한국외국어대학교 국제지역연구센터

HK+국가전략사업단 총서시리즈 1

Supra-National Cooperation and Communication for the Sustainable Development of the Korean Peninsula

Edited by

HK+ National Strategies Research Project Agency,
Center for International Area Studies, Hankuk Univeristy of Foregin Studies

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EDITED BY HK+ National Strategies Research Project Agency, Center for International Area Studies, Hankuk University of Foreign Studies
(Oh, Gyeong-seob; Han, Sang-Un; Kim, Seung-Hyun; Hong, Yun Geun; Hayes, Peter; Kanaev, Evgeny Aleksandrovich; Wang, Yun (Ray); Haruki, Ikumi)

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Contents

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Part II

Seeking Supra-National Cooperation for the Sustainable Development of the Korean Peninsula

Mutual Assured Interdependence : Regional grid connection and microgrids*

- Hayes, Peter -

* Acknowledgements: This work rests on funding from various donors, but especially MacArthur Foundation; and the research work of my Nautilus colleagues, especially David von Hippel, and Nautilus' partner scholars and practitioners in all countries of Northeast Asia involved in the Regional Energy Security Project, and the Nagasaki 75th Anniversary Pandemic-Nuclear Nexus Scenarios project. I am also grateful to Tatsujiro Suzuki for his phrase "mutual assured dependence" which becomes mutually assured interdependence in this essay.

1. INTRODUCTION

This paper describes four different but convergent imperatives that define supra-national cooperation and communication needed to enable sustainable development of the Korean Peninsula. By definition, supra-national refers to a level of cooperation that transcends that arising from relations between nation-states, but who and how effects supranational cooperation is an open-ended question.

Korea is also a peculiar case in that it is one nation divided into two nation-states that are recognized by the United Nations and via bilateral recognition between other states and the two Koreas, but neither Korea recognizes the other's sovereignty over itself or the territory of the Korean Peninsula.

In this essay, we will assume that supranational cooperation includes but is not limited to inter-Korean state-level cooperation as well as between other states and inter-governmental organizations such as development banks, but also encompasses non-state actors such as market and civil society actors.

Sustainable development in this essay is defined to include four dimensions viz: the maintenance of security and peace between states, the geopolitical dimension; the provision of habitat and biodiversity that provide environmental services to all humans, the geo-ecological dimension; the conduct of economic activities that meet essential human needs for shelter, food, and energy security, or (when integrated across borders) the geo-economic dimension; and, the current restructuring of all dimensions of human existence due to pandemics that force humans to spatially distance in all sectors to manage infection from pathogens, resulting in a global re-spatialization of human society at all levels and in all dimensions, referred to here as the geo-epidemiological dimension.

In the rest of this essay, I describe the evolution of sustainability in each of these four dimensions as it pertains to the Korean peninsula. I conclude with a policy recommendation for consideration by policymakers in the post-Trump era of COVID-19 multilateralism that weaves together these four themes into a practical initiative at the regional level in Northeast Asia based on truly supranational cooperation to resolve multiple and urgent problems at the same time.

2. SUPRANATIONAL COOPERATION FOR KOREAN SUSTAINABILITY

In this section, we examine supra-national cooperation in the four dimensions listed in section 1, geo-politics, geo-ecology, geo-economics, and geo-epidemiology.

A. Geo-political cooperation

As is well known, the first phase of supra-national cooperation with the DPRK began in earnest with the eruption of the DPRK nuclear issue in 1991-92. This issue became the subject of international concern in the late eighties as the DPRK constructed a reactor suitable for producing plutonium that could be used in a nuclear weapon and without a plausible argument to do so that related to its plans for power reactors then under contract for supply from the former-Soviet Union FSU). Driven by decades of nuclear threats from the United States and the collapse of its external security alliance with the FSU, the DPRK began a slow-motion proliferation program involving plutonium reprocessing and missile test, combined with threat rhetoric. The DPRK leaderships' clear intention was to force the

United States to change its "hostile" policy towards the DPRK by making the proliferation threat increasingly potent, both verbally and with highly calibrated fuel cycle activities and missile testing events. This form of nuclear compellence (forcing someone to stop what they are already doing, not deterrence, which forces someone to not do something they are not already doing) was encapsulated in a single phrase spoken to me by Kim Yong Sun's translator, that the nuclear issue is "the barrier that makes the water flow."

The confrontation over the DPRK's withdrawal of reactor fuel rods from the Yongbyon 5MW reactor resulted in the 1994 US-DPRK Agreed Framework. The core of the Agreed Framework as a commitment by the United States to orchestrate the payment and construction of 2 1 gigawatt light water power reactors in return for which the DPRK froze its nuclear and missile testing program. The net results of this massive project that drew on 13 states led by the United States was the partial construction of these reactors until the project collapsed and ended in 2004 due to US-DPRK contention over the DPRK undertaking uranium enrichment and other proliferation activities. Importantly, neither China nor the Russian Federation were party to KEDO, creating an a-symmetry of power and resources between the states constituting KEDO, and the DPRK, a small, weak state afflicted by famine and dependent on external food aid to feed its population.

KEDO Hole in Ground and Foundations

KEDO image: LWR site

The KEDO project was an attempt to create a technological juggernaut that would force all parties to cooperate given the sheer scale of the committed resources, the momentum of such a large project, and the political difficulty of walking away from a multilateral effort which, once broken, could not be reconstructed again given domestic political conditions in the United States.[1] Once completed, the notion was that the

1) P. Hayes, "Should The United States Supply Light Water Reactors To Pyongyang?" paper to the symposium "United States and North Korea: What Next?" Carnegie Endowment for International Peace, Washington DC, November 16, 1993, https://nautilus.org/staff-publications/hayes1193-txt/

United States and the DPRK would move onto even tougher issues that divided them, in order to create confidence that the two parties intentions had shifted in increasingly irreversible ways. However, nuclear threat is a poor basis on which to build trust. In fact, this extortion attempted by both parties to force the other to cease and desist activities that the other found to be an existential (for the DPRK) or at least a vital (for the United States) security threat led to bad faith actions, and a downward spiral of conflict and confrontation. Instead of shifting to a relationship of mutual assured interdependence via this project, the United States and the DPRK lapsed back into an acrimonious relationship based on increasing threat to use nuclear weapons against each other that ultimately would result in a condition of mutual assured destruction. The best that can be said of this form of top-down geopolitical supranational cooperation is that it delayed the DPRK's nuclear weapons program by about eight years, and the reduction of tension and avoided costs of

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P. Hayes, "Light Water Reactors at the Six Party Talks: The Barrier that Makes the Water Flow, NAPSNet Policy Forum, September 21, 2005, http://www.nautilus.org/fora/security/0578LWR.html

P. Hayes et al, "Grid-locked: North Korea needs energy. But can the parties negotiating a solution to the nuclear crisis come up with a viable way to plug in the North?" Bulletin of the Atomic Scientists, 62, no.1 (January/February 2006): 52-58, https://journals.sagepub.com/doi/full/10.2968/062001014 increased US-ROK military readiness over these years likely greatly exceeded the net cost of the KEDO project, which was about $0.6 billion per year.

B. Geo-ecological cooperation

This same period—from 1991 to early 2000s—was also one in which supranational ecological cooperation in Northeast Asia accelerated, including many engagements of the DPRK on these issues under the rubric of UN specialized agencies such as the UN Development Program, the Asian Development Bank, UN ESCAP (Tuman River development program), and the Global Environment Facility regional projects on climate change, oceans management, biodiversity, etc.

By about 1998, it became evident that the KEDO reactors could not operate on the DPRK electric power grid because it was too small, too simple in terms of interconnections between power stations and distribution nodes in the national network, and wildly unstable in terms of voltage and frequency fluctuation as well as outages. This was well understood by KEDO and its DPRK counterparts, but not by most senior policymakers in the states that made up KEDO. In fact, I was told directly in 2008 that DPRK technical experts had advised DPRK supreme leader Kim Jong Il that only power reactors of 400 megawatt or less could be run on the DPRK grid (this was optimistic given the grid's technical state, but at least got the scaling correct).

However, the bargaining during the Agreed Framework negotiations meant that the United States was only willing to deliver liquid coal ("heavy fuel oil"), not the refined product demanded by the DPRK; and, it viewed the grid support requirements of the KEDO reactors to be a problem for the DPRK to solve—and one that would be addressed in the future once the reactor itself was completed or near so—as part of the technological juggernaut effect of the KEDO project that would lead to expanding cooperation over time.

This view greatly underestimated the cost and scale of overcoming the fundamental shortfalls of the DPRK grid. Light water reactors require a highly stable grid with a tiny frequency fluctuation and very rare outages. Forced outages are one of the main pathways that lead to rapid shutdown of reactors and possible loss-of-coolant accidents in light water reactors, and the KEDO reactors would simply not operate on any conceivable DPRK grid, even if it grew in size and connection density sufficiently to support 2 one gigawatt reactors (at the time, the North Korean grid ran on roughly 5 gigawatt of coal-fired power plants, and five gigawatts of hydro-power plants, with each being seasonal in availability—

but due to the DPRK's post-Soviet rupture in technical assistance and the collapse of its economy in the mid-nineties, the actual available generation was 1-2 gigawatt, not the installed 5 gigawatt in a given season). Moreover, just reconstructing the DPRK grid (let alone expanding it sufficiently to operate nuclear reactors safely) was estimated to cost roughly $40 billion over a decade—an annual cost roughly equivalent to the KEDO project's total cost at the beginning. No party was willing to entertain shouldering the financing of this cost and the issue was left unaddressed.

Russia-DPRK-ROK Grid Linked to KEDO LWRs

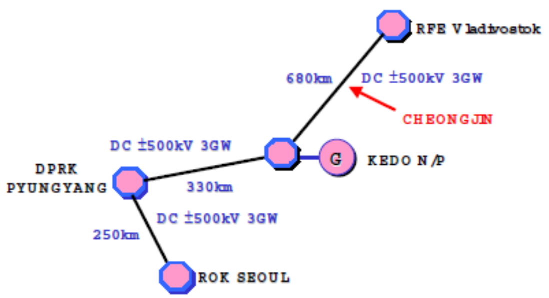


Figure 6: New Scenario Including the KEDO N/P

Source: Yoon Jae-young, Kim Ho-yong, Park Dong-wook, "Environmental Impacts and Benefits of Regional Power Grid Interconnections for the Republic of Korea," 3rd Workshop on Power Grid Interconnection in Northeast Asia, Nautilus Institute, Vladivostok, September 30, 2003, https://nautilus.org/esena/energy-and-the-environment/

For all these reasons, it was glaringly obvious by 2000 that there were only two ways to operate the two KEDO reactors should they be completed. The first was to construct a tie-line from the Russian Far East Vostok grid via the DPRK land-bridge to the ROK for a commercial power trading relationship that could link to the KEDO reactors, sending electrons in either direction depending on demand and available supply in what would have been a three-way ROK-DPRK-RFE power trading scheme. Alternately, the ROK could have built two AC lines to the KEDO reactors and set up a generation island in the DPRK which would have exported the power directly and only to the ROK, earning the DPRK baseload bulk power rates that would in turn allow it to pay off the concessional loans advanced by KEDO to the DPRK and still make a profit over decades of operation. Neither scheme allowed for direct export of power to the DPRK, then suffering from extreme power supply scarcity. Technically, this could only have been achieved by installing expensive AC-DC-DC-AC converter stations (as are used between Japan's two grids that operate on different frequencies) in order to ensure that the DPRK grid could not "export" its instability to the reactors, and it would almost certainly have been uneconomic.

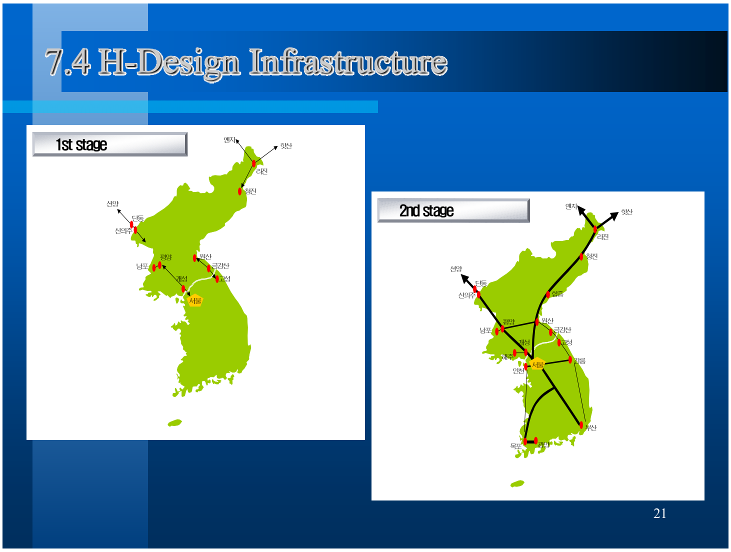
To explore the realistic conditions in which such a tie-line could be built, a series of regional power grid meetings were held in China and the Russian Far East involving utility experts from the six parties involved in the nuclear issue, including from the DPRK itself.

A critical dimension of these discussions was the potential environmental impact of cross-border tie-lines, including greenhouse gas emissions, habitat impact, migratory species impact, harmonized environmental standards for grid operation, and biodiversity corridor impact. Each of these aspects were studied in depth and the results shared between technical specialists.[2] One assumption that was explored and largely rejected was that DPRK grid refurbishment would simply be based on its existing network structure, and would follow the H-shaped infrastructure development concept based on an east and western coastal urban-industrial corridor, with an east-west connecting corridor from Pyongyang to Wonsan.[3]

2) See the many papers on these topics at https://nautilus.org/esena/energy-and-the-environment/

3) See W.B. Kim, "Design of Infrastructure Development in North Korea: A Practical Approach," presented at DPRK Energy Experts Working Group, Nautilus Institute, Beijing, March 8, 2008, http://oldsite.nautilus.org/DPRKEnergyMeeting2008/papers/

DPRK H-Infrastructure Design



Source: W.B. Kim, "Design of Infrastructure Development in North Korea: A Practical Approach," presented at DPRK Energy Experts Working Group, Nautilus Institute, Beijing, March 8, 2008, at: http://oldsite.nautilus.org/DPRKEnergyMeeting2008/papers/

However, this broad-brush concept had little relationship to reality on the ground. As the key generation, transmission and distribution elements of the DPRK's grid were already fully depreciated and beyond their economically useful life, and only operated at high cost, with huge externalities, and with constantly improvised repairs while enduring long outages on a daily basis, there was no reason to presuppose that the new urban-industrial geography will replicate the old Soviet and Chinese-inspired colocation of industry and populations, especially if wartime contingencies were removed from locational decisions. Already by this time, the haphazard and bottom-up provision of generation supply that became prevalent in the 2015-2020 period (of which more below) by households, villages, factories, and the military was an emergent property of the chaos on the ground.

Thus, technocratic and planned avoidance of the environmental impacts of cross-border corridors and tie-lines became increasingly disconnected from reality as the DPRK's isolation grew. This dynamic in turn led to contradictory tendences. The economic downturns in the DPRK meant that many pristine and isolated habitats were de facto preserved; but equally, the coherent planning of corridors to connect remnant habitats with each other, the relatively well preserved Demilitarized Zone, and the adjacent biodiversity assets of China, the Russian Far East, and Japan (for migratory birds) was impossible, and attempts to advance a policy agenda on a regional biodiversity corridor[4)] faded into the background.

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4) G. Bennett and Kalemani Jo Mulongoy, Review Of Experience With Ecological Networks, Corridors And Buffer Zones, CBD Technical Series No. 23 (Secretariat of the Convention on Biological Diversity, March 2006), www.cbd.int/doc/publications/cbd-ts-23.pdf and T.H. Moon, , "Sustainable Development In Korea, Key Issues And Government Response," *International Review of Public Administration* 11, no.1 (2006), http://post.cau.ac.kr/~thmoon/lecture/epps/06-KeySustainableIssues-IRPA11%281%29.pdf

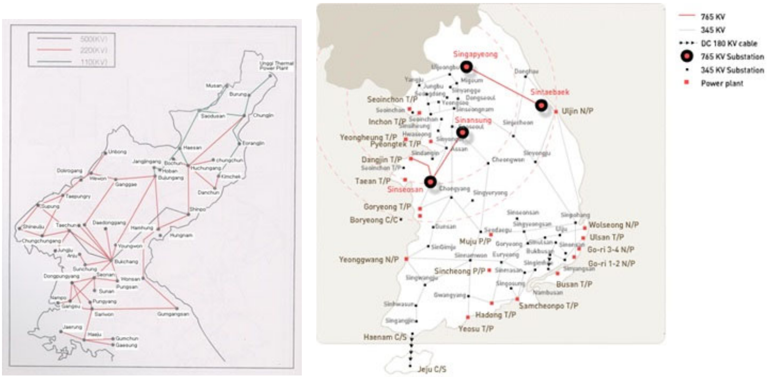
Regional Biodiversity Corridor

Source: T.H. Moon, , "Sustainable Development In Korea, Key Issues And Government Response," *International Review of Public Administration*, 11:1, 2006, at: http://post.cau.ac.kr/~thmoon/lecture/epps/06-KeySustainableIssues-IRPA11%281%29.pdf
"Sustainable Security in the Korean Peninsula: Envisioning a Northeast Asian Biodiversity Corridor," *Korean Journal of International Studies,* 8:10, 2010, pp. 197-230, at: http://nautilus.org/wp-content/uploads/2011/12/KJIS-Hayes-Biodiversity-Corridor-Final-As-Published-Dec-2010.pdf

C. Geo-economic cooperation

In the first decade of these dialogues, the focus of potential cooperation increasingly shifted from abstract economics and ecological impacts to more hard-nosed commercial and political considerations in trading power across borders.

DPRK and ROK power grids



Source: P. Hayes, et al, "South Korea's Power Play at the Six-Party Talks," July 21, 2005, at: http://www.nautilus.org/napsnet/sr/2005/0560ROK_Energy_Aid.pdf

For starters, the basis of the Russian-ROK trading relationship—the existence of surplus energy and peak generating capacity at different seasons in the RFE-ROK utilities—were reduced by rapid growth in demand in both utilities, thereby reducing the commercial basis for power trading. Concurrently, it became increasing clear that the geo-political aspect of the US-DPRK nuclear threat relationship would predominate over cooperation imperatives, leading to the increasing isolation of the DPRK land-bridge due to sanctions, albeit with expanding cross border trade between China and the Russian Far East with the DPRK reducing further North Korean incentive to cooperate with the United States. For its part, the United States was increasingly preoccupied with emerging competition with China at a global and regional level, and often the DPRK issue was relegated to a low priority in the US strategic calculus.

The net result is that regional dialogue on economic and grid integration diminished after 2008, and largely stagnated on a regional basis. States sought to cut their own deals with the DPRK and many did so, albeit on a stop-start basis.

Increasingly, regional dialogue was on a bilateral basis and the most vibrant were between China and Russia. Only after 2016 did quadrilateral dialogue on interconnected power systems occur again, leading to a 2016 Quadripartite MoU on cooperation on interconnected electric power grid signed by the State Grid Corporation of China, Japan's Softbank Group, Republic of Korea's KEPCO ("Korea Electric Power Corporation") and Russia's Rosseti ("Russian Grids"). As Valentin Voloshchak describes, "The four parties agreed to conduct feasibility and business evaluation studies on multinational power grid interconnections in order to propose their findings and suggestions to the relevant governments." Thus, the dialogue shifted from a track 2 civil-society convened dialogue with government observers to a track 1.5 dialogue involving the utilities themselves.[5)]

Russia-China Grid Integration Potential

Source: VALENTIN VOLOSHCHAK, "RUSSIA'S PERSPECTIVE ON NORTHEAST ASIA ELECTRICITY INTERCONNECTIONS", NAPSNet Special Reports, October 02, 2020, https://nautilus.org/napsnet/napsnet-special-reports/russias-perspective-on-northeast-asia-electricity-interconnections/

Concurrently, China began to convene a global interconnected grid project with a Northeast Asian sub-group (the DPRK invited, but not attending); the Asian Development Bank undertook a regional grid study focused on Mongolia as a key supplier of electric power using solar

5) VALENTIN VOLOSHCHAK, "RUSSIA'S PERSPECTIVE ON NORTHEAST ASIA ELECTRICITY INTERCONNECTIONS", NAPSNet Special Reports, October 02, 2020, https://nautilus.org/napsnet/napsnet-special-reports/russias-perspective-on-northeast-asia-electricity-interconnections/

energy for shipping over long-distance power lines; and the GOBITEC consortium[6)] began to promote a regional renewables-based grid concept. Almost none of these dialogues had any prospect of immediate take-up. And, the United States and the DPRK were conspicuously absent from these attempts to define a supranational cooperative effort to integrate regional grids, being domestically preoccupied or driven by their mutual threat to reinforce their nuclear antagonism, not resolve it.

Yet within markets, there was a new movement that portends a transformation of power utility structure, the relationship between generators and the transmission-distribution system, and the technological foundations of power production and end-use. In turn, this bottom-up, technology-driven and primarily market-implemented trend portends a radical shift in how power may be traded across borders.

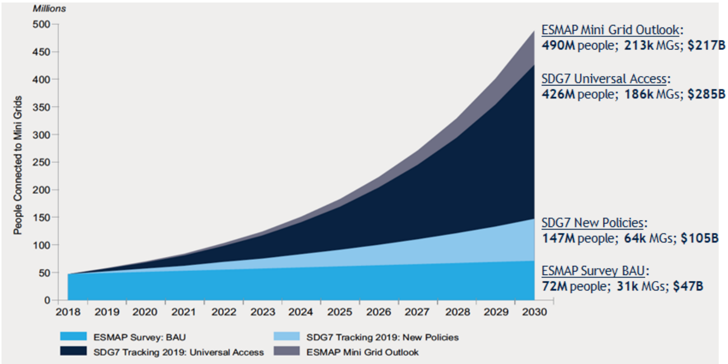
This trend is the rapid evolution and emergence of microgrids (also called minigrids), albeit at different rates and magnitudes in each country, but with astounding velocity when looked at globally, regionally and locally—and thus, largely unnoticed by policy practitioners operating in their respective geo-political, geo-economic, and geo-ecological

6) See GOBITEC INITIATIVE at https://gobitecdotorg.wordpress.com/about-gobitec-initiative/

spaces (but highly noticed in the geo-epidemiological sphere, as we shall see below).

Microgrids are simply grids that are relatively small in scale, controlled locally, and have either no (being remote) or limited reliance on national utility grids. They may be powered by biomass, hydropower, diesel, photovoltaic, or wind power, and often incorporate an energy storage system. As they may generate a surplus of power in times of resource superfluity relative to local demand, microgrids can also pump electricity back into the local grid, enabling the central grid to reduce large-scale, centralized generator output to save cost by dispatching demand to the least-cost supply, meet baseload demand, maintain adequate spinning reserves to avoid any instability in the grid leading to outages, and to offset intermittency of renewable energy supply when microgrids are short of energy to generate power locally. According to the World Bank, there are (pre-COVID-19) about 31000 microgrids already serving 72 million people with an investment to date of $47 billion. In 2020, the World Bank already has over 2275 microgrid projects under development, which will connect about 690000 customers and serve about 3.5 million people in its portfolio of 26 low-income countries. In 10 years, ESMAP estimated that microgrids will serve 490 million people via 230000 microgrids with a cumulative investment of $217 billion. Microgrids have arrived big-time in the developing world.7)

Expanding Microgrids in Developing Countries



Source: Chris Greacen, "INTEGRATING MINI GRIDS INTO NATIONAL GRIDS: TECHNICAL AND ORGANIZATIONAL ASPECTS", NAPSNet Special Reports, September 22, 2020, https://nautilus.org/napsnet/napsnet-special-reports/integrating-mini-grids-into-national-grids-technical-and-organizational-aspects/

But that is just the start of the microgrid revolution. In many developed countries where utilities running grids stressed by fires, facing extreme temperature-driven high demand, and stressed by rapidly increasing costs for fuel and hardware, consumers have implemented their own local,

7) See Chris Greacen, "INTEGRATING MINI GRIDS INTO NATIONAL GRIDS: TECHNICAL AND ORGANIZATIONAL ASPECTS", NAPSNet Special Reports, September 22, 2020, https://nautilus.org/napsnet/napsnet-special-reports/integrating-mini-grids-into-national-grids-technical-and-organizational-aspects/

corporate or community-based microgrids, connected to the grid, and are pumping power into the large utilities on a highly competitive basis at the same time as new and competitive storage systems are being deployed. In Northeast Asia, China has the most diverse and fully developed set of microgrid pilot projects,[8] followed by Japan in the aftermath of the 2011 tsunami and Fukushima reactor catastrophe that drove municipalities and households to shift to renewables and end-use efficiency.[9] The ROK too has a substantial microgrid development and testing program.[10] Even Mongolia has implemented microgrids on a large-scale relative to its national grid.[11]

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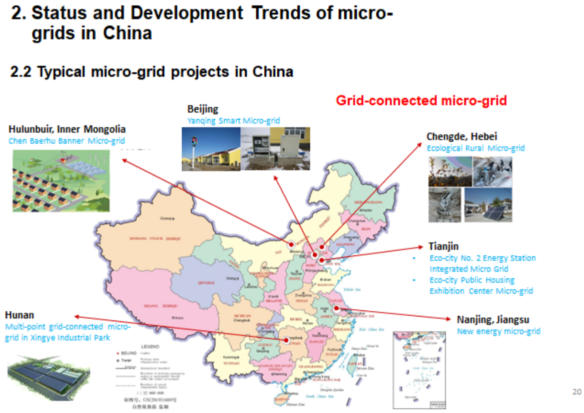
8) Yang Dechang, "MICROGRIDS FOR ELECTRICITY GENERATION IN CHINA", NAPSNet Special Reports, December 02, 2020, https://nautilus.org/napsnet/napsnet-special-reports/microgrids-for-electricity-generation-in-china/

9) Kae Takase, "Microgrids and Renewable Energy Trends Post-Fukushima in Japan," presentation, 2019–2020 Regional Energy Security Project, SECOND WORKING GROUP MEETING, Ulan Bator, December 10, 2019.

10) Woohyun Hwang, "MICROGRIDS FOR ELECTRICITY GENERATION IN THE REPUBLIC OF KOREA", NAPSNet Special Reports, September 27, 2020, https://nautilus.org/napsnet/napsnet-special-reports/microgrids-for-electricity-generation-in-the-republic-of-korea/

11) Tovuudorj Purevjav, "MONGOLIAN GRID DATA ", NAPSNet Special Reports, September 20, 2020, https://nautilus.org/napsnet/napsnet-special-reports/mongolian-grid-data/

Typical micro-grid projects in China



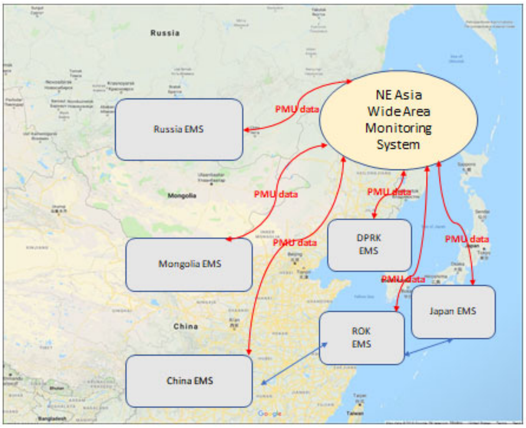
Source: Yang Dechang, "MICROGRIDS FOR ELECTRICITY GENERATION IN CHINA", NAPSNet Special Reports, December 02, 2020, https://nautilus.org/napsnet/napsnet-special-reports/microgrids-for-electricity-generation-in-china/

Admittedly, it is early days on the decadal scale of capital stock turnover in the energy sector. Conversely, microgrids and renewables have the advantage of being rapidly deployable and scalable in response to short term shifts in supply and demand, and in response to major discontinuities such as earthquakes, tsunamis, and (as we shall see below) pandemics. In short, microgrids already offer least cost, diversity, and resilience to existing grids, and as they mushroom, bottom-up, will shift the relationship between the transmission system and energy suppliers away from a few centralized generators to a large number of decentralized micro-grid operators.

The significance of rapidly growing microgrids in each country is that it portends shifts in the way that grids are monitored and managed, with implications in turn for how grids connected across borders will cooperate. In traditional, centralized grids, the centralized grid operator uses energy management systems at a few control stations to estimate periodically the status of the grid using software to calculate the grid's current and future performance, seeking to anticipate runaway and cascading failures of transmission or distribution lines, sub-stations, or sudden outages of big power plants. As the algorithms used to make these estimates contain non-linear variables, the computations can be inaccurate, and failures can transmit faster than operators can respond across the grid, and even be exported into neighboring, connected grids, leading to regional blackouts.

New Regional Grid System based on PMU Data Sharing

PMU phasor measurement units or synchro-phasors



PMU measurements are typically 30-120 observations per second – compared to every 2-4 seconds using conventional EMS technology.

Source: Jay Giri, "DATA AND MODELING EXCHANGE REQUIREMENTS FOR DESIGN AND OPERATION OF ELECTRICITY GRID INTERCONNECTION", NAPSNet Special Reports, September 29, 2020, https://nautilus.org/napsnet/napsnet-special-reports/data-and-modeling-exchange-requirements-for-design-and-operation-of-electricity-grid-interconnection/

Microgrids, by contrast, and increasing large scale grids, increasingly use actual measurement of a sufficiently large sample of grid links to determine the actual current status of the grid, communicated back to control stations 20-100+ times a second, thereby supplementing calculated estimates of current and future status with actual data.12) This approach

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12) Quang-Dung Ho, Tho Le-Ngoc, “Smart Grid Communications Networks: Wireless Technologies, Protocols, Issues, and Standards,” pp. 115-146, in

allows more precise and reliable grid management, and the ability to avoid cascading failures. The corollary is that linked grids must be willing to share this data with each other on a real-time basis, the more so to the extent that they are linked together.

The implications for the visions of future grid integration as microgrids grow and connect with each other and the national grid are massive. Instead of top-down mega-engineering transmission systems designed to be the architectural support for a small number of huge power stations—often run by the same oligopolistic power companies that control generation and transmission assets at the same time—the grid will evolve from the meshed networks of microgrids with long-distance transmission lines implemented to support local power production and use, not the other way around. In turn, cross-border connection entails importing and exporting not only electrons, but large amounts of data in real-time with vastly increased transparency.[13)]

M. Obaidat et al, edited, Handbook of Green Information and Communication Systems (Academic Press, 2013). https://www.sciencedirect.com/topics/engineering/phasor-measurement-units

13) Jay Giri, "DATA AND MODELING REQUIREMENTS FOR ELECTRICITY GRID INTERCONNECTIONS", NAPSNet Special Reports, May 09, 2019, https://nautilus.org/napsnet/napsnet-special-reports/data-and-modeling-requirements-for-electricity-grid-interconnections/

Regional Microgrid Experts in Mongolia, December 2019

Microgrids and Regional Power Connections field trip, Mongolia, December 14, 2019

Source: Nautilus Institute, photo Kosima Liu Weber

Ironically, the DPRK has begun to implement microgrids out of sheer necessity, due to the impact of UNSC council sanctions on diesel and equipment imports, and the shutdown of coal exports to China. The total decentralized power capacity already matches that of the central utility although the exact ratio is hard to estimate because it will be activated as the central grid stop-starts on a more or less random and haphazard manner.[14] But of all the grids in the region,

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14) David von Hippel and Peter Hayes, "DPRK IMPORTS OF GENERATORS IN RECENT YEARS: AN INDICATION OF GROWING CONSUMER CHOICE AND INFLUENCE ON ENERGY SUPPLY DECISIONS?", NAPSNet Special Reports, November 02, 2018,

because the centralized grid and power plants have effectively failed as a system, microgrids are mushrooming in the DPRK out of sheer necessity, and the transition to a micro-grid dominated national power system may be faster and easier than in any other country in the region—depending on the extent to which external constraints impose limits on microgrid growth. But the radical transparency needed to support the supranational cooperation needed to link power grids across national borders is a frontal challenge to the vertically structured and monopolistic utility structure and culture of the DPRK, and will be a major obstacle to regional grid connectivity under conditions of microgridification of national grids in the coming decade.

D. Geo-epidemiological cooperation

The pandemic is a truly global force. In less than a year, it has disrupted massively human existence and exchange on a global basis. It has reduced greenhouse gas emissions by slowing energy use; it has reduced human noise to a degree that's measurable on a global scale; it has ruptured and

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https://nautilus.org/napsnet/napsnet-special-reports/dprk-imports-of-generators-in-recent-years-an-indication-of-growing-consumer-choice-and-influence-on-energy-supply-decisions/

shortened global supply chains. It has isolated entire countries, regions, cities, communities, and households by requiring stringent lockdowns to disrupt the transmission of the coronavirus.[15)]

Many analysts argue that it has "merely" accelerated existing trends and brought suppressed conflicts to the surface, but the change involved is incremental, not systemic at the level of inter-state relations. Others suggest that due to the re-spatialization of human affairs in all sectors and at every level, we are in the midst of a global systemic transformation which will lead to a totally different distribution of power capacities in geo-political, geo-economic, and geo-ecological dimensions, only we just don't yet perceive the shape and dynamics of the new global system. This shift, they aver, is on a scale with the change wrought by the rise of European imperialism and the displacement of disconnected societies all over the world by colonialism; and the global bifurcation of the entire world into two competing blocs by the United States and the FSU after World War II. This pandemic, they suggest, is the start, not the end of this process as more pandemics, not less, and possibly far more lethal, are likely to hit humanity as more people commingle with habitats that are the non-human reservoirs for pathogens

15) INSERT SCIENCE article

that lead to pandemics, and the various infection pathways are likely to operate for the foreseeable future across borders and at a global level, no matter how good a vaccine is in one or other location.[16)]

This potential to disrupt and forcibly reshape power systems is particularly evident in power systems. Grids have proven remarkably resilient in the short term as COVID-19 took grip. That said, the pandemic has intruded powerfully into the microgrid world in a way that will sharpen the competition between microgrids and centralized grid operators for control in the future, although there are many contrary tendencies that may be observed at the same time.

The most obvious impact is that the pandemic has made it harder to implement microgrids, but also increased greatly the opportunity for those microgrids that survive or startup under pandemic conditions to take root over time.

In many locations in the region, COVID-19 restrictions slowed the installation of microgrids because engineering crews (especially international personnel) could not travel to the sites to perform surveys or install mini grid equipment and collect payments. Also, transport of hard has slowed, and

16) C.J. Nicholas Mascie-Taylor and Kazuhiko Moji, "PANDEMICS", NAPSNet Special Reports, October 12, 2020, https://nautilus.org/napsnet/napsnet-special-reports/pandemics/

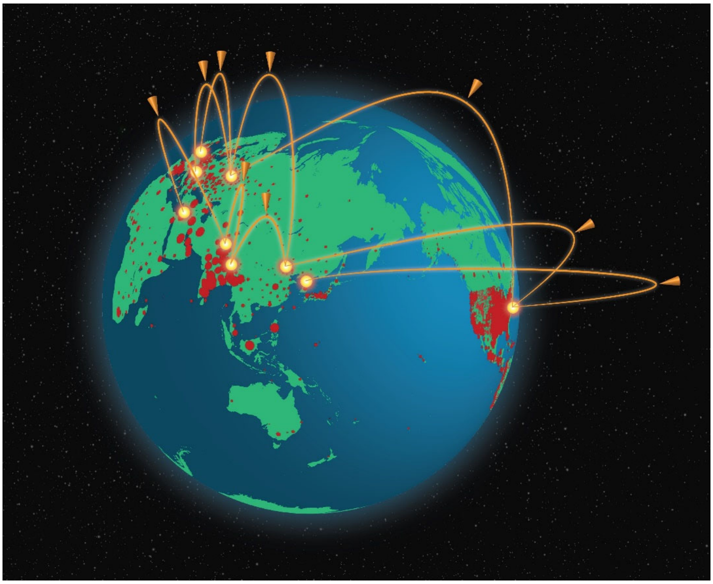
many essential mini-grid components have also become hard to source as factories in China shut down. Companies that install and operate mini grids have seen electricity demand and revenue fall significantly, and many are concerned about solvency.[17)]

Conversely, in many parts of the world, COVID-19 is making seasonal supply of power from the central grid much less reliable, and micro-grid powered communities are seeing the reliability benefits of local, decentralized generation. As Chris Greacen notes, "Communities that have functioning mini grids are still able to process rice, keep lights turned on at night, and charge cell phones necessary for communication."[18)]

17) Ulziilkham Uuganbayar and Tovuudorj Purevjav, "THE IMPACT OF COVID-19 CRISIS ON THE MONGOLIAN ENERGY SECTOR", NAPSNet Special Reports, September 24, 2020, https://nautilus.org/napsnet/napsnet-special-reports/the-impact-of-covid-19-crisis-on-the-mongolian-energy-sector/

18) Chris Greacen, "INTEGRATING MINI GRIDS INTO NATIONAL GRIDS: TECHNICAL AND ORGANIZATIONAL ASPECTS", NAPSNet Special Reports, September 22, 2020, https://nautilus.org/napsnet/napsnet-special-reports/integrating-mini-grids-into-national-grids-technical-and-organizational-aspects/

COVID19 Distribution September 25, 2020



Source: Sophia Mauro for Nautilus Institute. This graphic shows the pandemic distribution from the COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU) as of September 25, 2020; and the two-directional nuclear threat relationships between nuclear-armed states in the form of missile trajectories with re-entry vehicle at the apogees.

Moreover, even as national and local demand for power dropped due to producer and consumer lockdowns, fossil-fuel powered plants were often the highest cost and first to be turned off because renewables have the lowest short-run marginal supply cost. System operators managed to run grids at more than 70 percent renewable energy supply, contrary to conventional wisdom. In critically important end uses such as hospitals and clinics, distributed generation became the new power supply backbone due to modularity, speed, and low cost, especially for the rapidly expanding demand to support new hospitals built almost overnight to race against the exponential spread of coronavirus. For this reason, the pandemic has kickstarted many new microgrids, and hospital microgrids will become the backbone of new microgrids once the immediate COVID-19-related needs have passed. None of this happens by itself. As Greacen explains, this process requires collaboration across health, energy and water sectors, adapting cloud-based procurement and monitoring platforms, and using geospatial datasets of vulnerable populations to help to determine the most critical sites for system deployment. At the same time, it is necessary to ensure that inventories of solar panels, batteries and other components are matched with needs revealed by medical facility surveys and streamlined procurement documents and technical standards in the 24/7 race against the pandemic.[19)]

In short, microgrids have proven peculiarly adaptive to pandemic conditions and their growth in national power systems is almost certain to be accelerated greatly by *pandemonia*, or the continued chaotic adjustments forced by pandemic challenges for the foreseeable future driven

19) *Ibid.*

especially by the re-spatialization of human society.

3. CONCLUSION

This essay suggest that geo-epidemiological imperatives will rapidly expand microgrids and long-distance transmission support for regional meshed networks within national grids, setting the scene for linking grids across borders under new conditions of microgrid-dominated national grids over the coming years. The pandemic accelerates this trend driven already by geo-economic competition and market forces, and geo-ecological pressures to reduce greenhouse gas emissions and other ecological impacts of large-scale power generation. In the DPRK, the geo-political dimension has also forced the DPRK to early adoption of microgrids on a large scale relative to the pre-existing national grid, preparing it for early entry into a regional network of meshed microgrid networks —provided it is willing to be transparent in real time about the operating status of its own grid and share it with its connected neighboring grid operators and command centers.

At the same time, the pandemic may disrupt the long-term emergence of a gigacity corridor that connects cities from

Shanghai to Nanjing to Beijing to Shenyang to Pyongyang to Seoul to Tokyo, known to urban geographers as BESHOT O.[20] The infill between cities may slow or even reverse due to pandemic re-spatialization and disordering of globalized production supply chains in China and the region.

The outcome of these macro-trends is indeterminate at this early stage in this pandemic. What can and must be admitted is that the maintenance of a high standard of public health is now a first order security issue because no-one is safe from a pandemic unless everyone is safe. Public health infrastructure and standards is likely to emerge as an important topic of supranational cooperation in Northeast Asia. With that conversation comes the pre-existing geo-political, geo-ecological, and geo-economic baggage that must be jettisoned or redefined to accord with the existential imperatives of an emerging new world order defined by the pandemic.

Part of the solution to the legacy geo-political, ecological, and economic conflicts rests in embracing microgrids as a shared solution to complex, inter-linked common problems.

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20) Formerly BESOTO, but became BESHOTO as it was evident that the corridor already extends to at least Shanghai in the late 1990s. See Ulaanbaatar, "The transnationalization of urban systems: The BESETO ecumenopolis," Fu-chen Lo, Yue-man Yeung, ed, Emerging world cities in Pacific Asia (UN University Press, 1996), https://archive.unu.edu/unupress/unupbooks/uu11ee/uu11ee00.htm#Contents

This essay has sketched how this agenda may develop in supranational cooperation for provision of sustainable energy in the Korean peninsula.

In conclusion, I argue in this essay that a resilient, meshed power network will cross many borders but such cooperation is only possible with increased access, transparency and data sharing across national grids, and between and among microgrids. This conclusion has major implications for all countries of Northeast Asia—but most importantly—for the DPRK's power future, inter-Korean cooperation, and six party denuclearization agendas. In short, policy measures that recognize the seamless interconnections of these seemingly disparate problems is the pathway to realizing mutual assured interdependence in this region.