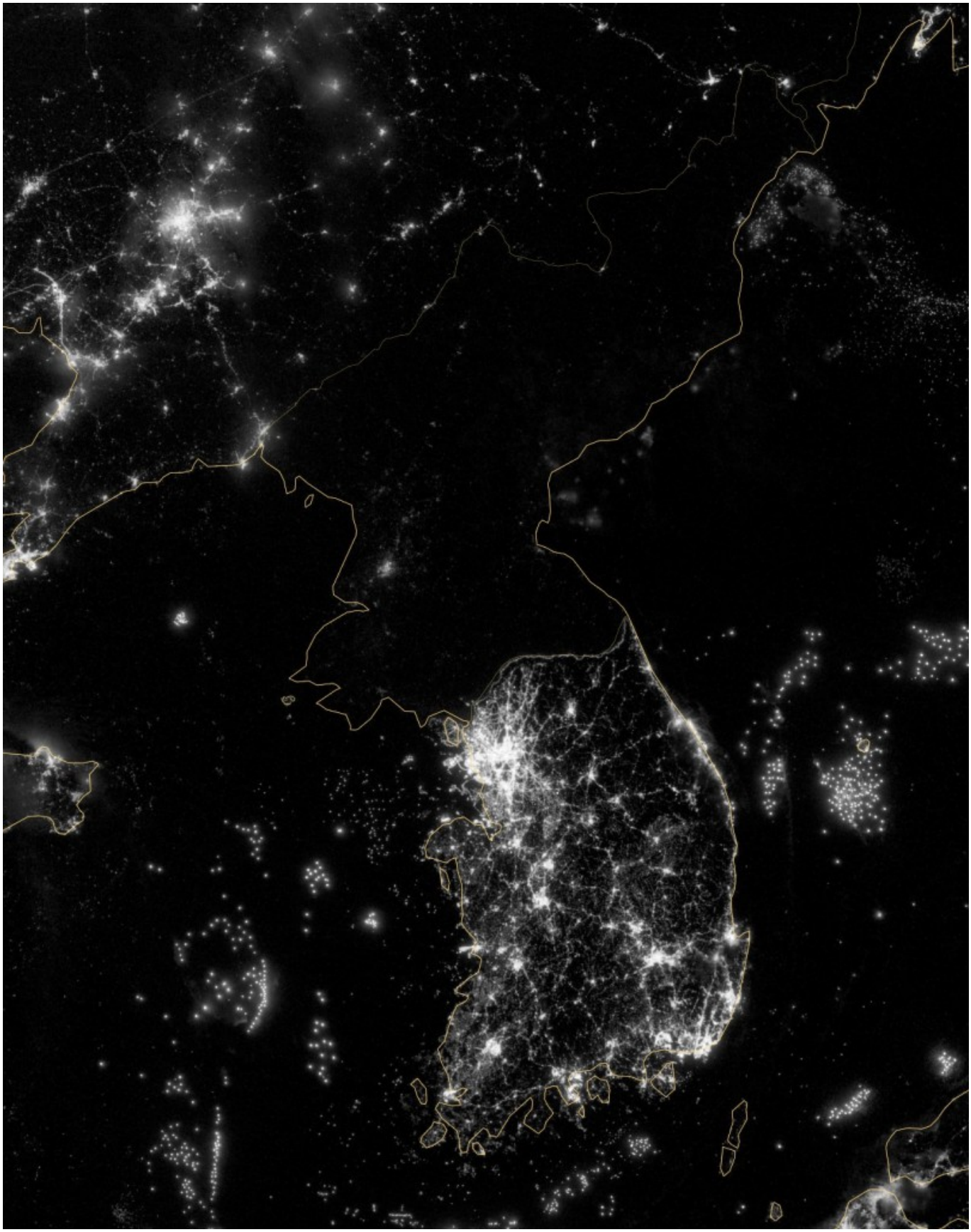
Energy Needs in the DPRK


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Energy Needs in the DPRK, and Opportunities for Collaboration on Energy Sector Engagement and Redevelopment

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I. INTRODUCTION

A series of events in the last few years and months have kept the Democratic People's Republic of Korea (DPRK) in the news. Starting with the succession of Kim Jong Un to the leadership of the DPRK following the death of his father, Kim Jong Il, and including events such as a nuclear weapons test and satellite launch/missile tests, the closing and re-opening of the Kaesong Industrial complex, and, more recently the publication of a United Nations report on DPRK violations of human rights, relations between the DPRK and the international community, as well as with the ROK and its other neighbors in the region, have both rocky and variable. Recent months have also, however, seen some positive signs, with the ROK and DPRK entering into talks regarding reunions of separated families and other matters, and the DPRK periodically indicating willingness to rejoin international negotiations regarding its nuclear weapons program.

One underlying aspect of the DPRK international situation, its "energy insecurity" or lack of reliable supplies of fuels to maintain and build its economy, has changed little in the past few years, and remains both an underlying driver of the DPRK's behavior in discussions with other nations and a possible lever, if used correctly, for other nations to use to begin and sustain the process of engagement with the DPRK.

The DPRK's energy sector needs are huge. At the same time, the choices that are being and will be faced by the DPRK, and the potential partners that could, particularly if the current political impasse is surmounted, assist the DPRK in economic redevelopment, will have crucial ramifications for the energy future of the DPRK and, indeed, the Northeast Asia region. This Working Paper compiles Nautilus' thoughts on the energy needs in the DPRK, and on opportunities for bilateral, international, and private sector collaboration on DPRK energy sector redevelopment. This Working Paper begins with a summary of key energy sector needs in the DPRK and how they might be addressed, and continues with a summary of key options for assistance by the international community, and particularly the ROK, to address key DPRK energy/environmental needs. Also provided are a discussion of key opportunities for bilateral and multilateral cooperation in redeveloping the DPRK energy sector, and of issues related to such cooperation with the DPRK. This Working Paper concludes with a discussion of the potential synergies and challenges in involving the DPRK is regional energy infrastructure and trading opportunities.

II. Key Energy Sector Needs in the DPRK: "Energy Insecurity"

Working with colleagues in Northeast Asia, Nautilus has adopted a definition of "energy security" that goes beyond the traditional fuel supply/fuel cost focus to include elements of energy supply, economics and economic impacts, environmental impacts and environmental security, technological security, social and political security, and military security.(2) In the case of the DPRK, the last two decades have seen a profound erosion of energy security in both the narrow and the broad senses, with significant impacts on the DPRK's economy, society, and environment. A few summary examples of these impacts, and the energy needs that underlie them, are presented below, echoing the results of our DPRK energy sector analysis as provided in an earlier EGS Working Paper. Lack of consistent supplies of coal and electricity for industry have idled many, perhaps most of the DPRK's industrial capacity, leaving the former workers at those largely state-owned facilities also idled, though they may nominally continue to hold their jobs. The relationship between energy supplies and the industrial sector in the DPRK is complicated, however, because when the Soviet Union was dissolved in 1990, the DPRK lost not only its major supplier of crude oil and of parts for its (in many cases, Soviet-built) power plants and factories, but also the markets for the bulk of the goods that its factories were designed to produce. It is thus difficult to fully understand what fraction of the decline of the DPRK industrial sector is due to a lack of energy, and which part is due to a lack of markets, though presumably with sufficient energy supplies, coupled with funds for investment in new capital equipment (and access to international markets for same), North Korean factories would be able to retool to provide goods needed at home and with markets abroad.

- Lack of energy for transport, including gasoline and diesel fuel for trucks, buses, and cars, and electricity for trains and trams, exacerbated by energy-related problems with obtaining spare parts for vehicles and transport systems, has decreased the amount of passenger and freight transport available. This in turn has affected a number of other sectors, including agriculture (see below), and electricity generation, as, with the exception of a few large power plants that are located next to coal mines, the lack of energy for transportation systems keeps coal from being distributed to power and central heating plants. In particular, the lack of transportation fuels means that in many areas, particularly away from cities, most North Koreans are obliged to walk, ride bicycles, or use animal carts to get where they are going and transport goods, or to hitch rides on (mostly military) trucks when they can. Apart from the burden to individuals, the lack of sufficient passenger transport in most areas means that time that people could be spending on productive activities is spent in getting from place to place. This mostly human-powered transport also uses calories in a country where food shortages have been frequent in recent years.

- In the agriculture sector, the lack of commercial fuels—specifically electricity and diesel fuel—increases the requirement for human and (where available) animal labor to plow fields, cultivate, weed, harvest and transport crops. This has, in part, resulted in the use of urban workers to help in agricultural activities. It is entirely possible (though we have not confirmed this) that lack of fuel for key end uses such as land preparation and planting have reduced crop yields, but a number of sources have indicated that lack of energy and equipment for proper and timely post-harvest processing (threshing, drying, and cleaning of rice, for example) have caused crop losses on the order of 15 percent, with additional losses of up to 5 percent from crops harvested too early.(3) More crops are lost due spoilage through insect or fungal attack, or from other causes related to lack of proper storage facilities, some of which can also be traced to inadequate energy supplies. In addition, and as further evidence of the many ways in which energy shortages in one sector of the North Korean economy affect other sectors, lack of energy in the industrial sector has resulted in shortages of fertilizer, which have further depressed crop yields, and in shortages of

spare parts for domestically-produced agricultural equipment, further reducing the availability of motive power for agriculture. The lack of availability of electricity for water pumping for irrigation, including flooding of rice fields, was previously a serious problem, but has become somewhat less of an issue in the several growing areas of the DPRK, as a result of the recent completion of major irrigation canals providing water by gravity flow. The first of these, the Kaechon-Taesong Lake irrigation canal, was completed in 2002, and provides water to 100,000 hectares of land along the Western coast of the DPRK.(4) Another key factor inhibiting agricultural production in many areas is soil erosion caused by deforestation, which in turn has largely, in recent years, been caused by the use of wood and other biomass used as in homes as substitutes for other fuels (see below).

- Residences and even, in some areas, military units suffer from lack of the availability of commercial fuel, largely coal, for cooking and space heating. The result—again, varying in severity by region—has been increased use of wood and other biomass fuels, which have in many areas been harvested beyond the levels of sustainable yields, as well as on slopes where the result has been significant erosion, often with potentially long-term effects on soil fertility. In cities, lack of fuel for central heating plants and/or lack of spare parts for those plants result in reduced or no provision of heat to apartment blocks, leaving those residences to go without heat and/or to use small amounts of other fuels when available—kerosene, coal, or biomass, for example—to try and make up for lack of heat supply. Lack of heat in the winter, combined with often inadequate diets, makes residents more susceptible to disease, and less productive when they are able to work. Office buildings, even in Pyongyang, are reported by visitors to be often barely heated during the winter, further affecting productivity. Lack of electricity—outages range from occasional, in places like Pyongyang, to chronic or continuous in many more isolated areas—means that residents must either do without light or use poor substitutes, such as lamps (in our experience, sometimes makeshift) burning diesel fuel, or battery-powered lanterns. Lack of light reduces opportunity for after-dark study by students, as well as other educational, social and productive activities.

Improving the DPRK's energy security, and meeting the energy end-use needs described above, is a requirement of improving the security situation on the Korean peninsula and in the broader region as a whole. Measures designed to address energy needs in the DPRK, including measures undertaken with assistance from groups in other nations, will and do face an array of challenges that must be fully appreciated and reflected in the design of plans for assistance activities. These challenges range from technical challenges related to DPRK infrastructure to institutional challenges related to the structure of the energy sector in the DPRK, to challenges related to lack of human capacity. A sampling (but hardly a complete list) of key challenges, many of which follow from DPRK energy sector problems described earlier, that assistance activities must address, include:

- Problems with the DPRK economy's physical infrastructure, and most notably its energy infrastructure, pose a challenge to getting energy assistance problems underway. Much of the energy-using infrastructure in the DPRK is reportedly antiquated and/or poorly maintained, including heating systems (including district heating systems) in residential and other buildings. Industrial, power supply, and other facilities are likewise aging and based on outdated technology, and often (particularly in recent years) are operated at less-than-optimal capacities (from an energy-efficiency point of view). The DPRK electricity system, though it is nominally a nationwide transmission and distribution grid, is in effect an patchwork of a few regional and some local grids, centered around major and smaller power plants. Most of the large thermal (almost all coal-fired) power plants are only partially in operation due to damage of various kinds to one or more generating units, and/or to transformers, substations, or other parts of the transmission and distribution system. This means that even if large amounts of fuel for power plants, or supplies of electricity from outside the country(5) were suddenly to be available to the DPRK, distribution of

that energy would be problematic. Likewise, the status of crucial transportation infrastructure will place limits on how rapidly, and where, the DPRK's energy needs can be met.

- The combination of erosion in its energy system and industrial infrastructure, together with similar erosion in its transport infrastructure in many areas, and with lack of investment capital, means that the DPRK will not be able to reconstitute, or perhaps more accurately, redevelop, its energy system and economy in general without outside help. Rebuilding power plants—most of which, remember, were built with major components imported from the USSR or elsewhere—could not be done, at least for many years, using materials "made from scratch" in the DPRK because the industrial infrastructure to make the required power plant components either is no longer operating or, in fact, was never present in the DPRK. Similarly, decades of relative isolation have left the DPRK substantially without the capabilities in modern metallurgy, electronics, and other fields that would allow it to develop new industries. This means that the DPRK cannot redevelop its infrastructure sufficiently to develop a sustainable, peaceful economy without outside help.

- There is a suppressed and latent demand for energy services in the North Korean economy. Lack of fuels in many sectors of the North Korean economy has apparently caused demand for energy services—lighting, heating, and transportation of people and goods among them—to go unmet. When and if supply constraints are removed there is likely to be a surge in energy (particularly electricity) use, as residents, industries, and other consumers of fuels increase their use of energy services toward desired levels. This means that as energy infrastructure is established or rebuilt, it will need to accommodate or otherwise manage this surge in demand. In addition (again, as noted in an earlier EGS Working Paper), key energy sector measures such as energy efficiency improvements—sorely needed in virtually all sectors of the DPRK economy—will not appear as effective as anticipated, because a significant portion of the energy saved will be absorbed by previously latent demand.

- The DPRK substantially lacks markets for energy products, which compounds the risk of a surge in the use of energy services when energy supplies improve. With a few small exceptions (as noted above), most electricity is provided to residents and organizations for a flat monthly fee per connection, if it is priced at all. Other fuels are more typically allocated to end users rather than sold in markets. Although markets for some goods and services have started to develop, sometimes haltingly, in the DPRK in recent years, input factors for goods, including energy goods (for example, coal used in power generation), are still not priced at market levels, which makes determining market prices that will cover costs of production difficult. Without fuel pricing reforms, there will be few incentives for households and other energy users to adopt energy efficiency measures or otherwise control their fuels consumption, and no guarantee that electricity generators, coal mines, and other fuel suppliers will recover through energy sales sufficient funds to cover their costs of production, let alone to reinvest in further supply expansions or other upgrades. The lack of a rational pricing system also deters outside lenders and investors from supporting energy sector improvements, because there is no guarantee that, for example, electricity generators will be able to recover their costs, including costs of financing infrastructure investments, from consumers. Anecdotal indications are that some pricing reforms are underway in the North Korean economy, including, for example, some experiments with card-based metering systems in the Pyongyang area, but it is not yet clear (to us) to what extent pricing reforms have been broadly implemented in the energy sector.

- A lack of human capacity in many fields in the DPRK will need to be overcome to implement most types of measures to improve the DPRK's energy security. DPRK citizens generally have a strong general education in reading, writing, and basic math and science, and are among the hardest-

working, most disciplined people on the planet. In working directly with DPRK Koreans, we have, as noted above, found our colleagues to have good fundamental engineering skills and to be quick and very eager to learn. Decades of relative isolation, however, have made human capacity scarce in the DPRK in such fields as advanced science and engineering (particularly with respect to the use of modern tools and analytical methods), economics and finance, regulation, and policy development. Lack of expertise and understanding in these and related areas among DPRK engineers, technicians, and officials, will therefore constrain, at least until capacity-building programs bear fruit, the rate at which measures to improve energy security can be implemented.

- An institutional lack of capacity to usefully absorb aid, including energy aid, is also an important challenge to be overcome as the DPRK energy system and economy is rebuilt. At present, the DPRK's political structure is set up such that a limited number of DPRK officials can come into contact with foreigners. These limits on interactions with the outside world currently constrain the number of projects that the DPRK can be involved with at any given time. In addition, the compartmentalization of the DPRK's dealings with foreigners means that it is often difficult for foreigners working on project with the DPRK to contact and be allowed to work freely with the right people in the DPRK. For example, the political officers controlling a cooperation project may limit foreigner's access to the technical people in the DPRK with the knowledge and expertise to help design a new energy system such that it works with existing DPRK infrastructure. Even when the right people to work with can be identified and are made available, decisions on how to proceed may be made as much on political grounds as with regard to practical considerations, sometimes with suboptimal results in terms of project impacts. Finally, an existing culture where graft and patronage are commonplace means that it is highly likely that providing too much aid too soon—particularly in the form of very large projects with necessarily complex management structures—will result in inefficient use of resources, and at worst, failure of the projects altogether.

Taken together, these constraints on the capacity to absorb aid, coupled with the other generic challenges to energy projects in the DPRK listed above, drive our advice to focus, especially in the first years of energy sector assistance, on small, fast, cheap, and local energy projects with significant demonstration value. This aid approach is reflected in the list of technologies and processes for assistance and energy sector redevelopment provided below.

III. Key/attractive Energy Sector Technologies and Processes for Energy Sector Redevelopment in the DPRK

A selection of suggested energy sector technologies and processes for energy sector redevelopment in the DPRK are provided below. Most of these options—all of which, in our view, are crucial pieces of the redevelopment puzzle for the DPRK—have elements that can be implemented in the short-term (for example, capacity-building and humanitarian aid), and medium-term (for example, demonstration projects), but all, ultimately, will require a concerted program of assistance over many years(6).

1.1 Rebuilding of the Electricity Transmission and Distribution (T&D) System

The need for refurbishment and/or rebuilding of the DPRK T&D system, and the types of materials and equipment that will be required, have been identified in earlier publications by the authors of this Working Paper.(7) The most cost-effective approach for international and ROK assistance in

this area will be to start by working with DPRK engineers to identify and prioritize a list of T&D sector improvements and investments, and to provide limited funding for pilot installations in a limited area—perhaps in the Tumen River area, in counties where key industries for earning foreign exchange (such as mines) are located, or in the Kaesong area. Ultimately, it will be necessary to engage the World Bank as a leader in North Korean power sector refurbishment, likely with funding from the Japanese government. In the short-to-medium term, local solutions could be focused on projects that would help the DPRK earn foreign exchange in acceptable manner, such as repairing T&D infrastructure and local power plants in particular areas so that facilities such as key mines can operate.

1.2 Rehabilitation of Power Plants and Other Coal-Using Infrastructure

Rehabilitating existing thermal power plants, industrial boilers, and institutional/residential boilers will result in improved efficiency so the coal that is available goes further, will reduce pollutant emissions, and will improve reliability so that the lights and heat stay on longer. Accomplishing these upgrades will require a combination of training, materials (especially control systems), and perhaps assistance to set up and finance manufacturing concerns to mass-produce small boilers and heat-exchange components.

An initial focus, in the area of boiler technology, should be on improvements in small, medium, and district heating boilers for humanitarian end-uses such as residential heating and provision of heat and hot water for hospitals, schools, and orphanages, many of which have reportedly had little or no heat, and/or have used biomass fuels for heating, in recent years. If possible, it would be optimal to provide such upgrades first in areas of the country away from Pyongyang, those hardest hit by the DPRK's economic difficulties.

The DPRK building stock, even in rural areas, tends to make extensive use of masonry and concrete, with leaky windows and doors, and minimal insulation. A program of boiler upgrades should go hand-in-hand with a program of "weatherization" (insulation, caulking, weatherstripping, and window replacement). Even minimal weatherization measures promise significant savings, with attendant reductions in coal use (making the supply go further), and in local and regional pollution.

Another early focus should be on rehabilitation of boilers in key industries that could help the DPRK to "bootstrap" (begin the revitalization of) the civilian economy. As a specific example, the DPRK has, as noted in Chapter 2, one of the world's largest deposits of the mineral magnesite, which is used in making refractory (furnace-lining) materials. To the extent not already addressed by Chinese investors, helping to rebuild the boilers or kilns that are used to produce magnesite, along with the fuel- and ore-supply chains that feed them, would help to boost magnesite production, and would bring much-needed additional foreign exchange into the country. We suspect that with international and ROK government participation and guidance, a private sector partner from the ROK or elsewhere could be found to assist with this type of rehabilitation, and to share in the profits of a joint-venture firm.

In the short run, it may also be useful for the international community to provide the DPRK with coal for selected power plants (to the extent that they are operable) in areas now poorly served by the existing coal and electricity supply systems. Providing such supplies, perhaps, as was done to some extent in one of the agreements made during the Six-Party Talks, in an agreed-upon exchange for reduced deliveries of heavy fuel oil (HFO, if it remains a part of assistance packages in the future), would help restore humanitarian services and assist in economic revival while other energy sector upgrades are underway, and could reduce the impact of high and fluctuating HFO prices on the United States and other Six-Party Talks partners providing energy sector assistance to North Korea.

1.3 Rehabilitation of coal supply and coal transport systems

Strengthening of the coal supply and transport systems must go hand in hand with boiler rehabilitation if the amount of useful energy available in the DPRK is to increase. Foreign coal industries—in the United States and Australia, for instance, as well as China and Russia—have significant expertise to assist with evaluating and upgrading coal mines in the DPRK, including improvements in mining technologies and equipment, in evaluation of coal resources, in mine ventilation systems, and (we guarantee) mine safety. The needs in this sector are so extensive, however, that no one should expect that substantial rehabilitation of the coal sector will happen quickly. For example, even once power is restored to mines, electrical and other equipment has been replaced or upgraded, and in-mine life support systems are adequate, in many mines it may take literally years before many coal galleries are pumped sufficiently free of water to be worked again. Coal processing to remove ash and improve fuel value could be another focus of assistance, as could the tapping of coalbed methane for use as a fuel(8) (and to improve mine safety).

In parallel with any mine upgrades, rehabilitation of the coal transport network must also take place. This involves making sure that train tracks between mines and coal users are operable, that locomotives have electricity or diesel fuel to operate, and that working coal cars are available. In turn, this may mean providing or helping to set up a remanufacturing facility for steel rails, providing or helping to renovate factories for rail car and locomotive parts, and other types of assistance.

1.4 Development of alternative sources of small-scale energy and implementation of energy-efficiency measures

The North Koreans we have worked with have expressed a keen interest in renewable energy and energy-efficiency technologies. This interest is completely consistent with both the overall DPRK philosophy of self-sufficiency and the practical necessities of providing power and energy services to local areas when national-level energy supply systems are unreliable at best. Such projects should be fast, small and cheap. Some of the key areas where the United States and partners could provide assistance are:

- Small hydro turbine-generator manufacturing: Much of the rugged topography of the DPRK is well suited to small, mini, and micro-hydroelectric development, and the DPRK government has given its blessing for local authorities to undertake hydro projects. The DPRK does manufacture some workable small turbine-generator sets (see Figure 1), but it is clear that assistance would be helpful to produce more reliable and cost-efficient units, as well as to expand mass production.

Figure 1: DPRK-made Mini-Hydroelectric Turbine-Generator(9)



- Wind power: Likewise, the dissemination of wind turbines is botha national goal and, from our first-hand observations, a keen interest of individuals in the DPRK. The barren ridges of the interior of the country are likely to be excellent wind power sites. The DPRK-manufactured wind generators and control components that we have seen, however, are at best grossly inefficient, and more likely non-functional. Design assistance and joint venture manufacturing of wind power systems are needed. A first phase might be the manufacture of lower-technology water-pumping windmills (see Figure 2).

Figure 2: Water-pumping Windmill Installed by Nautilus and North Korean Engineers at Unhari in the Year 2000(10)



- Agricultural equipment efficiency measures: Helping North Koreans to feed themselves should be a high priority. The rice harvest in the DPRK is, based on our 1998 and 2000 observations at harvest time in the "rice basket" of the country (as well as the observations of many visitors since), a nearly completely manual process. To increase productivity, improvements are needed in tractor design and maintenance (including spare parts manufacture) to make sure that the diesel fuel that is used in agriculture goes further. Improvements in motors and drives for electrically-driven agricultural equipment, such as rice threshers and mills, will stretch supplies of electricity.

- Building Envelope Improvement/Building Energy Efficiency:The thermal efficiency of building envelopes in the DPRK—the efficiency with which buildings keep heat in and cold out, or vice versa (depending on the season), is generally quite poor. Existing multi-unit residential buildings and commercial/institutional buildings in the DPRK are typically made of precast concrete or reinforced concrete pillar construction, with the walls filled in with concrete blocks and mortar. Few such building have any substantial insulation, and those that do may have some insulation made of lightweight concrete, which has far less insulation value than modern insulation materials. Cooperation on building energy efficiency including production (or, initially, import) and use of insulating materials, collaboration on development of building designs in the residential and

commercial/institutional sectors with excellent thermal properties, and production or import of key building components that would contribute to high-efficiency buildings (doors, windows, radiators, heat controls, and other components) is one of the most important options to pursue from the energy savings, economic, environmental, and humanitarian perspectives. It is also an option very much of interest to the DPRK, as witnessed, for example, by a presentation provided by a DPRK delegation at the 2008 DPRK Energy Experts Working Group Meeting, March 8 and 9, 2008, Beijing, China, entitled “Introduction of the Building Sector in DPR Korea”, and including conceptual designs of energy-efficient buildings (see Figure 3) among other details.(11)

Figure 3: Conceptual Residential Building Design from 2008 Presentation by DPRK Delegation



- Residential lighting improvements: Three or four times as many households can be supplied with much higher quality light with the same amount of electricity if DPRK incandescent bulbs are replaced with compact fluorescent light bulbs (CFLs) or light-emitting diode (LED) bulbs. As noted above, this measure has reportedly been taken up by the DPRK government, with distribution of CFLs to many households. Ultimately, joint venture manufacturing (or at least assembly) of CFLs and LEDs in the DPRK could be undertaken, but until then provision of CFLs and LEDs of robust quality should accompany any local power supply or T&D improvement initiative. We have found this measure to be invaluable for securing grassroots support, as it provides a direct and tangible improvement in the lives of ordinary Koreans (see Figure 4), as residents have found the improvement in light quality in their homes from installing CFLs to be considerable.

Figure 4: Compact Fluorescent Light Bulb Installed in North Korean Residence during the Unhari Project, 1998(12)



- Industrial and irrigation motors: The opportunities for efficiency improvement in large electric motors and motor drive systems are estimated to be considerable. Imports of efficient motors, pumps, air compressors, and other motor-related equipment may be the first step (once power quality has been improved sufficiently), followed by assistance in setting up facilities to manufacture or assemble equipment in the DPRK. Improving the reliability and efficiency of irrigation pumps will help the DPRK move toward feeding its populace.

- Humanitarian measures: Even the best orphanages, hospitals, and schools in the DPRK are cold and bleak today. Providing on-site power (preferably with renewable energy systems), water purification equipment, and efficient lighting and other end-use devices are necessary and highly visible first steps toward meeting humanitarian needs in the DPRK.

1.5 Rehabilitation of rural infrastructure

The goal of a rural energy rehabilitation program would be to provide the modern energy inputs necessary to allow North Korean agriculture to recover a sustainable production level, and for the basic needs of the rural population to be met. Rural infrastructure rehabilitation will also serve the crucial task of helping to slow the movement of rural citizens to the cities, once such movement is allowed, to a rate at which cities can accommodate migrants. The priority areas for rehabilitation would be those for which energy shortfalls most seriously affect agricultural production, human health, and fundamental quality of life. These areas include maintenance of soil fertility, farm mechanization, irrigation and drainage, and lighting, heating, cooking, and refrigeration for households and essential public institutions such as clinics and schools.

A comprehensive rehabilitation program for rural areas would feature a combination of short to medium-term energy supplies from imports and medium to long-term capital construction and rehabilitation projects. Components of an import program would include fertilizer, tractor fuel, and electricity at levels sufficient to enable agricultural recovery in the shortest attainable time. Some imports of tractors themselves may be necessary, as many of the DPRK tractors have suffered for years from lack of spare parts and poor fuel quality. A capital construction program for rural energy would include projects necessary to achieve the sustainable rehabilitation of the DPRK Korean rural energy sector in the medium term (approximately 5 years).It is possible to outline some of the main elements of such a program: rehabilitation of the rural electricity transmission and distribution grid, development of reliable local power generation, improving the energy efficiency of the irrigation and drainage system, modernizing fertilizer and tractor factories, and improving the transportation of agricultural inputs and products. Many of these projects have already been proposed in the context of UN-sponsored agricultural reconstruction studies. An integrated, county-level project of rural rehabilitation would be more useful, and a more useful example for similar initiatives in other areas of the country, than piecemeal efforts in many locations. Another key element of rural rehabilitation with links to the energy sector is rehabilitation of the agricultural sector. The United Nations AREP (Agricultural Recovery and Environmental Protection) project in the DPRK noted a number of agricultural sector problems that, if addressed, would likely help to improve consumable crop production per unit energy input, including reducing post-harvest losses and early crop consumption, ensuring that field operations (tilling, planting, fertilization) occur at the right time of year (and have the inputs available to do so), optimizing fertilizer application (amount, type, and timing),improving seed stocks, and other improvements.(13) Post-harvest crop losses and early crop consumption alone have been estimated to reduce usable crop production by 20 percent in the DPRK.

1.6 Electricity grid interconnections

Although hardly either a quick fix or a short-term project, it is imperative and attractive, from the perspectives of virtually all countries in the region, to move ahead with the consideration of electricity grid interconnections involving the ROK, the DPRK, Russia, and possibly China as well.(14) The driving force for the implementation of such interconnections, in the medium-to-long term, will be, as noted above, the need to provide a means of safely "turning on" reactors built on the Simpo site (in the event that construction is resumed, if the state of the partially-built infrastructure even allows resumption of construction without starting over) once they are complete (at this point, probably no earlier than 2020, if indeed they are ever completed at all), and/or to provide a means of transferring significant amounts of power from the ROK to the DPRK, as proposed by the ROK in 2005.

1.7 Gas supply/demand infrastructure

Little or no natural gas is used in the DPRK at present. Given, however, the keen and ongoing interest in Russia and the ROK in extending a gas pipeline from the vast resources of Siberia and the Russian Far East to the consumers of South Korea, it may be worthwhile to start to establish an appreciation for the benefits of gas on the part of the DPRK. Initial steps might be to build very small demonstration power plants fired, for example, with liquefied petroleum gas imported to small storage facilities, and also to use gas piped from such facilities to provide essential humanitarian services and residential fuel to a small surrounding area. If these types of small, local gas distribution systems can be established, it may be possible to build a small liquefied natural gas (LNG) terminal in the DPRK and, as gas consumption increases and a local pipeline network begins to coalesce, consider, as a next step in energy relations between the DPRK and its neighbors, an international pipeline. As a relatively clean fuel, and one that is relatively resistant to diversion for most military purposes, it may in the long run prove worth the ROK's effort to begin the process of

introducing gas as a fuel in the DPRK.

IV. Assistance Approaches for the International Community

When and if the Six-Party Talks—or, more likely, whatever diplomatic venue emerges to replace them from the recent conversations between the Koreas, the United States, and other nations in the region—resume, negotiations will center on the dismantling of the DPRK's nuclear weapons program, and on the incentives that will be offered by the international community to induce the DPRK to do so.(15) Chief among the incentives will be energy sector assistance to the DPRK. Below we outline a number of generic policy areas where assistance would be in order, as well as some ideas for cooperation activities in specific energy sectors. Neither set of suggestions is intended to provide an exhaustive list of the opportunities for cooperation, and neither is intended to provide a "schedule" of any kind to guide the development of a package of options to offer the DPRK. Development of such a package is necessary (and is a critical need), but is beyond the scope of this Working Paper, and must necessarily involve consultations among key policy actors in the ROK, the US, China, Russia, the EU and other nations, as well as, to the extent that such conversations are possible, the DPRK.

Key economic resources for the DPRK include a large, well-trained, disciplined, and eager work force, an effective system for dissemination of technologies, the ability to rapidly mount massive public works projects by mobilizing military and other labor, and extensive reserves of minerals. What the DPRK lacks are modern tools and manufacturing methods, fuel, arable land (though the land it does have might be just sufficient to feed its population with improvements in agricultural methods), and above all, substantial financial capital and the means to generate it (other than weapons sales). As a consequence, given the energy sector problems outlined above, a coordinated program of assistance from the ROK, the United States, and other countries that builds upon these skills will be needed. Providing key assistance in a timely manner will enhance security in Northeast Asia, accelerate the process of DPRK Korean rapprochement, and help to position the countries and firms as major suppliers for the DPRK rebuilding process.

The nature of the DPRK's energy sector problems, however, mean that an approach that focuses on one or several massive projects—such as a single large power plant—will not work. A multi-pronged approach on a number of fronts is required, with a large suite of coordinated, smaller, incremental projects addressing needs in a variety of areas. For example, installing a large power plant in the DPRK without addressing problems of fuel supply, end-use efficiency, and electricity transmission and distribution, and without helping the DPRK to develop the means to peacefully and legally earn the money to pay for the plant plus its operating expenses, is "putting the cart before the horse". Providing a power plant with no fuel supply, or a power plant with fuel supply but no workable grid, or fuel supply and an upgraded grid but no power plant, or even a power plant with fuel supply and an upgraded grid but no efficient end-use equipment (or no end-use equipment at all) with which to use the electricity, are neither cost-effective nor even feasible options in the DPRK, and will not improve the security situation in the long term. A coordinated approach is necessary.

Below, we identify priority areas where we see DPRK energy sector assistance as both necessary and in the best interests of all parties.(16) All of these interventions would put foreign (US, ROK, or other) engineers, trainers, consultants, and other program staff in direct contact with their DPRK counterparts and with DPRK energy end-users. In our own experience working on the ground in the DPRK, visitors working hard to help and to teach DPRK Koreans has great effectiveness in breaking down barriers between our peoples. Actions speak louder than words or missiles in negotiating with

the DPRK.

Many of the options described below are also consistent with the key areas for international cooperation to assist in developing the DPRK energy sector and the broader DPRK economy outlined by Dr. Ji-Chul Ryu of the Korea Energy Economics Institute in his presentation for the DPRK Energy Experts Working Group Meeting entitled “Energy Crisis in DPR Korea and Cooperation Issues”.(17) We summarize Dr. Ryu’s key areas for cooperation as:

1. Abandoning the DPRK’s self-reliance economic policy, including opening the energy system to commercial energy supply from overseas.

2. Establishing market mechanisms for distribution of energy, and creating energy markets, including introducing energy pricing and tax systems and reforming energy legal structures.

3. Promoting active regional/international cooperation, including for rehabilitation of the existing energy facilities, and expansion of the energy system through accommodating foreign investments.

4. Adopting cost-effective energy options in rebuilding the DPRK energy sector, including increasing the role of petroleum in the DPRK’s energy mix while at the same time pursuing in parallel the development of new and renewable energy in the short term, and development of natural gas in the medium-long term goals.

5. Strengthening the energy policy-making capability in the DPRK by improving energy statistics and modeling infrastructure, and through training of energy experts and scientists.

ROK--DPRK cooperation in many of these areas have been initiated in the past, as reported by Dr. Kyung Sool Kim of KEEI in his 2006 presentation “Current Situation and Prospects of Energy Cooperation between Two Koreas”. Though Dr. Kim noted that the cooperative interactions between the ROK and the DPRK until that time (though this observation continues to be accurate) had been “very limited”, they have included the supply of oil for a railroad interconnection, the supply of materials for road building, the development of the Gaesung (Kaesong) Industrial District, and humanitarian aid related to the 2004 rail accident. Dr. Kim noted that possibilities for “Major Inter-Korean Energy Cooperation Projects”, including transmission lines and gas pipelines involving the Russian Far East as well as the two Koreas(18). These opportunities continue to be salient.

Below we describe several assistance areas that we think are likely to particularly productive in both helping to address the DPRK’s energy sector problems and in promoting peaceful and productive engagement with the DPRK.

1.8 Provide Technical and Institutional Assistance in Implementing Energy Efficiency Measures

Focusing in particular on energy efficiency (though some of these ideas also apply to other types of measures), regional cooperation would be useful to help the DPRK to:

- Obtain access to energy-efficient products, materials and parts. Since these items will probably, at least initially, be imported, this will entail a loosening of restrictions on imports to the DPRK. China, North Korea's largest trading partner, would be a good source of efficient technologies and equipment that may be more easily absorbed (and more affordable) than those available from other countries. The flow of such equipment from China to the DPRK China has in fact stepped up dramatically in recent years, as the rapid growth of trade in televisions, bicycles, and computer goods (to name just three product categories) attests. China is the DPRK’s major energy supplier,

and thus may have an interest not only in marketing equipment, but in reducing North Korea's dependence on (in some cases, reportedly subsidized) energy imports from China (particularly given China's own tight energy supplies).

- Pursue sector-based implementation of energy efficiency measures. One point made forcefully by studies of East European economies "in transition"(19) is the need to pursue energy efficiency opportunities on a sector-by-sector basis, as opposed to through an overarching "Least Cost Planning"-style of analysis as has been practiced for electric and gas utility service areas(20). It is people at the sectoral level who must work with energy-using equipment daily to do their jobs who are most likely to be interested in energy-efficiency opportunities, rather than planners in a central ministry.

One way to gain support for energy efficiency measures is to emphasize those that achieve multiple goals. Energy-efficient technologies can be combined with building retrofits that increase the comfort of residents, the rebuilding of factories to improve output, the renovation of power plants to cut down on forced outages, and other upgrading efforts that have little--explicitly--to do with energy efficiency. China, in the 1980s, introduced a major process improvement to the steel industry—continuous casting—primarily as an energy efficiency measure, and supported its introduction with funding from the national program of efficiency investments. In China's other energy-intensive industries, such as chemicals and cement manufacturing, measures to increase energy efficiency have typically resulted in greater product output and higher product quality as well, resulting in high rates of adoption once the benefits of the measures have been appreciated by other manufacturers.

To the ultimate users of energy efficiency measures, the relative costs per unit of energy savings of the various possible industrial process, transport, and energy supply improvements is less than meaningful--what matters is how energy efficiency opportunities stack up to other potential uses for the investment funds that they have available (for example, investment funds allocated from the central government). In addition, it is often counterproductive to charge personnel from the typically supply-oriented energy sector with equipment decisions in end-using sectors of the economy, because they would bring with them a strong supply-side bias.

- Carry out demonstration projects. The most effective way to convince decision-makers in the DPRK—both at the national and local levels—that energy efficiency measures and programs are worthwhile will be to show that they work in specific North Korean situations. Carefully designed, effective demonstrations of energy efficiency and renewable energy technologies that involve local actors as much as possible are likely to catch the interest of North Koreans. Given the good system for technology dissemination in the DPRK, this approach is likely to lead to the adoption of energy efficiency measures into the DPRK Korean way of doing things. One word of caution here is to make sure that any demonstration projects carried out can be replicated elsewhere in the DPRK—measures unique to one or a few specific industrial plants, for example, are not likely to be widely replicated.

1.9 Promote Better Understanding of the North Korean Situation in the ROK

South Koreans have a deep and natural interest in what goes on in the DPRK, but have no better access to information on the DPRK than those in other countries. It will be important in particular to involve South Korean actors—to the extent allowed and desired by DPRK and South Korea—in the types of research and training activities mentioned above. This suggestion follows partly from the proximity of the two countries, partly from the shared language and cultural bonds, and substantially from the considerable economic support and technical know-how amount that the

South can offer the North. In addition, given the premise that the two countries will ultimately reunify, we believe that the more contact officials from the two countries have, and the more they know about each other, the less painful will be the process of reunification.

1.10 Work to open opportunities for IPP companies to operate in the DPRK

As noted above, the scale and complexity of the energy sector problems in the DPRK mean that the most reasonable way to address those problems is on a local and regional level. Though the ROK (and US, for example) governments might reasonably provide technical assistance and limited direct humanitarian aid, as well as support for international efforts, it is probably unreasonable to expect other countries to directly underwrite the renovation of DPRK infrastructure on even a county scale. What the other governments can do, however, is pave the way for companies such as Independent Power Producers (IPPs) to operate in the DPRK. In this liaison role, the governments could provide assistance to firms in identifying, negotiating with, and working with DPRK counterparts, underwrite performance guarantees, and provide low-interest financing. The governments can also help by providing DPRK Korean counterparts with training in the economics of project evaluation and in international contract law, both of which are, as noted above, at present largely alien concepts in the DPRK. The goal would be to assist IPP firms in working with DPRK authorities to set up with local and regional infrastructure (for example, power plants of less than 50 MWe) using small hydro installations (perhaps, in many cases, refurbishing or completing existing installations), wind farms, or mid-sized coal-fired plants. In most cases, infrastructure projects would need to be coupled with the initiation or re-establishment of local revenue-generating activities so that IPP products and services can be compensated, and of market mechanisms to collect payments for power and service customers. A necessary condition for the implementation of IPP projects is the development of markets for electricity in the DPRK that would allow IPP companies to recover their costs and profit from their investments.

1.11 Cooperation on technology transfer for energy efficiency, renewable energy

A number of suggestions for beginning to work with the DPRK on confidence-building measures in the realm of energy efficiency and renewable energy are listed in our 1995 report on the topic(21). Briefly, these include:

- Provide information and general training in energy efficiency to high-level government officials.
- Provide specific information and training to local actors (such as power plant managers, industrial energy plant overseers, and building boiler operators).
- Encourage and support implementation and enforcement of energy efficiency standards.
- Assist in establishing a program of grants and concessional loans for energy efficiency investments to industrial organizations and others.
- Encourage the modification of existing incentives that thwart energy efficiency improvements.
- Assist in and encourage the reform (or establishment) of energy pricing.

  Promote and support joint ventures and licensing agreements between the DPRK and foreign firms, possibly as part of development of the Rajin-Sonbong Free Trade Zone, or the further development of the Kaesong Industrial Park(22).
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- Initiate a program of exchange focused around methods of and training in energy planning (and the data gathering needed to make such planning relevant), including consideration of the

environmental and economic impacts of energy choices.

V. The DPRK as a Participant in Regional Energy Infrastructure

Resolution of the DPRK nuclear issue would open opportunities for regional cooperation on energy issues that heretofore have been stymied, at least in part, by the difficulties in including the DPRK in regional projects. There remain, however, many different opportunities for developing regional energy infrastructure and for energy cooperation activities—many of which could involve the DPRK—that would have the potential to benefit a number of regional parties on many levels. For example, as the DPRK economy becomes more integrated with the economies of the region, pipelines and transmission lines could be developed to pass through the ROK, providing service to the DPRK as well. Additional markets for all types of technologies (and services) would open as the DPRK is redeveloped. In fact, the redevelopment of the DPRK will provide a considerable opportunity to install efficient end-use equipment and renewable energy systems, as the DPRK economy (and infrastructure) will need to essentially be rebuilt from the ground up. In the process the DPRK may in a way provide a "laboratory" for application of energy efficiency and renewable energy measures in a way that nations with infrastructure that has been more recently updated cannot. Regional cooperation on energy sector initiatives also provides an opportunity to utilize DPRK labor, and to help to build a sustainable economy in the DPRK. Finally, as the international rules for applying Clean Development Mechanisms (CDM) under the Kyoto protocol of international climate agreements, which allow nations to take credit for financing greenhouse gas emissions reduction in other countries, are worked out, redevelopment in the DPRK may provide a host of opportunities for countries within and outside the region to apply CDM in energy sector investments in the DPRK.

1.12 Regional Cooperation Options in the Energy Sector

Regional cooperation options in the energy sector range from very large infrastructure projects linking many of the countries of the region, to more modest arrangements on technology sharing and capacity-building. Some of these possibilities, in brief, include:(23)

- **Regional oil pipelines**, carrying oil from Siberia, the Russian Far East, and even Central Asia to consumer in Chinas, Japan, and possibly the ROK and DPRK. Some of these pipeline projects, most notably the Eastern Siberia to Pacific Ocean Oil Pipeline (ESPO) project, are well underway, while others are in the preliminary planning stages. It is possible that such pipelines could be routed through DPRK territory, providing some oil to North Korean refineries on the way to the major refineries in the southern ROK.

- **Regional natural gas pipelines** have long been of interest to both Russia and the ROK, with China and Japan also seen as possible consumers. Such pipelines would carry gas from The Russian Far East, Siberia, and East Asia to the ROK. Although undersea routings from Russia to the ROK have been contemplated, it is likely that a routing via the DPRK would also have benefits. In such a configuration, some gas could be used by the DPRK, perhaps initially in a few gas-fired power plants, and later by end-use sectors as DPRK distribution networks develop, with the remainder shipped to the ROK.

- **Electricity grid interconnections**, designed mostly to allow power produced from hydro, coal,

and possibly nuclear plants in the Russian Far East to be shipped to the ROK, have also been contemplated for well over a decade. Key issues here include the technical requirements for grid interconnection, the choice of AC or DC power for transmission (and its implications on how power can be tapped from the line to consumers along the route), and economic and environmental issues such as how the power would be priced and how trans-border environmentally sensitive areas can be protected. Here, the DPRK could obtain "rent" from hosting the line, even if the DPRK does not initially (or for some year) receive power from the line. There are technical options for including the DPRK in a grid interconnection through the Korean Peninsula that would have ramifications as well for whether the nuclear plants at Simpo are completed and brought on line—and conversely, the completion of the LWRs at Simpo would have implications for the prospects of a Russian-Far-East-to-ROK interconnection as well(24).

- The development of **renewable energy and energy efficiency technologies** have been of keen interest in many countries of Northeast Asia. Climate change, local and regional environmental concerns, and the desire for economic development all contribute to the attractiveness of these options. Northeast Asia includes countries that are leaders in the technical know-how needed to mass-produce renewable energy and energy-efficiency devices, and have the funds to finance development and deployment of renewable energy and energy efficiency, as well as countries with significant markets for such devices. (In some cases, countries fall into both categories.) Cooperative strategies that allow the countries of Northeast Asia to share and co-develop technologies to utilize renewable energy sources and to improve energy efficiency could make for accelerated deployment of these technologies, relative to a situation where countries develop and/or deploy the technologies largely on their own. Cooperation could take advantage, for example, of technology, research and development infrastructure, and financing from the ROK, Japan, and possibly the United States, mass manufacturing infrastructure, labor, and quite likely financing from China, labor from the DPRK (once the current political impasse has been relieved), renewable resources in varying availability across the region, energy efficiency potential (that is, untapped energy efficiency "resources") in all nations, particularly the DPRK, China, Russia, and Mongolia (significant resource potential exists in the ROK and Japan as well), and potentially huge combined regional markets.

- **Sharing of excess oil refining capacity** to avoid the need to build additional capacity elsewhere in the region. For example, there may be available capacity in Japan that is "mothballed" or otherwise under-used, that could be used to provide oil refining for China, which faces a refining capacity shortfall soon. In so doing, China would defer or avoid having to increase its own refining capacity. Similarly, the ROK currently has refining capacity beyond what it needs to provide its own needs for petroleum products.

- **Cooperation on transportation infrastructure** to improve access by all of the nations to markets for their goods, and to reduce the time and energy required to deliver raw materials and finished goods to market. Improved roads, rail facilities, and ports have already, to some extent, been the targets of cooperation activities among the DPRK, China, and Russia, but broader cooperation, even towards the dream of developing a rail-based "New Silk Road" from the ROK through the DPRK and Russia to Central Asia and Europe, have also been discussed.

- **Co-development of LNG import capacity by the DPRK and ROK.** It is possible (given a settlement of the current political impasse) that the ROK and DPRK could share an LNG terminal located in a suitable area relatively near the border of the two countries. An LNG terminal located, for example, near Nampo on the West coast of the DPRK, would be able to serve both the Pyongyang area and, via pipeline, areas of the ROK near the border (possibly including some of

Seoul). This would provide a way to finance gas import facilities in the DPRK (by selling gas to the ROK) while the DPRK's gas distribution infrastructure and gas demand is built up.

- **Cooperation on regional emergency fuel storage,** including, potentially, agreements on sharing fuel storage facilities, tapping shared storage resources in the event of a supply crisis, and rules for the amount of fuel to be stored (similar to those in force in OECD countries) are all possibilities(25).

1.13 Benefits of the DPRK's Involvement in Regional Energy Cooperation

As witnessed by the 15-20 years that options regional energy sector coordination in Northeast Asia have been under consideration and discussion with, thus far, relatively few concrete steps forward, there exist considerable barriers to such cooperation. Examples of such cooperation in other regions of the world, however, indicate that these barriers could, with time and patience, be surmounted. If and when energy cooperation strategies are implemented in the region, there are a number of potential benefits, to the DPRK, to the region as a whole, and to the broader international community, of the DPRK's participation. These benefits include:

- The DPRK could gain access to energy resources—oil, gas, and electricity, for example—that would be difficult to develop on its own (due to lack of capital and technology, for example), and could be less expensive than securing those resources some other way.

- The DPRK could obtain "rents", either in the form of monetary payments on in the form of energy (an allotment of gas from a pipeline, for example), in exchange for allowing energy infrastructure to transit its territory.

- The DPRK could obtain better access to conventional energy, energy efficiency, and renewable energy, and related technologies, allowing the more rapid and cost-effective redevelopment of the DPRK economy.

- The DPRK would be obliged to work with the countries of the region to negotiate access rights and fees, tariffs, and other parameters of cooperative projects. Doing so would provide on-the-job experience to DPRK counterparts of regional participants, which would help both the DPRK and the international community in subsequent interactions between the two.

- The DPRK would also need, in order to participate in international energy projects (particularly those involving shared infrastructure) to undertake thorough assessments of its own energy resources and infrastructure and, moreover, to make the results of those assessments available to the international consortium planning the project. For example, to participate in a regional power grid interconnection, the DPRK would need to supply data on its transmission and distribution grid, power plants, and electricity demand centers (and in fact did so, to some extent, during discussions of interconnection options during the 2000s).(26)

- Through cooperative projects, North Koreas will gain experience with economic cost-benefit analysis and other economic and financial concepts necessary to participate effectively in the international marketplace.

- Cooperative projects will provide substantial opportunities for, and in fact, require, capacity-building for North Korean officials and technicians. Many of the types of cooperation activities identified above, in fact, could have as their first step capacity-building and information-sharing

programs of various types.

- In many cases, cooperative projects will allow foreigners better access to the DPRK, allowing them to learn more about the DPRK's needs and situation, providing an improved appreciation for the perspectives through which North Korean citizens interact with the rest of the world, and forming individual relationships with North Koreans.

- Correspondingly, through cooperative projects DPRK residents will have expanded contact with people from other nations, and will thus obtain a better appreciation for what life is like in other nations, and for how to interact constructively with foreigners, as well as forming their own individual relationships with international counterparts.

Overall, international projects involving the DPRK will be even more difficult to manage than cooperative projects involving other Northeast Asian countries, which pose significant challenges of their own. Involving the DPRK in such projects, however, can offer significant benefits in terms of engagement of the DPRK with the international community, even apart from their energy and economic benefits.

VI. REFERENCES

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(2) See, for example, von Hippel, D.F., T. Suzuki, J. H. Williams, T. Savage, and P. Hayes (2009), "Energy Security and Sustainability in Northeast Asia", in Asian Energy Security Special Issue of Energy Policy, and currently available at http://dx.doi.org/10.1016/j.enpol.2009.07.001; and von Hippel, D.F., T. Savage, and P. Hayes (2008) "Introduction to the Asian Energy Security Project: Project Organization and Methodologies", forthcoming in Asian Energy Security Special Issue of Energy Policy, and available at http://dx.doi.org/10.1016/j.enpol.2008.01.010. See also D. von Hippel, T. Suzuki, J. H. Williams, T. Savage, and P. Hayes, "Evaluation of the Energy Security Impacts of Energy Policies", in The Routledge Energy Security Handbook, Routledge, 2010.

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(4) R. Ireson "Why North Korea Could Feed Itself", 38 North, Washington, D.C.: U.S.-Korea Institute at SAIS, Johns Hopkins University, May 1, 2010. Available at: www.38north.org/?p=533.

(5) For example, in 2005 the ROK government proposed sending 2 GW of power across the DMZ to make up David F. von Hippel and Peter Hayes 8

(6) For a more detailed presentation of how energy sector assistance activities for the DPRK might be phased, see David von Hippel and Peter Hayes (2010), DPRK Energy Sector Assistance: Options

and Considerations, prepared for the Workshop on North Korean Economic Changes & Prospects, Organized by the Bureau of Intelligence and Research, U.S. Department of State, May 7, 2010, Washington, DC.

(7) See, for example, David von Hippel, and Peter Hayes (2012), Foundations of Energy Security for the DPRK: 1990-2009 Energy Balances, Engagement Options, and Future Paths for Energy and Economic Redevelopment, dated 18 December 2012, and available as https://nautilus.org/napsnet/napsnet-special-reports/foundations-of-energy-security-for-the-dprk-1990-2009-energy-balances--ngagement-options-and-future-paths-for-energy-and-economic-redevelopment/.

(8) Methane is the chief component of natural gas. Once processed to remove water, CO2, and other impurities, coalbed methane can be used in the same way and with the same equipment as natural gas, and can be injected into existing natural gas pipelines.

(9) Figure from David Von Hippel and Jungmin Kang, “Updated DPRK Energy Balance (Draft) and Work to Be

(10) 10 Photo by Nautilus Institute, 2000.

(11) Presentation available as http://nautilus.wpengine.netdna-cdn.com/wp content/uploads/2011/12/DPRKBuilding.ppt.

(12) Figure from David Von Hippel and Jungmin Kang, “Updated DPRK Energy Balance (Draft) and Work to Be Done” as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA).

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(14) See, for example, Alexander Ognev and Ruslan Gulidov, “Russia – DPRK Electricity Cooperation: the Role of INTER RAO UES Company at Current Stage”, prepared for the DPRK Energy Experts Working Group Meeting, March 8 and 9, 2008, Beijing, China, and available as http://nautilus.wpengine.netdna-cdn.com/wp-content/uploads/2011/12/RussiaDPRK.ppt, Yoon Jae-young, “Analysis on DPRK Power Sector Data & Interconnection Option”, prepared for the same meeting, and available as http://nautilus.wpengine.netdna-cdn.com/wp-content/uploads/2011/12/Yoon.ppt, and another presentation by the same author, entitled “Analysis on DPRK Power Industry& Interconnection Options”, prepared for the 2010 DPRK Energy and Minerals Working Group Meeting, September 21st-22nd, 2010, Beijing, China, available as http://nautilus.wpengine.netdna-cdn.com/wp-content/uploads/2011/12/01.-Yoon.ppt.

(15) For a perspective on the views of DPRK officials regarding energy assistance options and nuclear weapons dismantlement, see Siegfried Hecker,“Energy Dialog with DRPK Officials Aug. 23-27, 2005 Visit to DPRK”, presentation prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA. Presentation available as http://nautilus.wpengine.netdna-cdn.com/wp-content/uploads/2012/01/Hecker.ppt.

(16) See also Peter Hayes, “Options for DPRK Energy Sector Engagement”, presentation prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA.

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(17) Ji-Chul Ryu, “Energy Crisis in DPR Korea and Cooperation Issues”, presentation prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Available as http://nautilus.wpengine.netdna-cdn.com/wp-content/uploads/2011/12/Ryu.ppt.

(18) Kyung Sool Kim, “Current Situation and Prospects of Energy Cooperation between Two Koreas”, presentation prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA, and available as http://nautilus.wpengine.netdna-cdn.com/wp-content/uploads/2012/01/KEEI.ppt. Dr. Kim also presented information on the potential cost, capacity, and other features of these and other options, placed possible cooperation on these projects in the context of the goals of the 6-Party Talks, and reviewed an agenda for cooperation opportunities in other sectors, including non-physical capacity building, capacity building in the energy market system, and cooperation in the coal, oil, electricity, gas, new and renewable energy, and other sectors.

(19) Schipper, L. and E. Martinot (1993), Energy Efficiency in Former Soviet Republics: Opportunities for East and West. International Energy Studies, Energy Analysis Program, Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, California, USA. LBL-33929. Prepared for U.S. Department of Energy.

(20) Schipper and Martinot also point out two disadvantages of least-cost planning (a variant of which is called integrated resource planning, or IRP) in the context of the former Soviet Union that are probably equally relevant to the DRPK. First, stable energy markets and prices (which are inputs to Least Cost Planning) do not exist as they do (for the most part) in the West, and data on energy end-uses, as noted above, as well as cost data for domestic and imported equipment, are problematic. Second, Least-cost planning is sufficiently similar to the system of planning formerly in use in the USSR (and still, apparently, used in the DPRK) that it would provide a comfortable and familiar retreat for central planners, and thus could be considered a step away from, rather than towards, economic reform

(21) Von Hippel, D. F., and P. Hayes (1995), The Prospects For Energy Efficiency Improvements in the Democratic People's Republic of Korea: Evaluating and Exploring the Options. Nautilus Institute for Security and Sustainable Development, Berkeley, CA, USA. December, 1995.

(22) Relatedly, for example, Won Bae Kim, in a 2008 presentation for the DPRK Energy Experts Working Group Meeting, March 8 and 9, 2008, Beijing, China, entitled “ Design of Infrastructure Development in North Korea: A Practical Approach”, available as http://nautilus.wpengine.netdna-cdn.com/wp-content/uploads/2011/12/WBKim.ppt, advocated focusing on industrial zones in the “four corners” of the DPRK for infrastructure development to serve as a catalyst for overall North Korean economic redevelopment.

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(24) The reader is urged to consult the many papers presented during the 2001, 2002, and 2003 Workshops on Power Grid Interconnection in Northeast Asia, hosted by Nautilus and its partners in

Beijing and Shenzhen, China, and in Vladivostok, Russia, respectively. These papers provide background both in regional interconnection proposals and on the many different issues affecting and potentially affected by Northeast Asian grid interconnections. See https://nautilus.org/projects/by-name/asian-energy-security/worksho--on-power-grid-interconnection-in-northeast-asia/.

(25) See, for example, Eui-soon Shin (2005), "Joint Stockpiling and Emergency Sharing of Oil: Update on the Situations in the ROK and on Arrangements for Regional Cooperation in Northeast Asia", prepared for the Asian Energy Security Workshop, May 13-16, 2005, Beijing, China, and available as http://www.nautilus.org/aesnet/2005/JUN2205/Shin_Stockpile.ppt.

(26) See, for example, J. Y. Yoon (2008), "Analysis on DPRK Power Sector Data & Interconnection Option", presented at the DPRK Energy Experts Working Group Meeting, March 8 and 9, 2008, Beijing, China, and available as http://nautilus.wpengine.netdna-cdn.com/wp-content/uploads/2011/12/Yoon.ppt.

VII. DOWNLOADable .PDF file

2014-5_Workingpaper_Hayes_Hippel0.pdf

VIII. NAUTILUS INVITES YOUR RESPONSES

The Nautilus Peace and Security Network invites your responses to this report. Please leave a comment below or send your response to: nautilus@nautilus.org. Comments will only be posted if they include the author's name and affiliation.

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