

The DPRK Energy Sector: Current Status and Future Engagement Options

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The DPRK Energy Sector: Current Status and Future Engagement Options

By Peter Hayes, David von Hippel, and Scott Bruce

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I. Introduction

Peter Hayes, David von Hippel and Scott Bruce discuss changes in the DPRK energy sector (particularly since 1990) and look at the current supply and demand balance in North Korea, noting the vulnerabilities and critical needs of that sector. The authors also explore options for the rehabilitation of the DPRK energy grid that could be used in negotiations with North Korea as part of a “roadmap” to denuclearization. The report also considers the DPRK's legitimate energy needs if negotiations are not successful and the DPRK either collapses (due to an internal coup, succession crisis, or war) or continues to stagnate. The report concludes by identifying the robust strategies that are important in both engagement and non-engagement scenarios.

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II. Report by Peter Hayes, David von Hippel and Scott Bruce

-The DPRK Energy Sector: Current Status and Future Engagement Options

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Introduction - Importance of the Energy Sector to Engagement with the DPRK

North Korea's chronic energy insecurity is a fundamental dimension of its nuclear program. Resolving its energy dilemmas is central to alleviating the state of tension on the Korean peninsula. Without energy assistance, the Democratic People's Republic of Korea (DPRK) cannot meet its own goal of becoming a “strong and prosperous country.” Energy aid has been a key aspect of negotiations over the North's nuclear program, comprising one of the two primary components (along with diplomatic normalization) of benefits that were to have accrued to the DPRK under the 1994 Agreed Framework and as a part of the actions to implement the February 13, 2007 Joint Statement of the Six-Party Talks. Indeed, the DPRK will not halt its nuclear program without substantial progress toward a redeveloped energy sector. A reliable source of energy supplies is a necessary precondition to developing the DPRK's moribund economy in a way that ensures that the North is not dependent on the exports of weapons or illicit activities to earn foreign currency. Energy aid will form a component of any future negotiations over the DPRK's nuclear program, and will be a necessary, although not sufficient in itself, part of any effort to “denuclearize” North Korea. Even if negotiations, either bilateral or multilateral, do not resume, understanding the DPRK energy sector is still important. In the event of a collapse of the DPRK government, whether due to an internal coup as the result of a conflict with the Republic of Korea (ROK) and its allies or via an economic implosion, the North Korean population will need to be provided with basic and improved

energy services (for example, heat, fuel to support agriculture, and transport services) in order to stabilize the country. The degree to which North Koreans are provided with the essentials of life, including electricity, will affect how well the populace adapts to a change in government. If the DPRK is able to “muddle through” the current leadership transition, the availability of data describing the DPRK energy sector will be needed in order to gauge the North’s prospects for economic recovery. Energy data and related analyses can also play important roles in planning over the long term for the economic redevelopment of the DPRK, including contingency planning in case of the eventual collapse of the DPRK government or reunification with the ROK. Similar information and planning would be needed to facilitate integration of the DPRK’s energy system with that of the broader region, potentially through regional energy projects—for example, gas pipelines or large power transmission projects—with the People’s Republic of China (PRC) or Russia. Such energy/economic interconnections can reduce the incentive for conflict with neighboring states by increasing economic interdependence. It will also be important to assess the safety of the DPRK’s pilot light-water reactor program, given the time it takes to develop proper safety conditions for a nuclear power plant. [1] Nuclear safety is particularly in the forefront of public thinking in light of the nuclear crisis in Japan that has followed the March 11, 2011 T?hoku earthquake and tsunami. Given the importance of the DPRK energy sector considerations in creating and defining engagement opportunities, this article will examine the history and current status of the sector, including the status of DPRK energy imports. It will then propose realistic, negotiable options for energy sector engagement with the DPRK over the short, medium, and long terms. Although the authors of this study do not see a DPRK collapse as likely, this paper will also explore what aid options and contingency plans for the energy sector would need to be available in case of a DPRK collapse.

Methodology

The DPRK publishes few statistics on its energy sector (or other economic activities) and the few quantitative estimates describing activities in the DPRK energy sector made by outside groups tend to be uneven in quality. Given the lack of published and available data on the DPRK energy sector, this article has been prepared using information compiled in the Nautilus Institute’s DPRK energy database. This database utilizes information drawn from open source material, private data provided to the Institute by individuals and groups with DPRK experience, and data gathered through the Institute’s work in the DPRK, including our rural energy surveys of Unhari Village. [2] The database is organized as an intermittent series of annual “energy balances” that attempt to balance what is known or can be estimated about energy supply and the demand for fuels (oil, coal, and biomass) and other forms of energy (electricity and heat) as they have evolved in the DPRK over the years. This internally-consistent database has been continually updated for more than 15 years, and has been reviewed by our peers and colleagues. [3] The database underlies all of our assessments of the DPRK energy sector and is the basis upon which our policy recommendations for DPRK engagement are built.

Changes in the DPRK Energy Sector Since 1990

Despite its professed “Juche,” or “self reliance,” philosophy, the DPRK has always been dependent on external powers for key infrastructure and fuel supplies in its energy sector. The United Nations Command bombing campaigns during the Korean War destroyed most of North Korea’s urban energy infrastructure and necessitated post-war reconstruction with Russian and Chinese assistance.

Before 1990, thermal power plants and major factories in the DPRK were planned and built with significant involvement from the USSR; subsequently, North Korea became heavily reliant on oil imports from Russia to keep these plants and factories functioning. Russian assistance, however, substantially decreased in 1990 with the collapse of the Soviet Union. The DPRK was obliged to respond to a sudden drop in the available energy supply by seeking supplies from other nations and energy rationing. Energy demand decreased in part due to lack of fuel, as well as the loss of Soviet markets for the DPRK goods produced in factories mostly designed by engineers from the USSR.

Since 1990, energy consumption in the DPRK has declined by more than half. The country used around 1300 petajoules of energy in 1990, but now survives on slightly more than 500 petajoules. [4] The decline has been due to many factors. Industrial production, and, consequently, energy-use, has declined due to a lack of markets for industrial goods, spare parts, and fuel for factories. Coal and electricity use in the residential sector has fallen due to the decrease in power production from the decaying electricity transmission and distribution grid (which has also affected coal mining). Limitations in the supply of coal and other fuels to the population after the collapse of the public distribution system in the 1990s have also reduced fuel use. As of 2009, the primary source of DPRK energy supply continues to be domestic coal, constituting more than 50% of the total supply in the DPRK. Biomass (firewood and crop byproducts) constituted around 27 percent of the total estimated 2009 energy supplies, with, hydropower and refined petroleum products providing around 7 percent each.

Since 1990, the DPRK has struggled to secure reliable energy supplies. Oil from a variety of nations, with the source varying from year to year, has been imported in an attempt to fill the gap created when oil supplies provided on a concessional or barter basis from the USSR ended. The DPRK has little or no domestic oil production. For most of the past decade, however, the DPRK has had to make do with the imports of about 500,000 tonnes of crude oil annually (about 20 percent of what it imported in 1990), plus various levels of imports of refined products. Consequently, refined petroleum product production, remains very low, even compared to the already relatively modest energy demand that was serviced in 1990.

Although there appear to have been some increases in energy supplies between 2005 and 2008, supplies in 2009 dropped to near-2005 levels. Figure 1 shows Nautilus' estimates of DPRK energy demand in selected years both by sector and by fuel. [5] The decline in the industrial sector demand from 1990 to 1996 is most notable, but demand in the transport sector decreased as well because of the restricted supply of fuel, lack of spare parts, and the reduced need for goods transport. The residential sector energy demand does not show the same level of decrease as the industrial and transport sectors because in the residential sector, wood, and other biomass has been used as a fuel-of-last-resort substitute for coal for heating and cooking.

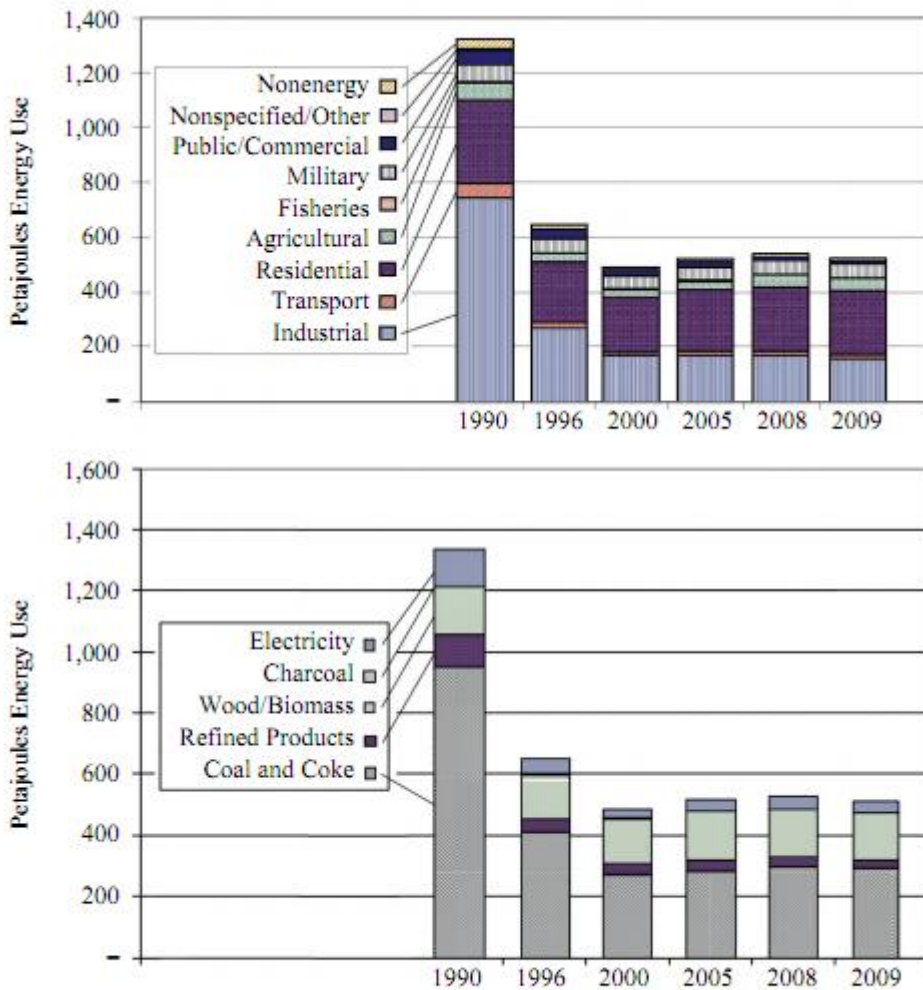


Figure 1. Estimated Energy Demand in the DPRK by Sector and Fuel
 Source: Updated Nautilus Institute estimates.

The acute energy shortage has also been driven by a lack of spare parts and energy assistance from the DPRK's former benefactor, the USSR, which has led to the degradation of the energy infrastructure in the North. The DPRK electricity grid began to decay shortly after 1990, including problems with power plants and with electricity transmission and distribution equipment. Today the transmission and distribution infrastructure in the DPRK loses an estimated 20 to 30 percent of power produced as electricity travels from generators to consumers. [6] Problems with electricity infrastructure have led to the reduced availability and quality of electrical power even in Pyongyang, which is one of the highest-priority areas for power supplies. Locations outside of Pyongyang have severely limited access to power, with electricity often only available seasonally. Our surveys of rural energy use in North Korea found that many households use car batteries to store electricity for use during frequent outages. The frequently-shown satellite photographs of North Korea and its neighbors at night, one of which is displayed below in Figure 2, [7] illustrate how limited electricity supplies are in North Korea compared to South Korea.

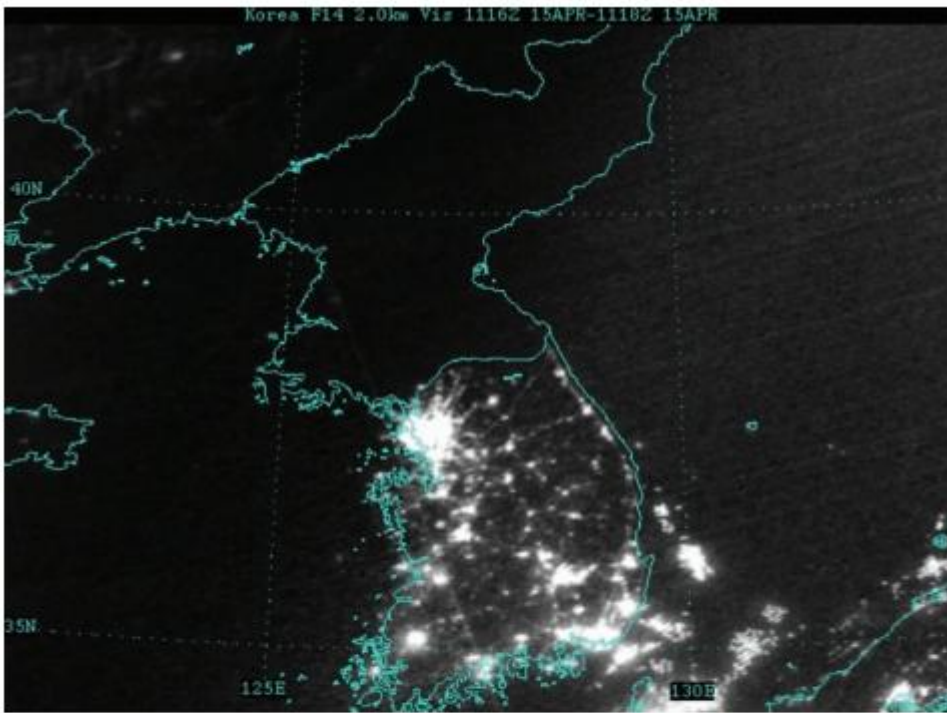


Figure 2. Satellite Nighttime Photo of the Korean Peninsula
Source: "North Korea is Dark," *GlobalSecurity.org*, <http://www.globalsecurity.org/wmd/world/dprk/images/dprk-dmsp-dark-old.jpg>.

The DPRK's electricity generation infrastructure also began to deteriorate in the 1990s. The lack of spare parts, a lack of effective maintenance, and the use of high-sulfur fuels, including, ironically, the heavy fuel oil provided to the DPRK under the Agreed Framework, have together depleted the DPRK's generation infrastructure. Power generation continues to decrease due to the aging and strained power generation systems or, at best, to be maintained at current levels through a combination of North Korean ingenuity, modest imports of spare parts, the addition of used power plants, and some new additions of small hydroelectric facilities. Electricity shortages led to a decrease in coal production due to the lack of available power to many mines. These difficulties were compounded by the floods that swept the country in the mid-1990s, causing damage to many facilities including the important Anju Coal Mine on the West coast of the DPRK. Reduced coal production has resulted in reduced coal supplies for power production, which has further exacerbated electricity shortages.

The DPRK has attempted to secure help from other countries to repair some of its thermal power plants; however, based on reports from visitors to the DPRK, these efforts have not produced noticeable results. Most coal plants in the DPRK, if they are functional at all, continue to operate at a very low capacity and a low level of efficiency. There has been a concentrated effort in the DPRK to expand hydroelectric capacity. The focus has been on domestically-built hydroelectric plants, most of which have been of small capacity (megawatts to tens of megawatts, with many plants under one megawatt). Although these additions have resulted in some increased supply, particularly in local areas near new plants, the additional hydroelectric capacity has had a relatively limited impact compared to the DPRK's overall electricity demand.

In response to the decrease in supplies of electricity and coal, there has been a significant increase over the past two decades in the use of biomass in the DPRK. The fraction of the DPRK's energy mix supplied by biomass has more than doubled since 1990, largely due to the decline in the supply and use of non-biomass fuels. The use of wood in the residential sector has increased to supplement reduced supplies of electricity and coal, which were traditionally provided by the state distribution system. As energy deliveries from the public distribution system became increasingly sporadic, the DPRK populace shifted to using biomass fuels. Increased biomass fuel use, in turn, contributed to deforestation in many areas of the country, with a related increased vulnerability to mudslides and

other natural disasters that the forest areas traditionally offered some protection from. [8] This increased vulnerability to natural disasters in turn puts any prospects for economic recovery at risk, and perpetuates the economic stagnation and malaise of the DPRK. Figure 3 shows the shares of 2009 energy demand by sector and fuel, based on Nautilus estimates. [9]

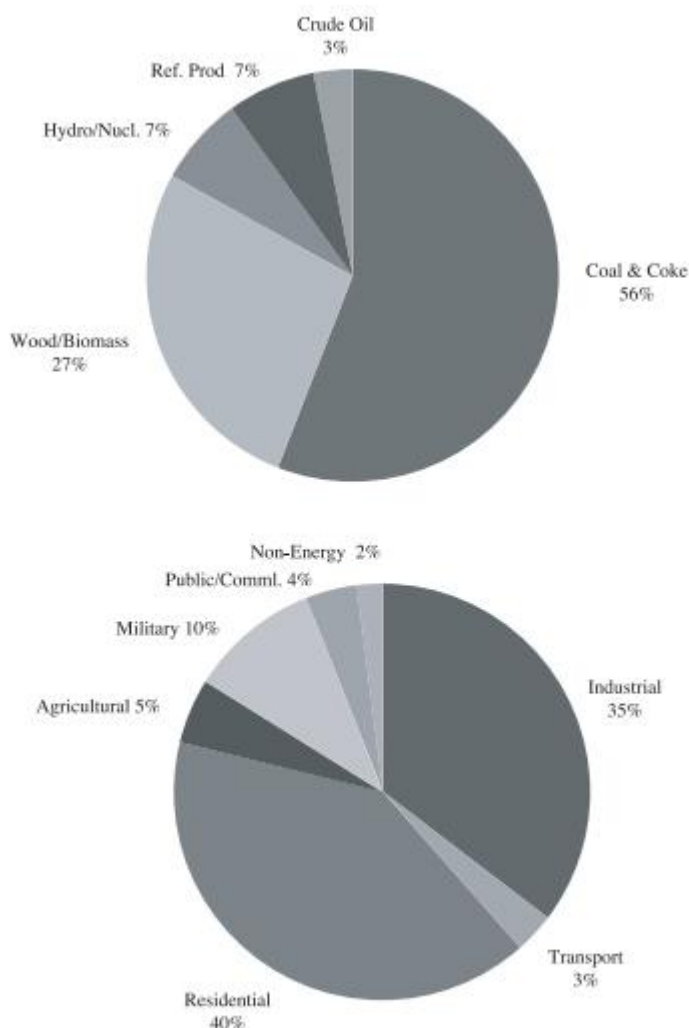


Figure 3. Estimated Energy Demand by Sector and by Fuel in 2009
 Source: Updated Nautilus Institute estimates.

Lack of energy has had a corresponding impact on North Korea's economy. Industrial production has decreased due to the degradation of factories and damage to industrial equipment from poor-quality electricity. Other factories have significantly reduced production due to fuel shortages (as well as a lack of markets for goods). Visitors to North Korea, including the authors of this report, have observed factories that appear to be abandoned, as well as others that have been dismantled for scrap. This industrial decline also affected the production of cement and steel. In recent years, the DPRK's trade has shifted away from such energy-intensive industries and has largely focused on typically less-energy-intensive industries such as trade in raw materials (particularly sales of minerals to China) and the output of small factories (such as factories assembling textile products). Other non-energy intensive additions to the economy in the past two decades have included the local markets and shops sporadically allowed by the DPRK government.

Whereas the industrial sector was the largest consumer of energy in the DPRK in 1990, its share of energy demand has since shrunk dramatically. The residential sector now consumes the largest share of energy as shown in Figure 3, though more than half of its total energy use is biomass, which is used relatively inefficiently. The military consumes an estimated 10 percent of the energy in the DPRK, with the agricultural and commercial sectors each representing around five percent of the energy demand in the DPRK. [10]

Energy Imports After 1990

China is the DPRK's largest trading partner. Pyongyang is dependent on Beijing for the majority of its imports of crude oil and oil products. China provides the DPRK with around 500,000 tons of crude oil every year via a short cross-border pipeline to the Bonghwa Chemical Factory, a DPRK refinery on the northwest coast near Sinuiju. [11] Like other energy trade between the PRC and DPRK, this oil trade appears to be based largely on market-driven principles. PRC companies charge the DPRK more for coal and oil products imports from China than they charge on average for exports to other countries that import energy from China; however, the price differential is not huge. Conversely, the PRC is able to insist on "friendship prices" for its imports of energy products from the DPRK, due to China's status as the prime export destination for these products and the DPRK's need for hard currency. [12]

North Korean imports of crude oil and refined petroleum products from China in the past few years have been more consistent, month-to-month, than in some previous years, though the annual volumes of crude oil and oil products shipped from China to the DPRK have changed relatively little in the past eight years. Many have suggested that these exports have been used as a lever to steer the DPRK towards Chinese policy goals; however, this leverage has not been exercised recently. Russia is also a significant source for DPRK energy imports. Russia supplied 340,000 tons of oil products to the DPRK, almost one-third of North Korea's total oil use in 2005. Russian energy exports to the DPRK are no longer on a concessional basis, however, and seem to vary considerably year-to-year, assumedly based on the DPRK's ability to pay or barter. The DPRK also has received refined products from Singapore, the Netherlands, Malaysia, and Indonesia over the past decade, likely mostly through relatively small "spot" purchases of oil-product cargos.

Energy imports from China and other nations do little to address the increasingly decrepit nature of the DPRK's energy infrastructure. Our findings indicate that a simple rehabilitation of the DPRK's energy systems is in most cases not an option. The systems are dilapidated and inefficient, and the parts to repair them are in most cases of Soviet origin and are no longer manufactured. The only practical option is therefore the replacement of energy infrastructure. This holds in particular for the DPRK's electricity transmission and distribution substations and transformers, which are largely based on technology from the 1950s, 60s, and 70s, and are now in many cases broken or failing. The replacement of this power infrastructure is estimated to cost around US\$10 billion, not including costs for the replacement/upgrading of transmission and distribution control systems, power lines, or generation facilities. The DPRK's current energy trade, together with the limited amount of technical support from outside the country coupled with some domestically manufactured parts and the efforts of DPRK engineers is barely keeping the country functioning. Existing energy trade has no transformative potential to rehabilitate or replace the aging energy infrastructure in North Korea and leaves the DPRK with a fundamentally unsustainable energy sector.

Energy Aid as Negotiable Options for Denuclearization

Energy aid is a powerful enticement during negotiations with the North because of the extreme limitations on the energy supply of the DPRK, its goal to become modern and prosperous, and its inability to independently rehabilitate the energy sector. Energy assistance, however, has to be provided in a comprehensive and coordinated fashion to be successful. The decrepit energy sector, outdated machinery, and lack of technical knowledge on the part of DPRK scientists and engineers regarding modern energy systems, together with the interconnected nature of DPRK energy problems, means that simply building a power plant (or several) will not suffice to put the DPRK economy on the path to sustainability. The DPRK is in need of technical training and technology transfer, together with laws and institutional reforms that can allow private companies to work in the DPRK. This assistance needs to be structured into negotiable options for the energy sector so that it can be used as a roadmap for denuclearization in bilateral or multilateral talks with the DPRK. Short-term energy assistance options should focus on "ice-breaker" projects that are easy to agree upon, implement, and build confidence between parties as dialogue resumes. These options include the provision of fuels, such as heavy fuel oil (HFO) to the DPRK. HFO is not an ideal vehicle for

energy aid, given its relative expense, the lack of any transformative effect of supplying or using it on the DPRK's energy infrastructure, and that its provision does not encourage much in the way of interaction between DPRK officials and technicians and people from other countries. HFO is familiar to North Koreans as a "currency" of international energy assistance and is very hard to divert to military purposes given its limited uses. For example, HFO cannot typically be used in the DPRK's trucks, tanks, planes, or (with a few exceptions) naval vessels.

Another short-term option would be the donation of diesel generators. These generators can be used for humanitarian purposes in schools or hospitals, in agricultural areas to increase food production, in mines to facilitate mineral resource development (especially given that many mines are powered by hydropower and subject to seasonal decreases in energy supplies). All of these applications would have to be supported by the additional provision of other materials such as lighting and refrigeration equipment for hospitals, efficient motors and other agricultural equipment, and diesel fuel to run the generators.

The training of DPRK personnel is very important given their limited exposure to and knowledge of the energy sector outside North Korea. Capacity-building training on topics including energy efficiency, renewable energy, power systems design, energy markets, the environmental impacts of energy systems, and many others would be a beneficial knowledge-sharing exercise, and would lead to interactions and technical cooperation with experts outside of the DPRK. This training would be supported by the provision of software and technical materials.

If negotiations are successful in making progress on addressing concerns regarding the DPRK nuclear program, in particular, on disabling, dismantling, and monitoring the DPRK's nuclear weapons production facilities, then longer-term options for transforming the DPRK's energy sector should be considered to ensure that these "denuclearization" steps are accompanied by tangible benefits to North Korea. While the results of these longer-term options should be designed to be very visible to North Korean officials, to ensure their support, assistance should also be geared toward making structural changes to address some of the major infrastructural problems in the DPRK energy sector.

Notable options in the medium term include refurbishing selected power plants in the DPRK. This could entail repairing one or more of the thermal or hydro power plants that support Pyongyang or other major cities, replacing worn-out power plant components and systems, insulating equipment to increase efficiency, and installing more sophisticated monitoring and control systems. Another option would be to rehabilitate one or more key mines in the country to support sustainable mining practices, and to help to provide the DPRK with a reliable and responsible source of foreign currency income. "Repurposing" the Yongbyon nuclear facility, for example, as a center for nuclear medicine, environmental protection, or energy research, is another possible medium-term assistance option. Work should be undertaken to slowly reconstruct and modernize the DPRK electricity grid, starting with the establishment of "mini-grids" linking small hydro, biomass, and other power plants to minerals production or light industrial facilities designed to generate income. This will start to redevelop the DPRK's energy infrastructure as well as facilitate increased economic production to support the economy, which in turn could help to provide the resources for future energy sector investments.

To address the problem of environmental degradation in the DPRK, measures should be taken to reforest degraded land to stabilize soils (thereby supporting agriculture), and ultimately to provide sustainable supplies of wood. These measures will directly involve local populations and allow them the opportunity to interact with foreign technical staff. Reforestation projects may be candidates for funding under the Clean Development Mechanisms (CDM) of the Kyoto Protocol to the United Nations Framework Convention on Climate Change.

Finally, undertaking additional capacity-building projects will be important to ensure that DPRK technical personnel understand and maintain the development momentum resulting from the energy aid provided to North Korea. Demonstration projects on energy efficiency, sewage treatment, renewable energy, and other topics will have significant benefits. These projects should include

study tours by DPRK officials and technicians to other countries as well as study-abroad opportunities for DPRK students. They should also, however, be focused on building or augmenting in-country training centers, and developing demonstration projects that create expertise among a group of North Korean scientists, technicians, and researchers who can then disseminate their training to others within the DPRK.

In exchange for the verifiable dismantlement of the DPRK's nuclear weapons, and the disposal of the DPRK's stock of fissile material, the DPRK should receive considerable, demonstrable energy aid to accompany a set of security guarantees. North Korea's traditional demand has been the completion of the light water reactor (LWR) program that was begun in the 1990s under the auspices of the Korean Peninsula Energy Development Organization (KEDO). As a part of the 1994 Agreed Framework, KEDO was to build two 1000 MW LWRs at the Kumho site on the east coast of the DPRK. The KEDO LWR deal unraveled in 2002-2006 as denuclearization negotiations fell apart. Since the construction of the Kumho reactors was suspended, the DPRK has begun its own light water nuclear reactor (LWR) and enriched uranium nuclear fuel supply pilot program. International assistance could be provided to potentially bring that program under international safeguards and start to build the regulatory and safety infrastructure to ensure the safe operation of domestically-constructed DPRK nuclear reactors, something that would likely take the DPRK decades to do on its own. [13]

Foreign nations could also help the DPRK to construct its domestic reactor, and/or offer the DPRK a "package" of other energy aid options roughly equal to the value of the LWRs that the DPRK would have received under the Agreed Framework. This package might include rehabilitation and expansion of some of the large hydroelectric plants in the DPRK, major improvements in and rehabilitation of thermal power plants, wind power plants, and energy efficiency improvements throughout the economy.

Other long-term energy assistance options could include large-scale infrastructure projects for the redevelopment and modernization of the DPRK. These projects could include electricity grid facilities, terminals for receiving liquefied natural gas (LNG) by ship, natural gas pipelines connecting the DPRK (and the ROK) to the Russian Far East, rebuilding railway infrastructure to facilitate trade, and other projects aimed at promoting the interconnection of energy and transport infrastructure in Northeast Asia. Such projects can be combined with regional initiatives that can offer the DPRK some economic security. For example, in gas pipeline or power line deals, the DPRK would act as a way-station for energy-for-capital trade between the Russian Far East and the ROK. In such projects, where the ROK provides the capital to develop energy infrastructure to tap Russia's energy resources for use in the ROK, the DPRK could effectively extract "rent" in the form of monetary payments or energy as the host of the pipeline or powerline running through its territory. Income from these types of regional projects can also help to offset the cost of required energy sector improvements in the DPRK.

Energy Aid in the Event of a North Korean Collapse

Developing, with the DPRK, a solution to its chronic energy insecurity is a necessary part of any negotiations over the DPRK's nuclear program. Energy assistance will still, however, be a key aspect of a foreign response in the event that these negotiations are not successful and the DPRK's economy continues to stagnate or collapses. Regardless of the initiating factor in a DPRK collapse scenario, maintaining regional security would necessitate a response. A North Korean collapse, if not effectively addressed, will create a high security risk for the ROK, Japan, China, and Russia. This means that considering scenarios for a DPRK collapse and planning for the provision of basic supplies in the case of such an event is extremely important.

Collapse scenarios cover a range of possibilities, from the collapse of the DPRK government following a war, to a coup d'état, the sudden death of Kim Jong Il, or to slow economic decline. [14] These scenarios vary in terms of the status of the DPRK's infrastructure. For example, the war and stagnation scenarios will result in a DPRK grid, power sector, and infrastructure that is more damaged than in the other collapse scenarios. The scenarios also vary in terms of the post-collapse

regime's relationship with the United States and the ROK, openness to foreign investment, and commitment to economic redevelopment. In all of these scenarios the ability to provide for the North Korean population after a collapse, including supplying access to energy services such as heating, will be critical in stabilizing the country and demonstrating the legitimacy of the new government. There are a number of plans that the ROK and United States can develop to be prepared for a DPRK collapse that span these different scenarios. Whether the United States and the ROK reconstruct the DPRK following a war scenario or a collapse from economic isolation and stagnation, significant effort will need to be spent rebuilding the DPRK's energy infrastructure. Immediate priorities will be on supplying emergency energy to the populace. Short-term options for emergency energy aid will include shipments of liquefied petroleum gas, which is easier to ship, receive, and store than liquefied natural gas, deploying power barges to coastal areas, and using diesel-fueled combined heat and power plants in inland areas.

Long-term options would include replacing substations, stabilizing coalmines to restart coal-fired power plants (with power plant refurbishment or replacement), and ensuring that agriculture programs have adequate energy to jumpstart food production. Transmission lines and the electricity grid are also likely to require major rehabilitation and replacement to reestablish domestic power distribution.

If a coup or the sudden death of Kim Jong Il results in a regime that is more inclined to reengage the outside world, there will likely be opportunities for the ROK and United States to engage the new regime to work toward integrating the DPRK with the rest of Northeast Asia. Here, energy aid might focus on helping to redevelop the DPRK's commercial and/or industrial sector to create an economy that can be integrated into the export-oriented economies of the region. Such a program would be likely to decrease the insecurity of the new regime and reduce the incentives for missile proliferation (sales of missiles and other military hardware by the DPRK to other nations to earn foreign currency) as well as eradicate narco-trafficking, currency counterfeiting, and other illegal economic activities that the DPRK has been accused of.

Conclusion

Our initial consideration of the energy sector implications of potential DPRK regime collapse pathways suggests that there are a number of initiatives that the ROK, the United States, and the broader international community that is interested in the future of the Korean peninsula can undertake to prepare for the eventuality of a DPRK regime collapse. These initiatives are useful and necessary in any potential scenario that involves future engagement with the DPRK, whether driven by the collapse of the DPRK government or undertaken following progress in negotiations over the DPRK's nuclear weapons program.

Possible initiatives include:

- Conduct capacity-building on multiple aspects of the energy system whenever possible. It is cheap, useful, and necessary under any circumstance, and has many ancillary benefits. Required capacity-building topics include technical training in electricity generation, energy efficiency, oil refining, renewable energy, environmental remediation, waste treatment, reforestation, and other similar disciplines. In addition, training will be required in running commercial enterprises, including economic analysis, building and operating regulatory and legal systems, and many other organizational topics. Ancillary benefits of capacity building include engagement on the individual and organizational level, exposing minds to new ways of thinking, increasing competence and personal connections for application at key movements of transition, as well as the availability of in-country trainers for rapidly expanding training.
- Start to plan now for the wholesale rebuilding of the transmission and distribution system. Rebuilding the DPRK transmission and distribution system is necessary and unavoidable, the only question is when. An initial step, particularly for the ROK might be to stockpile key components, such as transformers and substation switchgear, for rapid installation as needed. In any event, a concerted effort in advanced planning for grid redevelopment is imperative.

- Assess the ROK's current refining capacity versus the petroleum-product needs of a reunified (de facto, if not de jure) Korea. Such an assessment could also involve starting to talk with the Russians about the possibility of rebuilding and expanding the oil refinery at Sonbong to prepare for a rapid start of a refinery project when conditions permit. Even if Korea is not reunified any time soon, a rebuilt Sonbong refinery would serve Russian as well as DPRK interests.
- In order to reduce the burden on energy supply infrastructure (including reducing the amount of new energy supply infrastructure needed), have the discipline to provide high-efficiency energy demand (and supply) devices when rebuilding the DPRK economy and/or when providing any type of energy sector assistance to the DPRK. Provide high-efficiency demand and supply devices rather than, for example, marketing secondhand appliances, industrial motors, power plants, automobiles, and other devices to the DPRK. This would ensure that the DPRK has a better chance of "catching up" with technology in the South and in the rest of the region, yielding better outcomes from social, resource conservation, environmental, and economic/infrastructure integration perspectives.
- Think through how markets for energy goods can be established in the DPRK to spur private sector investments. Energy sector investments, whether in power plants, coal mines, or gas supplies, will not be useful if there are no markets that allow the energy goods to be sold at prices sufficient to stimulate further infrastructure investments.
- Plan integrated energy infrastructure/economic development demonstration projects on a national scale and prepare to implement some integrated projects, whether a collapse occurs or not. These pilot projects, if properly done, will help point toward sustainable redevelopment of the DPRK economy and its energy sector.
- Network with other interested parties to provide the best assessment possible of the DPRK's energy sector status and needs, and collaborate on concrete plans so as to be able to swiftly and effectively address those needs when an opening occurs. This should be a high priority no matter what the future holds for the DPRK's relationship with the international community.
- Finally, encourage the implementation of medium- and long-term regional energy projects such as a regional electric grid tie-lines and/or regional gas pipelines. Such projects could be implemented in ways that provide China, the ROK, and Russia with some leverage over the reconstruction agenda should the DPRK collapse as well as provide leverage to induce the DPRK to move toward economic integration with the region, even in the (likely) event that the collapse of the DPRK's government is avoided.

The DPRK's energy supply, industrial, and energy demand infrastructure is in poor condition, and the DPRK is unable to obtain sufficient fuel supplies to meaningfully redevelop its economy. Providing assistance to help to redevelop the DPRK's energy sector will continue to be a key to reaching an agreement to dismantling, or at least freezing, the DPRK's nuclear weapons program. There are a wide variety of different possible energy sector engagement options and strategies that would be workable and useful under almost any scenario of the evolution of DPRK relations with the international community, including (improbable, in our view) scenarios where the DPRK's government collapses. It behooves the international community to move forward with planning for such contingencies, keeping in mind critical issues such as phasing, engagement, and the usefulness of energy engagement for DPRK economic redevelopment, to be ready in the event that the DPRK comes to the negotiating table and says "Yes."

III. References

[1] "The development of a quality control/assurance consciousness [necessary for a modern LWR] together with a cadre of qualified and experienced supervisors and skilled workers would take 15-20

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[2] See David F. Von Hippel, Peter Hayes, James H. Williams, Chris Greacen, Mick Sagrillo, Timothy Savage, "Rural Energy Survey in Unhari Village, The Democratic People's Republic Of Korea (DPRK): Methods, Results, And Implications," The Nautilus Institute (May 20, 2001), https://nautilus.org/about/staff/peter-hayes/Unhari_Survey.pdf (accessed on March 31, 2011).

[3] The most recent published report summarizing this work to date is: David von Hippel and Peter Hayes, "Fueling DPRK Energy Futures and Energy Security: 2005 Energy Balance, Engagement Options, and Future Paths," Nautilus Institute Special Report (June 2007), <https://nautilus.org/wp-content/uploads/2012/01/07042DPRKEnergyBalance.pdf> (accessed on March 31, 2011).

[4] One petajoule is an amount of energy equal to one million gigajoules, or one million billion joules. One petajoule is the energy equivalent of about 25 thousand tons of oil. By way of comparison, the Republic of Korea uses the equivalent of about 250 million tons of oil annually, or about 10,000 petajoules.

[5] Data from Nautilus DPRK Energy Sector Analysis Database, updating analysis presented in, for example, P. Hayes and D. von Hippel, "DPRK 'Collapse' Pathways: Implications for the Energy Sector and for Strategies of Redevelopment/Support," prepared for the Center for Strategic and International Studies (December 15, 2010), http://csis.org/files/publication/101215_Collapse_Pathways_North_Korea.pdf; and P. Hayes and D. von Hippel, "North Korea's "Collapse" Pathways and the Role of the Energy Sector," *North Korea Review*, 2011 (forthcoming).

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[11] See, for example, Julia Joo-A Lee, "To Fuel or Not to Fuel: China's Energy Assistance to North Korea," *Asian Security* 2, no. 2 (2005): 45-72, <http://dx.doi.org/10.1080/14799850802689749>.

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[14] See, for example, P. Hayes and D. von Hippel, "DPRK Collapse Pathways: Implications for the Energy Sector and for Strategies Redevelopment/Support," Nautilus Institute Special Report (January 18, 2011), <https://nautilus.org/publications/essays/napsnet/reports/HayesVonHippelCollapse> (accessed on March 31, 2011).

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