result is three new inexorable political pressures on nuclear decision makers. The first is to accelerate direct disposal of nuclear waste while increasing underground interim spent fuel storage capacity—the latter being necessary to ensure that aerial bombardment of a spent fuel pond does not result in a massive radiological release in Korea which would render the surrounding land uninhabitable for thousands of years, while the spent fuel cools off enough to be disposed of deep underground.

The rapidly emerging deep borehole technology promises a realistic solution to this problem in the medium-term, but like Japan, due to the ideology of plutonium-based energy strategies, South Korea has not investigated this option in a meaningful way.[16] There appear to be suitable geological formations in both North and South Korea for emplacing high level nuclear wastes permanently into holes drilled three to five kilometers deep where the material will remain securely sequestered for millions of years.[17]

However, to exploit this option, two ideologies will have to be junked: first, that spent fuel is a precious resource that must be kept for future recycling rather than irretrievably disposed, a

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[15] MIT, *The Future of the Nuclear Fuel Cycle*, 2011, at: http://web.mit.edu/mitei/research/studies/documents/nuclear-fuel-cycle/The_Nuclear_Fuel_Cycle-all.pdf

[16] See P. Hayes, D. von Hippel, *Deep Borehole Disposal of Nuclear Spent Fuel and High Level Waste as a Focus of Regional East Asia Nuclear Fuel Cycle Cooperation,* NASPNet Special Report, December 13, 2010, at: http://www.nautilus.org/publications/essays/napsnet/reports/Deep%20Borehole%20Disposal%20von%20Hippel%20-%20Hayes%20Final%20Dec11-2010.pdf

[17] J. Kang, An Initial Exploration of the Potential for Deep Borehole Disposal of Nuclear Wastes in South Korea, NASPNet Special Report, December 16, 2010, at: http://www.nautilus.org/publications/essays/napsnet/reports/JMK_DBD_in_ROK_Final_with_Exec_Summ_12-14-10.pdf

paradigm based on the further error of thinking that uranium is in scarce supply; and second, that North Korea will remain forever an enemy of South Korea. Some observers have even remarked sardonically that a good place to start a deep borehole industry in North Korea might be at its mountain nuclear test site, already drilled deep underground.

The second trend is to look for new places to site reactors. The natural solution is to site them in North Korea and build a truly integrated, smart national grid that covers the whole of the Peninsula, and ties to the Russian, Chinese, Mongolian, and Japanese grids, thereby allowing massive amounts of solar generated power to be shipped to South Korea and Japan. Thus, if the South wants safe siting of nuclear power, it needs to hasten the rapprochement with North Korea. Period.

The third trend is to rethink the strategy of increasing reliance on nuclear power which ironically, reduces technological diversity in the power sector and makes it vulnerable to severe technological flaws that can shut down many reactors at the same time, as Japan has discovered to its chagrin in the last decade.[18] The introduction of a smart grid into the ROK with a much stronger emphasis on renewable and energy efficiency, combined with decreasing reliance on nuclear power as a fraction of electricity supply, appears to be a sensible strategy. Incidentally, such a strategy would reduce the risk of radiological hazard arising from state and non-state actor attacks on fuel cycle facilities in the South—a real hazard due to the continuing risk of war in the Peninsula that politicians and nuclear proponents prefer to not talk about, but no less real as a result of the neglect.

Meanwhile, the only place to find new sites for reactors is in the North or underground in the South.

It is hard to imagine South Korea engaging the North on cooperative approaches to power grids and reactors while conservatives rule in Seoul. However, the South not only faces an energy security and sustainability imperative with the North in relation to its own nuclear power. It also faces the threat of a nuclear accident in the North at the small light water reactor that is now under construction at Yongbyon. This reactor is intended to be about 10 percent of the size of one of the five reactors at Fukushima. Nonetheless, the North Korean reactor will be directly upwind from Pyongyang and Seoul much of the year. Thus, it presents a very real possibility of a loss-of-control and meltdown given the primitive technology and materials, not to mention the unreliable grid that is one of the identified pathways to causing an unplanned crash shutdown of light water reactors and contributes to the risk of meltdown accident.

I believe that the North Koreans are well aware of the technological challenge posed by the directive from the central political leadership to complete the reactor in time for celebrations of the 100th anniversary of the birth of Kim Il Sung. In 1994, the top leadership were briefed by competent electrical engineers that gigawatt sized reactors were too big for the North's electric power grid, and that they should not accept anything bigger than a 400 megawatt-electric reactor from the United States (the only problem being, no such reactor was commercially available at that size in the mid-

[18] The concept of technological diversity as a key attribute of energy security is explained in D. von Hippel et al, "Evaluating The Energy Security Impacts Of Energy Policies," in Benjamin Sovacool, edited, *Routledge Handbook of Energy Security*, Routledge,2011.

nineties). The leadership proceeded anyway with the Sinpo project for two gigawatt sized reactors, in spite of the technical absurdity of the project. All along, the KEDO project was primarily about engaging the United States to change its hostile policies towards the DPRK rather than about energy per se.

The North's small light water reactor project is no different in that it is driven by purely political imperatives to look strong at home, while offering an opportunity to the United States and other parties, including South Korea, to become deeply engaged in the North's small light water reactor project—and along the way, bring its enrichment program into some form of support for the light water reactor program.

Elsewhere, I and Nautilus colleagues have outlined in some depth what such an engagement would look like,[19] and provided examples based on South Korea's own difficult early experience with the construction and regulation of light water reactors from a safety perspective.[20]

Here, the point I want to make is that after Fukushima, Seoul must make a choice.

It could engage the North to ensure that the small light water reactor project becomes an authentically inter-Korean project, and is implemented to international standards for design, engineering, and construction—which is hard to visualize given the political and military standoff today. Obviously, this could not be done in isolation from resolution of the nuclear weapons issue and a radical shift in both South Korean and American policy towards the North.

Alternately, it could treat the North's small light water reactor as a rapidly emerging environmental security threat to South Korea's population and land, and decide whether it will act militarily to halt the reactor's operation once it is turned on. (This could be as simple as cutting the power lines so that it has nowhere to transmit to, provided this is done early enough to ensure that there is almost no radioactive waste fission products in the reactor core built up and able to vent to the atmosphere in case of a catastrophic cooling failure and meltdown). Such a military intervention runs the risk of war and for this reason, is as difficult to visualize as engaging the DPRK.

Taking the path of apparent least resistance between these two very difficult choices is doing nothing, a third, faith-based strategy that risks a meltdown of the North Korean reactor with a massive radiation release over South Korea. The Blue House could choose to run this risk and pray that nothing happens, at least not on its watch—and ensure that a lot of potassium tablets are stockpiled. A reactor accident in the North would almost certainly exceed the North's capacity to

[19] See P. Hayes and D. von Hippel, "Engaging the DPRK Enrichment and Small LWR Program: What Would It Take?" NAPSNet Special Report, December 23, 2010, at: http://www.nautilus.org/publications/essays/napsnet/reports/vonHippelHayesLWR.pdf

[20] See S. Levy, *Update Review of Safety Aspects of Nuclear Power Program in Republic of Korea*, World Bank/UNDP, April 1982, at: http://www.nautilus.org/publications/essays/napsnet/reports and L. J. Droutman, et al, *International Deployment of Commercial Capability in Nuclear Fuel Cycle and Nuclear Power Plant Design, Manufacture, and Construction for Developing Countries*, October 1979 for Oak Ridge National Laboratory, at: http://www.nautilus.org/publications/essays/napsnet/reports/LWR%20Droutman%20Nuclear%20Power%20Developing%20Countries%201979%20Final%20Report%20on%20Task%207.pdf

respond to the physical and logistical demands of dealing with the site stabilization and recovery operation itself, let alone evacuate large populations from downwind, possibly permanently. Paradoxically, such an accident might lead to a humanitarian operation involving external forces, possibly orchestrated by China or Russia, and even involving South Korean experts, equipment, and material.

However, compared with the rapprochement and engagement strategy, the other two strategies are fraught with the risk of war, and risk of meltdown and radiation.

Thus, a prudent South Korean leadership would carefully survey the post-Fukushima landscape of opportunity and peril in the nuclear world, and recast its North Korea policy with the lessons of Fukushima in mind, in order to ease the difficulties of pursuing nuclear power in a very small, crowded Peninsula and to overcome the security dilemmas created by nuclear power and nuclear weapons in this tiny land mass.