DPRK Energy Sector Assistance to Accompany Progress in Denuclearization Discussions: Options and Considerations

David Von Hippel
Senior Associate at the Nautilus Institute

Peter Hayes
Professor of International Relations, Nautilus RMIT Convener, Global Cities Institute, Climate Adaptation Program

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Executive Summary

Energy sector needs are a critical dimension of the North Korean nuclear weapons challenge. Energy sector issues—specifically, the Democratic People's Republic of Korea's (DPRK's) difficulties obtaining energy supplies and maintaining aging energy supply infrastructure—have been a driver of its nuclear weapons policies. On the other side of the coin addressing energy sector needs in the DPRK has played, and will continue to play, a key role in working toward a solution of the DPRK nuclear weapons dilemma. The denuclearization of North Korea will require provision of energy assistance by the international community in a phased package that is carefully coordinated with milestones in the denuclearization process. These energy options must be based on the realistic needs and capabilities of the DPRK noting economic and humanitarian conditions as well as political priorities in the country.

Over the short term these options should focus on symbolic, confidence-building projects with a goal of restarting dialogue and beginning negotiations over the more substantive issues. Short-term options thus include the direct provision of fuel, diesel generators, and agricultural equipment, as well as providing training for DPRK personnel on energy related issues.

In the medium term, in response to freezing of activities at and monitoring of nuclear facilities in the DPRK, energy aid should prioritize the rehabilitation of the DPRK's energy infrastructure and building the technical capacity of DPRK engineers and technicians. Specific aid options include the refurbishing of power plants and the electricity grid, reforestation projects, and other capacity building and model projects in the DPRK.

If negotiations are successful in causing the dismantling of the DPRK's nuclear arsenal and securing control of the country's fissile material, aid options should focus on rebuilding the energy infrastructure of the North. Negotiations will have to address the DPRK's demand for large Light Water (nuclear) Reactors for power generation. Offering one reactor and additional energy aid equal to the perceived value of the second reactor is a possibility. The provision of either one or two reactors will necessitate the interconnection of the ROK and DPRK electricity grids to some degree, and/or major electrical interties between the DPRK and Russia and/or China.

Resolving—or at least taking meaningful steps toward resolving—North Korea's chronic energy sector problems is a necessary (but not sufficient) condition to induce the country to surrender its nuclear weapons and fissile material. Failing to address the DPRK's underlying needs for energy services will virtually guarantee that any solution to the nuclear weapons issue will be unsustainable.

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1. Introduction

During the decade of the 1990s, and continuing through much of this first decade of the 21st century, a number of issues have focused international attention on the DPRK. Most of these issues—starting with the nuclear weapons proliferation issue that is the topic of this report, but also including, military disagreements, economic collapse, trans-boundary air pollution, floods, food shortages, droughts, and tidal waves—have their roots in a complex mixture of Korean and Northeast Asian history, global economic power shifts, environmental events, and internal structural dilemmas in the DPRK economy. Energy demand and supply in general—and, arguably, demand for and supply of electricity in particular—have played a key role in many of these high-profile issues involving the DPRK As a consequence, addressing DPRK "denuclearization" has been and continues to be linked with the provision, by the international community (acting both individually and collectively), of assistance in supporting and/or "redeveloping" the DPEK energy sector. Determining which energy assistance options to offer, and when (and how much), requires consideration of DPEK energy needs and capabilities, for a start, but also calls for an examination of potential energy assistance options from a variety of perspectives related to the economic, humanitarian, and economic conditions within the DPRK, as well as broader regional context in which the issue is set..

1.1. Matching Energy Sector Assistance to "Phases" in Denuclearization

In the text that follows, we match potential energy sector assistance options to one (and sometimes more) of three "phases" in denuclearization discussions/agreements:

- **Short-term options**, focusing on the symbolic, confidence-building, and easily-agreed-to items, matched to a primary goal of assembling the parties to restart dialog and to begin the process substantive negotiation on issues related to the DPRK weapons program.
- **Medium-term options**, provided in response to disablement, dismantlement, and monitoring of DPRK nuclear weapons production facilities. These options begin to provide for longer-term infrastructure and capacity-building, while still providing some immediate tangible benefits.
- **Longer-term options**, in exchange, ultimately, for dismantling of nuclear warheads themselves and a handover of fissile material. Longer-term options address major energy sector and economic issues, and must provide what is perceived by the DPRK as significant value.

The actual duration—in months and years—of these phases is very uncertain and, at present, unknowable, as it depends on how discussions proceed, how the parties respond to each other, and how events—related and unrelated to the nuclear weapons issue, and inside and outside of the DPRK—unfold. Given this uncertainty, some of the options designated below as alternatives for one phase or another may need to be accelerated in delivery, to the extent that they can be, within the limits of practicality and DPRK absorptive capacity for aid.

1.2. "Road Map" to this Paper

In the remaining subsections of this paper, we:

- Provide a brief review of estimates of recent trends in the DPRK energy sector, describing the setting for potential energy sector assistance activities;
- Identify some of the many goals and considerations involved in choosing, developing, and delivering energy sector assistance options as a part of denuclearization negotiations and activities;
- Describe some of what we see as the most promising options for energy sector assistance by "phase", and provide a summary evaluation of how the options fit (or do not) with the goals and considerations identified; and
- Offer our conclusions as to which options, in particular, are likely to prove most fruitful, where we see key pitfalls, and what issues will require particular attention as negotiations proceed..

2. Recent History and Current Status of the DPRK Energy Sector

In the following few pages, we provide a very brief introduction to the recent trends in and current status of the DPRK energy sector. Please see our more comprehensive reports on the topic for further details[1].

The economic, if not social and political, landscape in the DPRK has changed markedly during the 1990s. Although little data have been available from inside the DPRK, information from outside observers of the country indicates that the North Korean economy was at best stagnating, and most probably in considerable decline, through the mid-1990s. This economic decline has been both a result and a cause of substantial changes in energy demand and supply in North Korea over the last decade. Though recent anecdotal evidence suggests that the economy in some parts of the DPRK, particularly near Pyongyang, may have improved somewhat between about 2003 and 2006, it is not clear that the energy supply situation has changed substantially for the better nationwide since 2000.

Among the key energy-sector changes on the supply side in the DPRK in the early 1990s were a vast drop in imports of fuels from the Soviet Union and Russia. Though China continues to supply a largely steady 500,000 tonnes or so of crude oil per year to the one of the DPRK's two refineries that still operates, oil import restrictions have reduced the availability of refined

[1] See D.F. von Hippel and P. Hayes (2007), Fueling DPRK Energy Futures and Energy Security: 2005 Energy Balance, Engagement Options, and Future Paths (Nautilus Institute Report, available as http://www.nautilus.org/fora/security/07042DPRKEnergyBalance.pdf), for details on the estimates provided in these figures and for related information. Other related articles by the authors include von Hippel, D.F., and P. Hayes (2007), "Energy Security for North Korea", Science, volume 316, pages 1288 – 1289, June 1, 2007; and . von Hippel, D.F., and P. Hayes (2008b), "Growth in Energy Needs in Northeast Asia: Projections, Consequences, and Opportunities", paper prepared for the 2008 Northeast Asia Energy Outlook Seminar, Korea Economic Institute Policy Forum, Washington, DC, May 6, 2008, and available as http://www.keia.org/Publications/Other/vonHippelFINAL.pdf.

products in the DPRK. These restrictions arose partly (if indirectly) from external economic sanctions, and partly from North Korea's inability to pay for oil imports with hard currency. This lack of fuel, particularly for the transport sector, has contributed to the DPRK's economic malaise since 1990. Also contributing to the decline in the country's economic fortunes has been the inability to obtain key spare parts for both energy infrastructure and for factories, including factories built with foreign (often Soviet) assistance and/or technology in the 1970s (or earlier).

Among the other key changes (or continuing processes) for the energy sector since the mid-1990s have been:

- Continuing degradation of **electricity generation infrastructure** due to lack of spare parts, maintenance not performed, or use of aggressive (high sulfur) fuels in boilers designed for low-sulfur coal.
- Continuing degradation of **electricity transmission and distribution** infrastructure, resulting in much **reduced availability and quality of electricity** in most parts of the country away from Pyongyang, and in the last year or so, significant problems in Pyongyang as well.
- Continuing **degradation of industrial facilities** in general, and the damage to industrial electric motors from poor-quality electricity. Lack of markets (since the breakup of the USSR) for DPRK industrial good has reduced fuel demand in those factories that are applicable.
- Evidence of significant international trade in **magnesite (or magnesia**—a valuable mineral used for lining furnaces**)**, and, more recently, in coal and iron ore (trade with China) and other minerals.
- Continuing difficulties with **transport of all goods, especially coal,** and reduced availability of passenger transport.
- Difficulties in **coal production** related to lack of electricity, as well as mine flooding (in the Anju and other regions) and lack of production and safety equipment.
- Some **economic revival** has been noted since 2000, but mostly, it seems, associated with foreign aid, small markets and restaurants, small export-oriented industrial facilities, trade in raw materials with China, and/or in other areas of the economy that are generally not energy intensive.

Figure 1 compares estimated final energy demand by sector for the years 1990, 1996, 2000, and 2005,[2] and Figure 2 provides the same comparison for energy demand by type of fuel. In addition to the marked decrease in overall energy consumption, there are two notable features of these comparisons. The first is that, compared with 1990, the residential sector uses a larger share of the overall energy budget, while the industrial sector share shrinks to a third of the total. This change is the combined result of continued reduction in fuel demand in the industrial sector,

[2] We are updating the DPRK sector analysis from 2005 to a 2007 base year, but have not completed this work. The slow growth of the DPRK economy, however, and the ending of Six-Party Talks Phase 2 heavy fuel imports, suggests that the 2005 figures are likely to be similar to current figures for energy supply and demand.

relatively constant use of wood and other biomass fuels in the residential sector, and reductions in the use of other residential fuels (notably coal and electricity) that are not as severe as the reductions experienced in the industrial sector. Second, and for similar reasons, the importance of wood/biomass fuels to the energy budget as a whole is estimated to have increased dramatically over the course of the 1990s, persisting into the current decade, while the importance of commercial fuels has decreased. Increased use of wood and other stresses have resulted in significant deforestation and degradation of forest lands in the DPRK.

Figure 1:

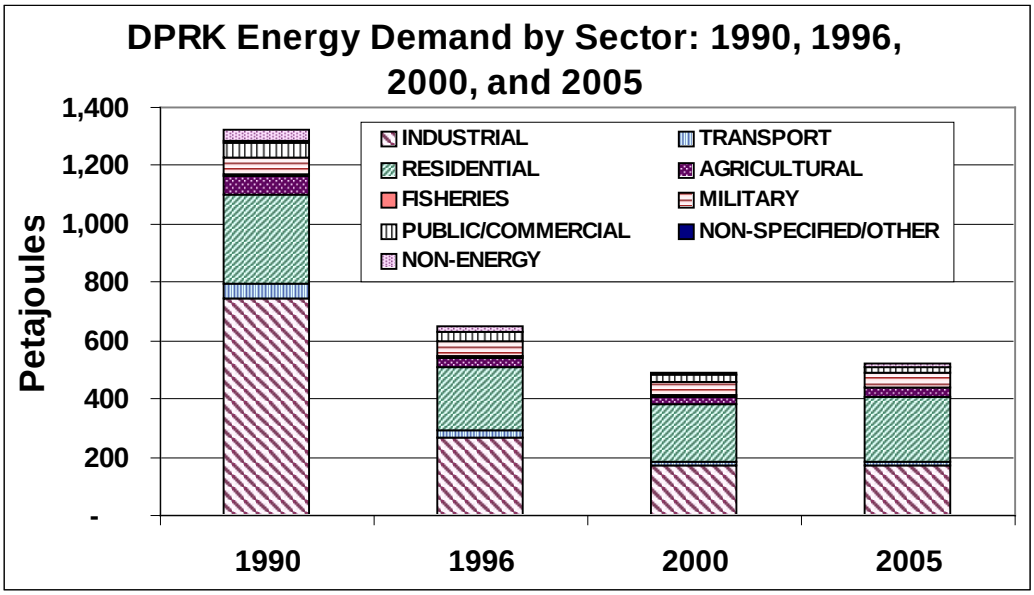
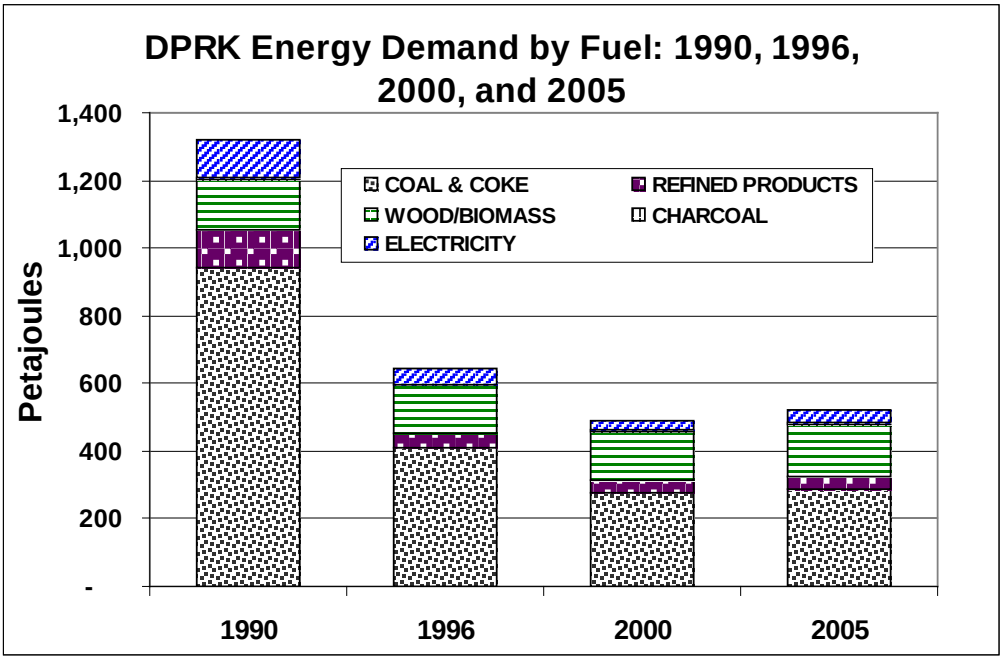


Figure 2:



Lack of fuels in many sectors of the DPRK economy has caused demand for energy services to go unmet. When and if supply constraints are removed there is likely to be a surge in energy (probably particularly electricity) use, as residents, industries, and other consumers of fuels increase their use of energy services toward desired levels.

The DPRK electricity sector is often a focus of interest, both for the impact that the sector has on the economy of the DPRK and on the daily lives of its citizens, and also because the status of the electricity sector had (and may again have) important political implications related to the former KEDO (Korean Peninsula Energy Development Organization) Light Water Reactor (LWR) project, and to electricity grid interconnection options[3]. Analysis of the current status of the DPRK electricity sector suggests that the thermal power generation system in the DPRK has been eroding significantly. In virtually all of the large power stations, only selected boilers and turbines are operating, and those that are still in use mostly operate at low efficiency and low capacity factors[4] due to maintenance problems and lack of fuel. As a consequence of the difficulties with thermal power plants, **hydroelectric plants** have shouldered the burden of power generation in the DPRK, but hydroelectric output is limited by maintenance problems and, equally importantly, the seasonal nature of river flows in the DPRK.

[3] For a more thorough discussion of this issue, see the Nautilus essay Modernizing the US-DPRK Agreed Framework: The Energy Imperative (D. Von Hippel, P. Hayes, M. Nakata, T. Savage, and C. Greacen, 2001), available as http://www.nautilus.org/DPRKBriefingBook/agreedFramework/ModernizingAF.pdf.

[4] The "capacity factor" of a power plant reflects the equivalent fraction of time (for example, during a year) that the power plant is producing its full rated output.

The total estimated supply of electricity decreased substantially between 1990 (46 terawatt-hours, or TWh[5]) and 1996 (23 TWh), and fell still further (by our estimate) by 2000 (to 13 TWh), before increasing somewhat to an estimated 16.6 TWh in 2005.

3. Considerations in Choosing Energy Assistance Options

3.1. Introduction

As is clear from even a cursory review of the other sections of this Report, the nuclear weapons issue and the DPRK's energy sector are only two aspects of the DPRK's national situation, and only a part—albeit an important one from many perspectives—of the concerns that the DPRK's situation raises among the countries of the region and the international community as a whole. As such, any energy assistance options will and should invariably be reviewed not just on the basis of what "works" for the DPRK economy and energy sector, and what gets the job done in terms of denuclearization agreements, but should and will be judged based on other criteria as well.

3.2. How Do the Options Considered Affect the DPRK Economy and Society?

Ultimately, most of those who have thought about the DPRK and its international setting would agree that the overall, long-term goal of the international community's diplomatic efforts involving the DPRK is to help to transform it into a "normal" country. That is, to catalyze a transformation of the DPRK into a country that, for example, is (at least largely) at peace with its neighbors and other nations, operates by rules that other countries can understand and live with (including abiding by international standards and conventions), is able to feed and provide the basic necessities for its people, engages in (at least relatively) free economic discourse with other nations, and attains acceptable standards with regards to the human rights of its populace[6].

An energy assistance option that helps the DPRK in evolving into a nation that is more positively engaged in the international community would include one, or more, of the following attributes:

- Help to fulfill basic human needs. Energy assistance options should ideally also help to improve the daily lives of North Koreans by improving access to one or more of food, health care, education, safe drinking water, effective sewage treatment, and, of course, energy services. Energy services here means the services that energy use provides, including lighting, home/office heat and cooling, cooking, reliable electricity supplies to allow

[5] One terawatt-hour is equal to 3600 terajoules, 3.6 million gigajoules, or one billion kilowatt-hours (kWh). By way of comparison, the District of Columbia used about 12 TWh of electricity in 2007 (US Department of Energy, Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/st_profiles/dc.html), which was perhaps a little more, after accounting for losses in electricity transmission and distribution, than the whole of the DPRK used in 2005.

[6] Of course, one path for achieving these goals is likely to be reunification of the Korean peninsula—depending on the conditions and timing of reunification. Here, we treat the goals discussed as basically independent of reunification, though there are likely to be significant overlaps between achieving these goals and the prospects for reunification.

increased productivity, human/goods transport, and other services. In short, energy assistance in the DPRK should meet international norms for increasing welfare in an equitable manner.

- Contribute significantly toward meeting energy needs. Options offered (beyond the first symbolic/confidence-building options) should be at a level that will demonstrably contribute toward energy needs. This may mean providing a significant (perhaps on the order of a percent or a few percent) fraction of current energy needs, or perhaps meeting a larger fraction of needs of a crucial fuel (electricity, heat, specific petroleum products) or of a particular energy end-use (for example, efficiency improvements for lighting or for district heat).

- Build human capacity. The process of providing/applying energy assistance options should offer training to DPRK workers, officials, architects, engineers, technicians, and others that can be applied as the North Korean economy improves.

- Build economic opportunities. As much as possible, energy sector assistance options should be tuned toward building opportunities for the DPRK to provide for itself in key sectors, and to earn from (non-military) exports. These kinds of opportunities could derive, for example, from training individuals and organizations to provide key energy goods and services, or from energy infrastructure refurbishment in areas where a consistent supply of energy could help to spur production. Many of these economic imperatives should be guided by efficiency measures that are standard norms in international development assistance and market-based investments.

- Allow (or effectively require) the engagement of DPRK citizens with those of other nations. Our experience in working with DPRK officials and technicians has been that the fastest way to change DPRK attitudes about those in other countries is to offer learning opportunities combined with person-to-person contact. Such assistance options could include developing opportunities for private companies from outside the DPRK—carefully vetted and briefed—to work with DPRK organizations; and enterprise-level training inside and outside the DPRK.

- Offer environmental benefits. Energy assistance options should, where possible, address chronic or acute DPRK environmental problems. From erosion due to deforestation, to indoor air pollution from the use of poor cooking and heating fuels and equipment, to industrial effluent problems, to air pollution from decaying boilers lacking emissions control equipment, the opportunities to provide environmental benefits are many.

- Increase energy security, as well as sustainability. Energy security includes diversity of supply by geographic area, fuel type, and technology; resilience of critical infrastructure against vulnerability to cascading network failures, to attack, and to the effects of climate change and other factors, including dual use dimensions of fuel cycles in relation to militarily useful technological diffusion and acquisition.

- Be visible to North Koreans**.** To the extent possible, energy assistance options should demonstrate to the North Korean populace that foreigners are "there to help", and thus begin to demonstrate the benefits of international engagement to the DPRK society, increasing, by

degrees, the acceptance of outsiders, at least on a non-official level. Food and other assistance provided in recent years, along with expanded trade (especially with China), have undoubtedly helped to start this process, and should be built upon.

3.3. What Does the DPRK Want?

Once negotiations begin, it will be easier to reach agreement on energy assistance options that the DPRK negotiators see immediately to be valuable. There are several sources of information that can be used to assist in figuring out which options these would be. Experience in negotiations to date (that is, since at least 1994) have shown that the DPRK will accept heavy fuel oil (HFO) as a mode of stopgap energy assistance. The DPRK has also accepted the concept of "equivalence" whereby HFO as fuel is converted to a dollar equivalent, and then those dollars are used to purchase materials or hardware that are acceptable to the DPRK and external parties. Other DPRK requests made through official channels have focused on equipment and supplies to rebuild key infrastructure, especially thermal power plants, district heating plants, and coal supply infrastructure, as well as the electricity transmission and distribution network. And of course (and we touch upon this topic again later in this section), the request/demand for light-water reactor nuclear plants (LWRs), provision of which that were the foundation of the 1994 Agreed Framework is a major point of national prestige, despite the severe practical limitations involved in operating LWRs in the DPRK.

\In non-official settings, DPRK delegations have also noted the upgrading of large thermal and hydroelectric plants as an emphasis, and have also stressed the national goal of acquiring nuclear power, but have also expressed sincere desires for assistance and training in areas such as improving building energy efficiency (and energy efficiency more generally throughout the economy), and small- and medium-scale renewable energy technologies (solar, wind, hydro, production of methane gas from wastes). A key focus of DPRK energy delegations attending international meetings has always been building human and institutional capacity, including acquisition of technical materials, receiving instruction in basic energy concepts and in the use of design and analysis tools and software, and, generally, learning so as to bring DPRK capabilities up to speed with those in other countries.

The difference between the official and non-official "wish lists" noted above underscores a negotiating reality: different actors in the DPRK—with different amounts of control over the negotiations—will likely have different perspectives on what are acceptable as preferred energy sector assistance options:

- For the **DPRK's leadership**, the options accepted should, from a domestic perspective, reflect well on Kim Jong Il's leadership, and not cross anti-US, pro-military first lines if possible.
- Again from the perspective of **DPRK leadership**, from a geopolitical perspective, attractive options will be those that offer the benefits of standing up to and reducing dependence on China, holding the United States at arms length but building a cooperative relationship, using the ROK where possible against the United States, China and Japan; and engaging Russia to

provide marginal leverage against the other great powers, serving as a buffer against the ROK, and keeping pressure on Japan via other parties.

- For those **DPRK diplomats** in lead roles in negotiations, their interest will be in how agreements are achieved; they will seek to use the Agreed Framework precedents wherever possible and to direct external energy support into channels from which they can extract rent or over which they can earn and bank credit with other state agencies.
- **DPRK economic planners**, who will play a minor support role at talks will be interested in issues associated with financing and obtaining access to international financial institutions, including Japan reparations, and short-term access to ROK support, as well as in topics such as capacity-building of a technocratic elite, building a relationship with the United States through training and study in the US, and development of free trade zones, big cities, big industry, foreign-exchange earning enterprises (including mines), and supporting the DPRK military/industrial complex.
- For **energy planners and line agencies**, who will likely not be represented at the talks, but might be consulted, their interests will lie in options that rebuild the coal and electricity generation/transmission/distribution sectors, and improve supplies of refined product through imports, distribution improvements, and expanded domestic refining of crude oil.
- **Humanitarian and social-economic needs** can be expected to have little or no DPRK voice in the negotiations.

3.4. What Happens if Negotiations Don't Go as Intended?

Success in inducing the DPRK to give up its nuclear weapons and nuclear weapons production capabilities is, unfortunately, not necessarily the only outcome of negotiations. The DPRK could simply decide that it will not, under any circumstances, give up its weapons, and if so, the rest of the world will need to decide on a response. Based on past experience, the most likely response is continued isolation at the equivalent of roughly recent levels, in which case it is reasonable to ask whether any of the energy options provided in either the short or medium-term phases would be likely to make the DPRK more of a threat to the rest of the world, rather than less. It should be noted that this situation—which would extrapolate indefinitely recent trends of very modest economic improvement and very limited opening—could be the result not just of the DPRK refusing to "play ball", but of other actors failing to reach agreement (either between countries or, for example, between the US Congress and Executive Branch) on a consistent, sustained approach to negotiations, and/or fail, for one reason or another, to live up to the agreements made.

3.5. What Happens if the DPRK Collapses?

There is a very real possibility, with incalculable odds, that the DPRK political system may collapse. Whether this is triggered by the death of Kim Jong Il before a succession strategy has been broadly agreed to, by another natural disaster that heaps just too much more misery on the North Korean people, or by a power struggle between DPRK factions (and/or a loss of

control of rank-and-file-soldiers by military commanders)—or a combination of these and/or other situations unanticipated—the result is likely the same: the ROK, with backing by the US and others (and watched, perhaps, with some apprehension by China), would need to somehow pick up the pieces of a shattered country. Given that such a collapse is conceivable, albeit of unknown (and in our view, based on eighteen years of direct experience of the DPRK in "crisis," very low) probability, it is nonetheless prudent to ascertain which of the assistance options provided in various phases will prove helpful, which unhelpful, and which neutral to efforts by the ROK to rebuild the collapsed North? This question is important both to ensure that the ultimate reconstruction burden for the ROK and the international community arising from the DPRK's "black hole" is minimized; but also to provide the international community with some measure of influence and even direct leverage on the ROK's decisions as to what to do with nuclear weapons, fissile material, technology, and personnel that it might inherit from the DPRK's collapse. It is by no means a given that the ROK will simply give them up.

3.6. How Much Aid Can the DPRK Absorb?

An important consideration in negotiating, and even more important in planning and delivering, energy aid options and packages to the DPRK is determining how much of a given option the DPRK can absorb in a given amount of time. Heavy fuel oil deliveries under the Agreed Framework were a case in point: in many years, the DPRK actually lacked the capacity to use the amounts of oil provided. Other types of capacity constraints are human and organizational. Too much aid too fast will outstrip the ability of DPRK ministries to put the aid to use, and the abilities of donors to ascertain that the aid is being used properly, and/or result in wastage through graft. We estimate that until training programs are completed, the DPRK can usefully absorb roughly $100 million of non-fuel energy assistance per year, at most.

3.7. Relationship to Regional Energy Systems

The growth in energy use in the region, and its attendant problems, together with the energy, financial, human, and technological resources available in the countries of the region, create opportunities for energy-sector cooperation in Northeast Asia. These opportunities include integration of conventional energy supply infrastructure (gas and oil pipelines, liquefied natural gas terminals, and electricity grid interconnections), cooperation on energy efficiency and renewable energy development, cooperation on regional emergency and strategic fuel storage, and cooperation on nuclear fuel-cycle facilities. As the major untapped resource base that would feed many of the regional energy transmission options are located in the Russian Far East, and one of the key potential customers for Russian gas and electricity (in particular) is the ROK, energy planners in the ROK and Russia have, not surprisingly, considered for many years the possibility of cooperation activities involving the "country in-between", that is, the DPRK.

Solving the DPRK nuclear issue may not be a strictly necessary condition to allow significant regional cooperation on energy issues and infrastructure, but it would certainly be helpful, and would probably accelerate activities in a number of ways, and for a number of reasons—including the advantages of a regional context for engagement of the DPRK on energy issues. Even once the nuclear issue is (at least largely) addressed, however, considerable challenges to bringing the DPRK into regional cooperation activities will remain. To cite just a

few examples, significant efforts will be needed to upgrade DPRK infrastructure, provide capacity building, and help to reform legal and administrative systems to allow DPRK to participate fully in regional initiatives (in many cases, similar efforts will be needed in other countries as well). "Geopolitics", that is, consideration of the impacts of regional energy cooperation activities on the relations between powers great and smaller both within and outside the region, are also likely to come into play—in ways that may be difficult to predict—as resolution of the DPRK nuclear issue nears.

In addition to the challenges noted above, resolution of the DPRK nuclear issue would undoubtedly open opportunities for cooperation on energy issues; and in this context, regional network integration would offer negotiating options with the DPRK, although these regional projects would be capital-intensive and long-term. 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 to take direct route to 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 other 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 final international rules for applying Clean Development Mechanisms (CDM), which allow the credit for greenhouse gas emissions reduction between nations, 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[7].

A special challenge—and opportunity—related to energy sector cooperation in Northeast Asia is related to the potential influence of the Simpo/Kumho (DPRK) nuclear reactors on grid interconnection proposals. As the major element of a 1994 agreement between the United States (and its allies) and the DPRK, a consortium of nations (the United States, ROK, Japan, and the European Union), organized the Korean Peninsula Energy Development Organization (KEDO) to finance and build the reactors. Until the beginning, in late 2002, of the current impasse between the DPRK and the United States (in particular, though other countries are involved in and assisting in attempting to resolve the dispute as well) over the DPRK's alleged nuclear weapons programs, KEDO was providing financing for and constructing two 1150 MW light water reactors (LWRs) at the Kumho site near Simpo on the East coast of the DPRK. Though KEDO was been officially shut down, as of mid-2006, and the LWR project "terminated" (see http://www.kedo.org/), completion of the reactor project remained, as noted above, a key point of negotiation in the Six-Party Talks, and continues as a key political demand of the DPRK.

[7] For additional detail on this topic, see "Future Northeast Asian Regional Energy Sector Cooperation Proposals and the DPRK Energy Sector: Opportunities and Constraints", published by the authors in ERINA REPORT, June, 2008 (http://www.erina.or.jp/en/Publications/er/pdf/Er82.pdf), and "Growth in Energy Needs in Northeast Asia: Projections, Consequences, and Opportunities", prepared by the authors based on a presentation at the Korea Economic Institute Policy Forum "2008 Northeast Asia Energy Outlook", Washington, DC, USA, May 6, 2008 (http://www.keia.org/Publications/Other/vonHippelFINAL.pdf).

The Simpo/Kumho reactors were intended to help alleviate DPRK electricity shortages, but use of these reactors in the DPRK grid was always problematic, at best[8]. First, the DPRK grid is highly fragmented, and reactors even a fraction as large as those being operated could not be operated without tripping on and off to a dangerous degree. Second, even if the DPRK grid were fully integrated and its plants were operating at their nominal (as of 1990) 10,000-12,000 MW capacity (of which we estimate that on the order of 2000 to 3000 MW were actually currently operable as of 2005), the grid would be too small to safely operate the reactors without serious grid stability concerns. Third, no source of reliable back-up power is now available to the Kumho site that would allow the reactors to be operated within international nuclear safety rules. What these technical constraints mean, effectively, is that some type of interconnection with the ROK or Russia/China (or, more likely, both), will be required if the reactors (if completed) are ever to generate power. This requirement, if reactor construction is restarted, is likely to add a significant political (and economic) impetus to the development of Northeast Asia grid interconnections, potentially affecting the timing, and type, of North-South grid interconnections[9].

3.8. What Options are Likely to Be Beneficial, and Which Problematic, from an ROK Perspective?

Outside of the DPRK, the country most directly affected by assistance options implemented as a result of negotiations will be the Republic of Korea. From the ROK's perspective, as a practical matter (at least in the longer term, though this may not be a current focus in the ROK), any implemented options that improve the DPRK's key energy, economic, transport, human, and other infrastructure make the transition to a unified Korea—whether operating as a single political entity or unified in a de facto sense through economic integration—that much easier and less painful. Short of reunification itself, options that improve the ability of the DPRK to cooperate economically with the ROK are also desirable, particularly, and especially in the current ROK political environment, if they offer scope to benefit the ROK economy demonstrably in the short term as well. Any options that benefit the DPRK military, or have potential for military diversion, will be problematic to the ROK (and its military ally the United States), as will options that result in further environmental degradation North of the DMZ. Options—such as shared energy infrastructure—that make the ROK dependent on the DPRK will likely be unattractive, at least in the short term. Conversely, it is also important that linkages between energy supply systems in the ROK not be destabilized or stressed by the DPRK energy systems—as could occur, for example, if the DPRK grid were connected to the ROK grid.

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[8] For more detailed discussions of issues related to operation of the (former) KEDO reactors, see John H. Bickel (2001), Grid Stability and Safety Issues Associated with Nuclear Power Plants. Paper prepared for the Workshop on Power Grid Interconnection in Northeast Asia - May 2001, Beijing, China, and available at http://www.nautilus.org/archives/energy/grid/papers.html.

[9] This discussion should not be taken as an argument on the part of the authors that completion of the Simpo reactors is either the best thing for the DPRK economy or the most cost-effective—in terms of providing energy aid—use of funds for DPRK energy assistance, as it is neither. Our discussion, rather, is designed to point out the political and technical realities associated with the reactor project.

3.9. Who Pays, and How Much?

Funds to support energy assistance activities by the allies working on the nuclear bargain with the DPRK must come from somewhere, and, particularly in the current economic climate, such funds cannot be expected to be unlimited. There are a number of different options and different potential sources—including different countries and institutions—that may be tapped for DPRK energy sector aid. Some of these—most notably Japanese reparations for damages imposed on Koreans before and during WWII—have deep roots in regional history. Others, including "Clean Development Mechanisms", are more modern in origin, and represent opportunities for other countries, as well as the DPRK, to benefit from the application of energy assistance options. When the ROK steps up to the status of an "Annex I" country under the Kyoto Protocol, opportunities for CDM investment close to home in the DPRK will look attractive to help meet announced ROK "green development" goals, in particular if they also fulfill some of the criteria noted in 3.8, above. Sill others, most notably support by international financial institutions (IFIs) such as the Asian Development Bank and the World Bank, are of keen interest to the DPRK, but will come with a host of preconditions.

Moreover, there are various metrics of value—perceived and otherwise—that can and will be applied by the DPRK to ascertain whether it is getting a reasonable "bargain" in negotiations. These metrics include the perceived value of nuclear weapons as a deterrent to hostile acts by others, and also, significantly, the perceived value to the DPRK of deals negotiated earlier.

For the former, if one assumes that the DPRK's GDP is on the order of USD 40 billion per year,[10] and that the military consumes 10-15 percent of GDP, and further, that the DPRK perceives that nuclear weapons have a deterrent value that allows it to reduce its military expenditures by on the order of 10-15 percent per year, then the ultimate value in trade, as it were, of the DPRK's nuclear weapons could be calculated at on the order of $400-850 million per year—should it ever substitute nuclear threat for conventional military capacity.

For the latter, the most straightforward points of comparison are the value of heavy fuel oil provided under the Agreed Framework, and the imputed value of the LWRs that were to be provided under the same agreement. At a cost of on the order of $270 per tonne (the price of heavy fuel oil in Asia as of about February, 2009), the original Agreed Framework provision of 500,000 tonnes of HFO per year would be worth about $135 million annually. Our very rough estimate of the value to the DPRK of the pair of LWRs, if completed, is that the worth of the reactors (after netting out DPRK payments on the low-interest, long-term loan used to finance the reactors) would be about $300 million per year[11].

What these rough estimates suggest, in sum, is that the DPRK will expect to receive a package of energy assistance options with a total value on the order of hundreds of millions of

[10] Economists differ on the size of the DPRK GDP and even how to measure it. This is a reasonable estimate in our view.
[11] A host of admittedly quite rough assumptions go into this estimate, including a reactor cost of $2500 per kW, sales of most of the electricity from the reactors to the ROK at a price of 6 US cents per kWh (not so different from average US wholesale electricity costs), and that the DPRK pays for other costs of running the reactors out of the proceeds of its power sales to the ROK.

dollars per year. The non-trivial, multi-dimensional problem of how these costs/values are distributed among different assistance options will be up to the negotiators, as will the time frame over which such benefits would be provided to the DPRK. Relatedly, energy assistance that is in the form of fuel can be delivered very quickly and with low risk from the DPRK perspective; whereas energy capital investments for the most part take many years to complete and to deliver energy benefits, although the cumulative benefits will far exceed immediate benefits from only receiving fuel.

3.10. Benefits to Countries of Contributing to Energy Sector Aid Packages for the DPRK

Beyond the significant global benefit of rolling back proliferation in nuclear weapons, and acquiring a more cooperative neighbor, countries involved in the denuclearization deals (and in paying for same), receive additional benefits. China and Russia reduce the likelihood of uncontrolled migrations across their borders.

In the medium-term, all of the countries involved (and groups of countries like the EU) begin to open access to new markets for goods and services in the DPRK, including access (as legal arrangements are finalized) to inexpensive DPRK labor. Some of the outlays by contributing countries can be expected to be spent on goods and services from their own firms. Russia gains markets for electricity and gas. The ROK gains access to many minerals it lacks, and the opportunity to import Russian resources over land, plus puts a down payment on and catalyzes the development of infrastructure and human capacity leading toward development of an economically-integrated Korean peninsula, without having to shoulder the full cost.

4. Options for DPRK Energy Sector Assistance

4.1. Introduction

Given the goal of international negotiations will be to convince the DPRK to give up its nuclear weapons and the capabilities to produce them, the DPRK's vast needs in the energy sector means that the number of potential energy sector assistance options, and the number of combinations of options that might be assembled into "packages" are many. Below we start with a thumbnail discussion of overarching DPRK energy sector needs and options, then present a review of more specific options that might be consistent with denuclearization goals in the short, medium, and longer term. We also highlight which options offer benefits, and which don't, from the perspective of the considerations noted above.

4.2. Overarching DPRK Energy Sector Needs and Options

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, sufficient arable land to reliably feed its populace, and above all, investment capital. As a

consequence, given the energy sector problems outlined above, a coordinated program of assistance from the ROK, the United States, and/or other countries that builds upon these attributes will be needed. Providing key assistance in a timely manner will enhance security in Northeast Asia, accelerate (or, given recent events, help to re-establish) the process of North Korean rapprochement to its neighbors, and help to position 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[12]. 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. Below, we identify priority areas where we see DPRK energy sector assistance as both necessary and in the best interests of all parties. All of these interventions would put foreign (US, European, ROK, or other) engineers and other program staff in direct contact with their DPRK counterparts and with DPRK energy end-users.

- *Provide technical and institutional assistance in implementing energy efficiency measures*. Focusing in particular on energy efficiency, regional cooperation would be useful to help the DPRK to provide the DPRK with access to energy-efficient products, materials and parts, pursue sector-based implementation of energy efficiency measures, and carry out demonstration projects.
- *Work to open opportunities for private companies to work in the DPRK*. Grants or loans from foreign governments cannot begin to fill the needs for energy infrastructure in the DPRK, but the US, ROK, European, and other governments can help to facilitate the efforts of private companies (including independent power producers) from abroad in the DPRK energy sector.
- *Cooperation on technology transfer for energy efficiency and renewable energy applications*.

Specific energy sector initiatives that will assist the process of rapprochement with the DPRK, help the DPRK to get its economy and energy sector working in a sustainable (and peaceful) manner, and help to pave the way for additional cooperative activities in the energy sector include:

- *Assistance for internal policy and legal reforms to stimulate and sustain energy sector rebuilding in the DPRK*. This could include reform of energy pricing practices, and the physical infrastructure to implement them, capacity building for careful energy planning to allow aid to be based on need and rational objectives, training for energy sector actors, strengthening regulatory agencies and educational/research institutions in the DPRK, and involving the private sector in investments and technology transfer.
- *Rebuilding of the T&D system*. The need for refurbishment and/or rebuilding of the DPRK T&D system has been touched upon earlier in this paper. The most cost-effective approach

[12] This argument should not, however, be interpreted to mean that the former KEDO LWR project must be totally abandoned (at least without the negotiated agreement of the DPRK). For all of its many faults, the reactor project, when active, was one of the few avenues for constructive communication with the DPRK, and it remains a political priority for the DPRK, and thus a main point of negotiation in the Six-Party Talks.

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 area of a special economic zone or in a "demonstration" county.

- *Rehabilitation of power plants and other coal-using infrastructure*. An initial focus should be on improvements in small, medium, and district heating boilers for humanitarian end-uses such as residential heating.
- *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. Coal supply system rehabilitation will require provision of basic systems for providing ventilation, light, and motive power for water pumping and extraction of coal to mines, as well as improvements in mine safety.
- *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, and should (especially initially) emphasize agricultural and humanitarian applications.
- *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 the basic needs of the rural population to be met.
- *Begin transition to gas use in the DPRK with Liquid Petroleum Gas* (*LPG) networks*. LPG is more expensive than natural gas, but the infrastructure to import LPG, relative to liquefied natural gas (LNG) is much easier, quicker, and less expensive to develop, and allows imports in smaller quantities. LNG is also clean burning, has limited military diversion potential, and setting up LPG networks can be a first step toward the use of natural gas in the DPRK—if done with a future transition to natural gas use in mind. Ultimately, natural gas pipelines and LNG terminals, shared with neighboring countries, can serve as a step toward economic development coupled with regional integration.

Many of these options, or elements of same, are included in the following recommended suites of assistance opportunities matched to the negotiation phases described above. More detailed descriptions of these options are provided in previous reports by the authors[13].

4.3. Energy Assistance Options Matched to Short-term Needs

In the short term, the key goal is for the parties to restart dialog and to begin substantive negotiation on issues related to the DPRK weapons program. As no large concessions would be expected on the DPRK side during this phase, most of the energy options suited for provision during this time will be likely be modest in scale, of a symbolic/confidence-building nature,

[13] [Reference to VH/Hayes 2007 Energy Analysis report, others reports as needed]

available for implementation at short notice, and/or consistent with options provided under previous agreements. The energy assistance options offered as inducements for the DPRK to join and continue in productive negotiations with the US and other partners will need to have several particular attributes. They will need to be relatively easy to deliver (meaning a lead time of a few months or less to mobilize), generally modest in cost (and scope), and, ideally, have significant symbolic and confidence-building value, ideally, to both the North Koreans and to those on the other side of the table. Some key categories of options for short-term assistance, and their positive and negative characteristics, include the following.

1. **Provision of fuels** for input to power generation and district heating facilities, and possibly to mineral-export-oriented industrial plants. Fuel provision options in the short term include heavy fuel oil (HFO) and coal. HFO is, for many reasons, a suboptimal choice as a fuel for the DPRK, as most (all but one or two) DPRK power and heating plants were not designed to use it in significant quantities, and its usefulness in other infrastructure is limited. Still, HFO has limited potential for military diversion, is relatively easy and quick to procure and deliver, and, most significantly, has a long history of being an element of denuclearization "deals", going back to 1994 (meaning it is relatively easy for both sides to agree upon). Provision of coal for power plants and heating plants is also an option, but only to the extent really needed and helpful. It should be remembered that the DPRK has, in the past few years, been exporting millions of tonnes of coal to China, but Chinese companies may pretty much have control of the entire production chain for those exports.

HFO provision has status as a historically-recognized currency of negotiation means that also has symbolic value to the DPRK. HFO provision does little to move the DPRK economy or energy sector toward self-sufficiency, though it does have some humanitarian benefit (allowing lights and heat to run longer in DPRK cities). HFO supply does little to promote capacity-building or person-to-person interactions, and is not particularly helpful to ROK interests in either a collapse or eventual reunification scenario. Provision of coal is perhaps somewhat better in some respects—for the reason that DPRK power plants are mostly designed to use coal, not HFO.

HFO provision is the most expensive of the short-term options, with costs in the $100-$400 million dollars per year range, assuming quantities shipped annually are similar to what has been offered in past negotiations. HFO provision will likely be paid for by a consortium of countries, as in the past. Coal provision could also be paid for by a consortium of countries, or could be the contribution by one country—China or Russia being leading candidates due to their easy rail and water transport links to the DPRK.

Provision of HFO, as in the past, will likely require interactions with at least some officials of the ministries responsible for electric power and for oil refining (the Sonbong refinery on the DPRK's East Coast is one likely drop-off point for HFO), as well as managers and workers at specific plants where oil deliveries will be made. Interactions with port officials and officials related transport ministries (railways, land and marine transport) may be required as well. As with all options, interactions can be expected with the Foreign Affairs Ministry and Korean Workers' Party officials with whom the agreements will likely be negotiated.

2. **Provision of diesel engine-generator sets, and of agricultural equipment, for various purposes** can be (and has been) considered as a short-term option for energy sector assistance. Here a key consideration is that diesel fuel, as well as parts and maintenance supplies, for the "gensets" and other equipment would need to be provided well into the medium term, ultimately at considerably greater expense than the gensets themselves. Specific applications for diesel engine-generators include:

- Diesel generators or modular combined heat and power systems for humanitarian applications like hospitals, clinics, and schools, likely supported also by provision of efficient end-use equipment for lighting, space heating, water heating, refrigeration, and special uses such as clinical devices.
- Diesel generators for agricultural applications, for example, to run rice threshers and mills in agricultural areas, and possibly efficient electric motors to use with them.
- Diesel generators to support mining equipment, safety equipment, water pumps (which could be diesel or electric), and lighting in coal mines, again, likely supported by provision of equipment to use with them (equipment which may either be absent or in poor condition in the mines where the generators will be used).
- Provision of diesel tractors for bringing in the harvest, and diesel engines to run pumps for irrigation or to directly run other agricultural equipment. With what is apparently expected to be a relatively good harvest currently in the fields, helping provide tractors to augment the (mostly) human and animal power used to bring in much of the harvest will help to ensure that the DPRK gets as much as possible out of its limited agricultural inputs.

For the options above where generators, tractors, and other equipment might be provided, humanitarian and social benefits can be expected, and, depending on how the units are provided, person-to-person contact at the local level is a possibility, as generators and tractors are disseminated to the countryside. There would be some benefit to the overall DPRK economy, but only so long as supplies of diesel, parts, and the wherewithal to maintain the machines (often under rugged use) continue to be provided. Diesel fuel diversion for military use is an issue that cannot be ignored; here providing liquefied petroleum gas (LPG) as an alternative fuel with less diversion potential is an option, but LPG is more expensive and a bit more cumbersome to provide, since it must be delivered in pressurized tanks. These "humanitarian equipment provision" options DPRK negotiators may see these types of

Humanitarian diesel installations, provision of farm equipment, and similar initiatives—at costs ranging from hundreds of thousands to, for more extensive programs, perhaps tens of millions of dollars—would probably be provided through bilateral aid (or, for example, through EU/EC aid programs).

In addition to interactions with DPRK negotiators, as noted above, provision and installation of humanitarian diesels and related equipment may involve a wide range of DPRK actors, from officials in the Ministries of Agriculture, Health, and/or Education (to the extent that their facilities are selected as host sites for assistance) to officials (county, city, and farm level, for example), technicians, managers and workers at the farms, hospitals, schools, or other installations where equipment is used.

3. **Initial efforts at building human capacity in the DPRK** to move its energy system forward. Such efforts could include study tours of DPRK officials/engineers/technicians to the United States and other countries on topics including energy efficiency, renewable energy, power systems design, energy markets, and training by experts from elsewhere on similar topics for groups in the DPRK. Involvement of DPRK students in existing University-based "short courses" on energy-related topics in other countries is also a possibility here.

Capacity-building efforts will have little effect on meeting DPRK energy needs in the short term, but will have significant symbolic/confidence-building value, and also will plant the seeds of longer-term human capacity building and social/economic changes that will be of benefit from the perspectives of most of the considerations described above, including those that affect the ROK. Capacity-building, especially in the form of training and transfer of software and technical materials, has typically been high on the list of requests of DPRK delegations to international meetings.

Study tours and other capacity building, with costs in the tens or hundreds of thousands of dollars, could be supported by governmental and non-government grants, national laboratories, and academic organizations, including by/in countries not previously directly involved, but with an expressed and consistent interest, in denuclearization discussions (for example, Australia, New Zealand, EU/EC, individual European countries).

Setting up capacity-building efforts such as those above could involve at least limited interactions with officials from a wide range of ministries, and from institutes operating under ministries. Possibilities include ministries responsible for electric power, coal mining, industry, finance, construction, commerce, education, universities, and institutes such as those for thermal engineering, non-conventional energy sources, or coal mining technology, and the broader State Academy of Sciences. The deepest interactions, of course, would be with the individual trainees—themselves academics, officials from ministries or related institutions, or engineers/technicians nominated by officials to participate.

4.4. Medium-term Energy Assistance Options

In the medium term, the objective of talks will be to make progress on getting the DPRK to disable and dismantle, or re-disable, their nuclear fuel-cycle facilities for producing fissile material for weapons, and to allow the international community to set up and run monitoring facilities to assure that facilities remain dismantled and that materials (such as spent-fuel rods) remaining in the country remain secure. In the medium-term, it is assumed that the parties have not yet reach the point where the DPRK has committed to dismantle their existing weapons or divest itself of its not-yet-"weaponized" Plutonium stocks. For this phase, which could last months or years, energy assistance options would include ongoing aid in the form of fuel supply, but would also shift to at least starting, perhaps on a local or county/provincial scale, to address infrastructure and human capacity issues with the DPRK's energy economy.

Assistance in the medium term will need to shift from simply trying to provide for immediate needs to beginning to address some of the major structural/infrastructural problems noted above. Assistance will need to be phased and organized so as to be shown to be providing significant value at points where the DPRK follows through with agreements to disable/dismantle its nuclear fuel cycle facilities, but with an eye toward the DPRK's capacity to absorb the assistance. Potential categories of options for application in the medium term, and analysis of their probable performance relative to the criteria provided earlier, are listed below.

1. **Refurbishing of selected major energy facilities**. This category of options involves projects to rebuild, and in some cases replace, a few key individual large energy facilities. In many cases, these individual refurbishment efforts could effectively be first projects to demonstrate and work out technical, logistic, financing, and other details of infrastructure rebuilding on a broader scale in the longer term. Options here include:

   - Assistance with refurbishing one or a few thermal power plants and district heating plants feeding DPRK cities, involving tasks such as replacing and repairing boilers and steam systems, installing modern control and environmental monitoring systems (for example, for air pollutant emissions), and improving system efficiencies through, for example, better insulation of steam lines and boilers, improved heat exchangers, and better coal preparation systems.
   - Assistance with refurbishing one or a few larger (say, 50 - 400 MW) hydro power plants, including repairing dams to reduce leakage (and danger of failure), dredging reservoirs to improve or restore capacity, and replacing or repairing turbines and generators to restore and, in some cases, add capacity to hydro systems.
   - Assistance with rebuilding coal supply infrastructure in one or a few key mines, ranging from providing technical advice on the refurbishment of selected existing mines with long-term economic potential, to providing mining equipment (including electricity supply, water pumps, air supply, and other crucial inputs) to helping to evaluate new coal seams, to assisting with rebuilding coal transport infrastructure.

Of these options, those related to improvement of coal infrastructure and thermal power plants will help to place the DPRK economy on a better footing, but will likely do little to address environmental concerns, and aren't easy candidates for CDM investments. These and other options that are focused on big facilities—such as hydro plant improvements, probably will have a limited impact in terms of person-to-person capacity building, as they likely will involve a few contractors working with a relatively few plant staff and the officials in charge of the facilities. All of these options, however, including the additional medium-term options described below, are of ultimate benefit to the ROK in aiding eventual economic integration, except to the extent that the energy produced by the refurbished plants is diverted to the DPRK military.

Coal infrastructure projects beyond the pilot/individual mine scale, and refurbishment of big thermal and hydroelectric plants, with costs of tens or hundreds of millions of dollars, are candidates for funding by IFIs, possibly involving international engineering companies (though the latter would likely require government-supported loan guarantees in order to participate).

Infrastructure projects such as those above will involve interactions with officials from ministries in charge of electric power and coal, as well as, potentially, construction and transportation (railways). More local interactions with individual plant managers and other officials, as well as plant technicians, will also be involved.

2. **Integrated energy supply/grid refurbishment/economic development assistance** (for example, in a mineral-rich county of the DPRK). Such projects could include mini-hydro and/or biomass-fired plants for new/rebuilt "mini-grids", and/or modest-sized coastal LPG terminals (delivery and distribution points for LPG) and gas-fired power generation, again with a new or rebuilt mini-grid, to start the development of gas distribution infrastructure and use for an export-oriented (non-weapons) factory complex.

County-level economic/energy projects have an excellent potential to catalyze similar projects elsewhere in the DPRK, with a longer-term prospect of being interconnected to re-form sub-national or national electric grids (see below). County-level projects also have the benefit (and burden, for organizers) of needing to involve a wide variety of DPRK actors (national, provincial, county, local) in different occupations, and in extensive consultation with those providing the assistance. Ministerial-level contacts that may be required—and these will vary by project—could include industries responsible for electricity, coal mining, light industry, construction, extractive industries, and many others. Pilot renewable energy projects will be particularly fertile ground for interaction with North Koreans, and can help to catalyze the development of local, and possibly even export, industries.

County-level initiatives, likely costing in the millions to tens of millions of dollars, may be funded by negotiating countries or groups of countries, possibly in combination with foreign commercial ventures (e.g. small mining or manufacturing firms).

3. **Additional capacity-building and related pilot/demonstration projects**. These initiatives may be distinguished from those suggested for the short-term in that they involve a broadened scope, including training for many more North Koreans through enterprise-level training, and training within DPRK universities and institutes with the ultimate goal of international experts providing "training of trainers" for much broader knowledge dissemination. Capacity-building would also likely include a broad program of training DPRK undergraduate and graduate students, as well as specialized post-graduate training, in universities around the world (China, Russia, Europe, Australia/New Zealand and the United States, for example. Specific training applications could include:

- Training in energy efficiency/renewable energy application, including the installation of pilot projects (especially those with a humanitarian angle, including health care, education, sewage/water treatment) guided by international experts but with considerable hands-on work by DPRK technicians.
- Capacity building, building on the initial program started in the short term(as described in 4.3, above) to train officials and others in the operation of energy markets and related organizational/legal issues, possibly including developing "centers of excellence" and/or training centers within existing DPRK institutes, ministries, or universities. One particular

venue for capacity-building here might be participation by DPRK officials in the APEC Energy Working Group.

Ongoing capacity-building, with broadening scope, extends and expands the benefits noted in section 4.3, have been consistently and demonstrably noted as desirable by the North Koreans we have interacted with, and will be of benefit to the ROK—by producing skilled North Koreans with experience interacting with foreigners—in any type of integration scenario.

Capacity-building ventures in the medium term may be broader and more costly than noted in section 4.3, but still within the means of a combination of bilateral aid and non-governmental actors. Renewable energy/energy-efficiency projects may also attract bilateral aid funding, and in some cases, capital from small private foreign ventures (likely supported by government loan guarantees).

These capacity-building efforts could involve interactions with the broad range of DPRK actors noted for short-term capacity-building efforts in section 4.3. Deeper interactions can be expected with agencies—including, for example, particular institutes and/or universities, that play host to "centers of excellence" or events for "training of trainers".

4. **Reforestation of areas degraded by the overuse of land for agriculture and/or wood harvesting for fuel in lieu of coal**. Note that this activity will need to be couple, in many cases, with provision of fuel supplies for local cooking and heating enduses in order to (help) assure that reforested areas grow mature trees.

Reforestation options may, depending on how they are organized, have significant humanitarian, social, and environmental benefits, but must involve local populations (so as to make sure that they understand what is needed to care for the new forests, understand the benefits to them of the reforestation efforts, to make sure that their needs for food and fuel are met so that they need not harvest the new forests too early, and make sure that other local considerations are taken into account) or risk failure. Reforestation efforts are desirable to the DPRK, having been a focus of domestic campaigns for a number of years, and help to create a more environmentally sound Korean peninsula for the long term.

Reforestation projects (and some energy efficiency/renewable energy projects), likely with costs in the millions of dollars or more, depending on scope, may be candidates for CDM funding, including from ROK sources.

Reforestation options will particularly involve official and staff of the Ministry of Forestry, but could also involve representatives of other ministries, including agriculture and transport, and of institutes such as non-conventional/new and renewable energy. Reforestation projects much also, as noted above involve local populations, meaning officials at the provincial and county level, and especially leaders of local cooperatives and, to the extent contact is allowed, individual local residents themselves.

4.5. Energy Assistance Options for the Longer Term

The major ultimate overall goal of negotiations, once existing nuclear fuel-cycle facilities are dismantled, is to induce the DPRK to give up its nuclear weapons, including dismantling its existing nuclear warheads and handing over to the international community for proper disposal

its existing Plutonium inventory. In recognition that this agreement on the part of the DPRK means giving up a significant military—and thus, through its effect on the military budget, economic—asset, energy sector assistance in the longer-term will need to have considerable economic and symbolic value, and be of a nature that demonstrably upgrades the capabilities of the DPRK's energy sector.

The DPRK will expect a significant level of economic/energy sector assistance, as well as implicit (through integration into international activities) and explicit security guarantees, in exchange for divesting itself of its nuclear weapons and fissile material inventory. Some of the categories of options that might be offered, and their attributes, are described below.

1. **Completion of one or both of the Kumho light water nuclear reactors**. As unappealing as this option may be to some in the United States and elsewhere, it is an important issue of national pride to the DPRK, having been negotiated by Kim Il Sung as part of the 1994 Agreed Framework. In addition, there are a number of reasons (see below) why this option is also appealing to the ROK. Completion of the LWRs would probably, in fact, be a topic of discussion from the very early days of reconvened negotiations, and implementation phases—including, for example, training in adherence to IAEA protocols and non-proliferation measures, assessment of the current status of reactor construction, and planning for restarting of construction—would likely start in the medium term, even if nuclear components are not delivered until not long before an on-line date that would probably, in the best of circumstances, not be before 2018.

   One possible one-LWR-equivalent "package" (albeit out of a practically infinite number of possible options) is described below[14]. This combination of elements offers the same net value to the DPRK—a total of about $600 million in discounted 2010 dollars—as would one LWR unit.

   - Hydroelectric plant rehabilitation: 600 MWe (Megawatts of electricity) net added capacity over 7 years
   - Thermal plant power and heating plant rehabilitation: 700 MWe addressed, providing major efficiency improvements, net power increase; the assumption is that the DPRK provides additional coal required.
   - 50 MWe local wind power with pumped-storage hydroelectric facilities (as a means of storing intermittent wind power), and diesel generators for local grid support; the DPRK is assumed to pay for diesel fuel after year 7.
   - About $500 million in (undiscounted) investment in energy efficiency to save electricity, heat, coal (and likely biomass) throughout the DPRK.
   - 40 MW diesels for humanitarian applications; the DPRK pay for diesel fuel after year 7.

[14] Adapted from presentation by P. Hayes and D. von Hippel, "The Six-Party Talks, Energy Assistance, and Korea's Energy Security", Briefing To IPUS Conference on "The Future of North Korea and Global Cooperation", March 13 , 2009, Seoul, ROK.

- One small LPG terminal and associated T&D infrastructure per year for 6 years; the DPRK pays for imported LPG after year 7.

Completion of the LWRs will force the interconnection of the reactors with the ROK grid, and of the DPRK and ROK grids, at least on a limited scale (to begin with). Interconnection with the Russian Far East electrical grid may be catalyzed as well, offering potential regional resource-sharing benefits. LWR completion will not help much with capacity-building or economic development in the DPRK, but will provide the DPRK with a steady stream of income from power sales to the ROK. Completion of the reactors also will benefit the ROK under an economic integration scenario (as the ROK lacks additional sites for nuclear power plants on its own territory). Under a DPRK collapse scenario, the reactors might be a target for violence or blackmail by a sub-national group, but if not, they would be an asset to quicker integration of North and South.

The ROK would provide much of the up-front capital—likely several billion dollars—for completion of the LWR project. Given its bitter experience in the last iteration of the project, however, it would likely only provide financing with a back-up guarantee from the United States, and possibly with some degree of long-term ownership of the project, though that might be a difficult sell to Pyongyang.

The LWR project itself would require interaction with a fairly limited suite of DPRK ministries—electric power, transport, and a few others—and with the immediate on-the-ground managers and laborers involved in the project. An LWR-equivalent "package" like the one described above would require interaction with a much broader group of ministries and individuals, including practically all of those mentioned above and below in connection with individual options.

2. **Larger national and international infrastructure projects**, candidates for which include:

- A smaller (relative to typical ROK, Japanese, or Chinese installations) LNG receiving facility completed in year 7, paid for by ROK, which gets 95% of gas. DPRK keeps 5% as rent, receives electricity and gas transmission and distribution infrastructure and port-related infrastructure, plus 50 MWe of gas combined-cycle electricity generating capacity. Such a facility would allow the DPRK to continue the process toward adopting gas use begun in the medium term, while offering the opportunity to obtain "rent" income in kind by bartering the site for the facility for gas.
- More extensive—relative to initiatives undertaken in the medium term—national electrical grid reconstruction, including installation of modern control and communications equipment, meters, substations, and software (and training in the use of same). Complementing and completing the local and regional grid improvements (in the context of projects to build the local economy) undertaken in the medium-term phases, these initiatives would seek to make the DPRK grid "national" once more by modernizing power transfer and switching equipment and software at all power flow control points, replacing (reportedly failing) transformers and other equipment at major substations (where high voltage power is "stepped down" in voltage for local use), rebuilding transmission lines and towers where needed, and a host of other improvements

that will likely add up to nearly complete replacement of the DPRK's transmission and generation infrastructure.

- Assistance with building natural gas grids (and marketing/metering systems) in conjunction with regional gas trade initiatives (as noted above). These could include grids fed by "pipeline" natural gas, from the Russian Far East, and/or by a terminal for importation by sea of LNG that would presumably be located near the ROK/DPRK border and shared between the two countries (for example, as described in the LWR-equivalent package noted above).
- More extensive assistance with coal supply infrastructure, including related transportation infrastructure (rail) improvements/rebuilding on the national level, again possibly in conjunction with regional initiatives—this time transportation refurbishment for the possible connection of rail and road transport facilities from the ROK through the DPRK to Russia/China and beyond (a "New Silk Road"). Coal infrastructure improvements beyond those suggested as medium-term options could include more extensive development and modernization of the largest key mines, completion of long-term refurbishment of major mines damaged by floods over the last 15 years[15], and provision of electricity supplies to mines in order to power safety and mechanized mining equipment.

These large infrastructure projects will be of benefit to the DPRK economy, and in some cases, the environment, and will also help with integration of the DPRK into the regional and global economy. In and of themselves, their impact on DPRK society—in the sense of providing broad opportunities for interaction of DPRK citizens and institutions with people and ideas from outside the DPRK—will be limited, as they are likely to involve only small groups of DPRK technicians at major facilities in direct contact with counterparts from, for example, foreign engineering firms. Fixing DRPK infrastructure, however, can be expected to bring along other forms of modernization—including communications—that can be expected to break the DPRK's isolation once and for all, as well as providing the underpinnings for an economy that better sustains the DPRK populace.

It is not entirely clear to us how DPRK negotiators might respond to the offer of these large infrastructure projects. On the one hand, many are consistent with national goals for the DPRK energy system, and with the DPRK's participation in some international fora in which regional interconnections have been/are being discussed. On the other hand, these projects will require, in some ways, a vast increase in the complexity of the DPRK economy's interactions with economies of neighbors and others. These increased interactions may look uncomfortable and/or "dangerous" (in terms of fostering dependent relationships on other nations) to DPRK negotiators sitting in 2009 (or whenever talks resume). From the ROK's perspective, any of the above infrastructure options bring the peninsula that much closer to easier economic integration, even in a "collapse" scenario, as well as helping the ROK to address its own energy needs.

[15] Some key DPRK coal mines located near the sea were flooded in the 1990s. Since then, the lack of sustained availability of electricity has kept these mines from being fully pumped out and restarted.

Several of these large infrastructure projects are candidates for IFI financing, in combination with commercial consortia (for electricity/gas/rail interconnections). These large infrastructure projects, all with costs at least in the billions of dollars, might also be financed in part with funds from Japanese wartime reparations.

Large infrastructure projects will involve interactions with many ministries, including those responsible for electric power, coal mining, industries, communications, transport, labor, construction, finance, agriculture (to the extent that hydro projects also affect irrigation) and foreign trade, along with officials at the provincial and county level, individual plant managers, and plant technicians.

3. Continued training, technology transfer, and other multi-faceted assistance in energy efficiency and renewable energy. This might extend the capacity-building and related activities in earlier phases of assistance to include establishing major degree programs at North Korean Universities, for example, or facilitating (through such mechanisms as loan guarantees) investment by companies from outside the DPRK in production facilities for solar hot water heaters, solar PV panels, wind power, insulation materials, high-performance windows, and other devices with markets both inside the DPRK and beyond.

These types of assistance build the human infrastructure for the DPRK to address its energy and economic problems in the longer term, including problems (such as climate change mitigation) not unique to the DPRK. Building a renewable energy/energy efficiency industry in the DPRK may help the whole region to move toward a low-carbon future, as well as being consistent with stated DPRK desires for the evolution of their own energy future. As noted in the context of short- and medium-term capacity building, the necessity of broad interactions between foreigners providing training/technology transfer and DPRK trainees/officials/institutions cannot help but build improved understanding between DPRK citizens and those of other nations.

5. Conclusions

Key conclusions from the above are as follows:

- Though the DPRK's energy sector needs are many and varied, possible energy options for the DPRK require consideration from many points of view, or risk unintended consequence when applied.
- The DPRK will insist that LWRs be on the table, so other parties should be ready to address that demand. A solution where one LWR unit is provided, along with a broad package of other options of similar perceived value, is a possibility.
- Options that involve energy efficiency and renewable energy initiatives are generally "robust" for application in the DPRK, fulfilling many different considerations with few "downsides". One aspect of such options that should not be overlooked, however, is that they will require a good deal of organization and coordination per unit of cost—relative, say, to work on a single major power plant. This requirement has many benefits, in terms of

capacity-building and intercultural interactions, but will need good communication to be effectively implemented and administered.

- Larger-scale options that contribute to regional economic integration, as well as economic integration of the Koreas, may have significant benefits, but will likely be candidates for longer-term application, set up by smaller, local projects and extensive human capacity-building.

Providing, or at least helping the DPRK toward, a sustainable solution to its long-term energy problems is a necessary, though not sufficient, condition for enduring success in getting the DPRK to give up its nuclear weapons, nuclear materials, and nuclear weapons programs. Conversely, failing to address the DPRK's underlying needs for energy services now unmet (or poorly met) will virtually guarantee that any solution to the nuclear weapons issue will be unsustainable.