South Korea's Power Play at the Six-Party Talks

East Asia Science and Security Collaborative Special Report

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1. Introduction

South Korea has made a decisive power play to reactivate the six-party talks that aim to denuclearize North Korea (hereafter also referred to as the Democratic Peoples' Republic of Korea or DPRK). By offering to supply two gigawatts of electric power to the DPRK if and when it dismantles its nuclear weapons program, the ROK attempted to shift the United States out of its own gridlock and into a more positive approach to negotiating a cooperative outcome with the DPRK. It also aimed to change Kim Jong Il's calculus by posing a concrete opportunity cost incurred by not abandoning the bomb. And the offer also kept the initiative in the hands of the Roh Blue House in domestic debates in South Korea as to what to do in relation to security dilemmas posed by the DPRK's nuclear proliferation threat. The power play symbolizes South Korea taking a leading role at the six-party talks that not even great powers could ignore.

The last time that such dialogue with the North occurred was in 1994, after roller coaster confrontations with the DPRK over the defuelling of its research reactor and removal of IAEA inspection of its nuclear facilities at Yongbyon. In return for a nuclear freeze and continuity of IAEA inspections, the North Koreans demanded during negotiations with the United States that it be provided with refined oil product and light water reactors from the United States. The United States wanted to send coal and no reactors. They settled on heavy fuel oil (HFO, or "liquid coal") simply because the DPRK had one power plant designed to use it; and on 2 gigawatts of light water reactors to be built in the DPRK. Both choices proved counter-productive for both parties although the Agreed Framework held for eight years.

HFO proved hard for the North Koreans to absorb, as only one large power plant in the country was designed to use HFO as a full-time fuel. The HFO sent to the DPRK also contained significant amounts of sulfur and other impurities that have reportedly accelerated the corrosion of heat exchangers in DPRK power plants designed to use coal, thereby reducing their generating efficiency (and capacity). Much HFO ended up in trenches because the DPRK had no way to store it or use it.

As for the reactors to be built at Kumho in North Korea, their long-delayed construction has been suspended, leaving them incomplete without generating a single kilowatt hour of electricity. Moreover, even if the reactors had been completed, the

North Korean grid could not then nor could it ever have supported these two reactors, as the grid was far too small and simple to run such large and potentially hazardous units.[2] During the negotiations of the 1994 Agreed Framework, North Korean grid experts told their leadership to not accept any reactors larger than (at most) 400 megawatts. American negotiators also knew about the grid constraint, but chose to ignore it because there were no (western) commercial reactor units available smaller than about a gigawatt (1000 megawatts), and because they believed that the North Korean grid problem was not theirs to solve.

Thus, the two parties were driven by irresistible political logic to proceed with a bad project that could never have worked on North Korea's grid. A decade of squabbling and slow motion construction then ensued, all over a project that could not satisfy North Korea's energy aspirations, even if it had been completed.[3] As the six-party talks resume in Beijing in July 2005, it is critical that the participants not repeat these errors.

Thus, it was with a sense of déjà vu and growing alarm that we learned of South Korean Unification Minister Chung Dong-young's announcement on July 12th that he had offered to supply 2 gigawatts of power to North Korea if it dismantles its nuclear weapons program. [4] Chung explained that he had proposed the scheme on June 17, 2005 at his meeting with Kim Jong-il in Pyongyang. Chung reportedly said: "Of the two main items sought by North Korea, this plan will help them solve their energy-economic issue. The other item, about security guarantees and the relationship with the United States, will have to be discussed and explored with the other countries in the six-party talks."[5]

While claiming that its hard line was behind the North Korean decision to return to the six-party talks, the US Government welcomed the scheme as lending substance to the US June 2004 proposal to offer energy aid as part of a comprehensive settlement package with the DPRK.[6] One un-named American official even characterized the ROK offer as "helpful".[7] We do not know if the ROK briefed the United States on the ROK initiative before Chung's June trip to the DPRK, although we doubt it. But Chung states that he briefed US Vice President Dick Cheney and Secretary of State Condoleezza Rice on the idea when he visited Washington in early July 2005.[8] However, few details about the scheme were passed to the American side at that time, and American policy-makers are preparing to fly to Beijing with their own laundry list of energy projects. However, neither they nor the other participants have compiled detailed picture of what type of energy assistance will work best for itself, its partners in the negotiations, its adversary North Korea, or interested third parties such as the EU, Canada, or Australia.

Rather, American policymakers appear to be assuming that they are heading back to Beijing to resume the six-party talks with real carrots on the table for the first time since late 2002, when HFO delivery was suspended and the KEDO light water reactors were shelved due to the DPRK's alleged uranium enrichment activities. This relaxed attitude is underscored by the widespread assumption that no pile of carrots can induce the DPRK to abandon its nuclear weapons program, and that the ROK's power play will prove insufficient to the task of inducing the DPRK to comply with its nuclear non-proliferation commitments.

If, as has been suggested, this energy scheme is the lead offer at the six-party talks, it appears to already have wobbly foundations. Thus, it is urgent to delineate the scheme's potential, the obstacles to its success, and the implications for the negotiations that arise from the energy issue in the DPRK. Indeed, within days of Chung's announcement of South Korea's power play, skeptical voices were raised in Seoul. On July 15, 2005, a former head of the Korea Electric Power Company was quoted in the media as warning that technical problems may impede the supply of 2 gigawatts of electricity to the DPRK.[9] Criticism of the scheme, possibly motivated politically and possibly by the prospect of consumers upset by prospective tax increases to pay for the estimated $2.3 billion to provide the power to the North, erupted in the opposition party.[10]

In this paper, we summarize what is known about or can be plausibly inferred to constitute the South Korean scheme. We review the status of the DPRK power system and the implications of this status for the ROK offer. We outline the technical problems and challenges associated with the South Korean scheme. We also note non-technical issues such as cost, institutional and coordination requirements, and political obstacles.

In conclusion, we argue that the participants at the six-party talks should consider the full scope of activities needed to implement the South Korean scheme; that they should explore an alternative approach that would link the Russian and South Korean grids, thereby achieving the same outcome at lower cost and lesser political risk; and that the six parties should consider adopting a short-term, alternative package rather than resuming HFO deliveries to the DPRK because this approach would provide more energy services, faster, and at lower risk and cost to give immediate substance to statements of longer –term intention to supply assistance to the DPRK. We further suggest that these issues be explored with the North Koreans at the six-party talks at a subsequent technical working group before major commitments are made to proceeding with the South Korean proposal.

2. The ROK Offer

South Korea's offer to Kim Jong Il appears to be benchmarked to past US-DPRK Agreed Framework energy assistance, and is designed to substitute for the power output of the two KEDO light water reactors that were roughly 2 gigawatt-electric in size (in fact, each reactor is slightly bigger than one gigawatt). The offer also entails running power lines from South Korea to the North. As transmission and distribution always loses some of the power generated at the power plant, often ranging from 5-10 percent, we will assume that South Korea offered to deliver two gigawatts of power plant, after reasonable losses are incurred in transmission (but not distribution).

Minister Chung referred to 2008 as the possible start-up date for delivery of this electric power to the DPRK. It is possible that other parties might also supply HFO to the DPRK as part of a settlement, but this does not appear to be part and parcel of the current ROK commitment. This extra electricity is also in addition to the electrical supply from South Korea to the Kaesong industrial zone north of the DMZ which houses South Korean industry and forms a "grid island" separated from the DPRK grid to ensure reliable, high quality power in the zone.

The cost of the proposed electricity aid has been estimated by MOCIE officials at roughly $2.4 billion. MOCIE estimated that it will cost about $1.5-1.7 billion to install the new transmission lines and transformer substations between Yanju, ROK and Pyongyang, in the DPRK; they also estimate that it will cost more than $1 billion per year to pay for the energy cost and to operate and maintain the transmission facilities. The ROK government has argued[11] that it will pay this bill out of the $2.4 billion that it has not yet spent on its commitments to the $4.6 billion cost of the KEDO light water reactor budget.[12] How on-going annual costs after construction and the first year of operation are to be paid for is unclear. In the KEDO light water reactor agreement, the DPRK was to be provided concessional financing that amounted to about a 50 percent grant of the total capital cost, and the annual uranium cost was a small fraction of total annual cost (unlike thermal power plants). Moreover, the DPRK was obligated to repay this loan. No such loan arrangement seems to be envisaged in the ROK proposal.

Nor has the destination of the power been disclosed, or even if the technical issues involved have been discussed with North Korea. Given the near collapse of the DPRK power system and its large-scale industry, we assume that two gigawatts of electricity could be absorbed only by large industrial plants and major cities, that is, in the Pyongyang-Nampo region, or if it is connected on a North Korean grid connection able to carry the power, to industrial cities such as Hamhung on the east coast. This constraint implies a crossing of the DMZ north of Seoul for a transmission corridor that aims straight at Pyongyang. Given the unreliability of the DPRK grid which now operates as a set of mostly separated grid islands, and on more than one frequency, we further assume that the ROK would build two high voltage (345 or 220 kV) transmission lines from the DMZ to Pyongyang, so that if one line has a forced outage, the remaining line should be able to transmit two gigawatts of electricity.

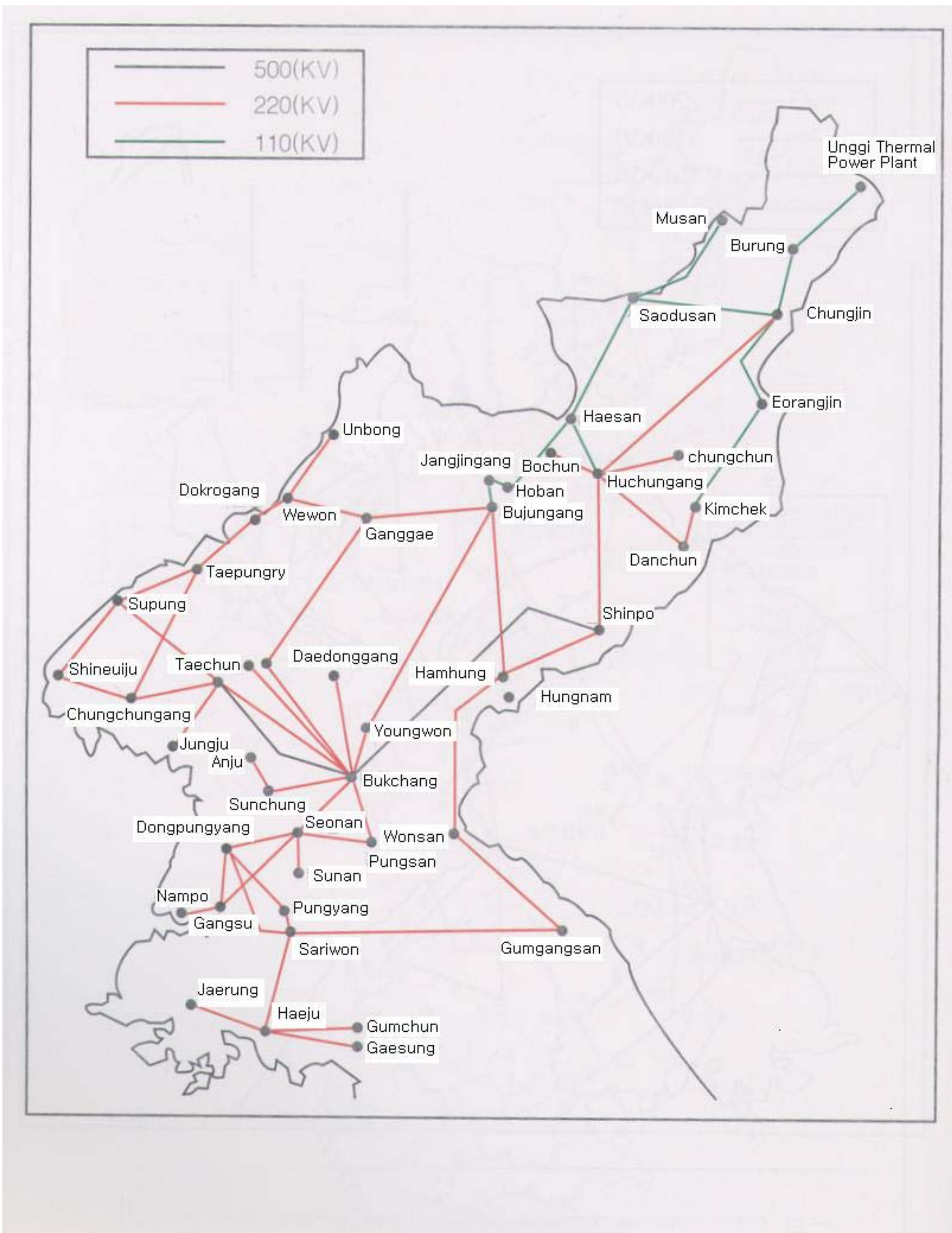
3. The DPRK Grid

The unified electrical grid in the DPRK apparently dates back to 1958. The DPRK transmission and distribution (T&D) system must nominally manage a fairly complex grid of 62 power plants, 58 substations, and 11 regional transmission and dispatching centers. The total reported capacity of generation resources as of 1990 was about 8 to 10 gigawatts, with the higher total probably including numerous small power plants of uncertain operability. A general map of the electricity transmission system in the DPRK is provided as Figure 1. The main transmission lines in the DPRK are mostly rated at 220 and 110 kV (kilovolts). Other transmission lines are rated at ~66 kV, with lower-voltage lines used for distribution.

Connections between the elements of the T&D system were, as of the early 1990s, reportedly operated literally by telephone and telex, without the aid of automation or computer systems. Although a United Nations project in the early 1990s installed some control equipment at a power plant and selected control centers in the Pyongyang area, few other upgrades have been undertaken. This system results in poor frequency control, poor power factors, and power outages[13]. Outages on the grid are reportedly frequent, and the process of reacting to outages and isolating areas where the outages occur is cumbersome and slow, often resulting in a cascading series of outages (and further delays in restoring power).

At present, the DPRK grid apparently operates not as a unified grid, but as a largely disconnected collection of regional and local grids. We estimate that operable generation capacity is on the order of 2 to 3 GW at present, and total electrical output fell from about 46 TWh (terawatt-hours, or billion kilowatt-hours) in 1990 to 13 TWh by 2000, with 2005 output likely not very different than in 2000. Voltage and frequency fluctuations are orders of magnitude greater than international standards, and electricity supplies, depending on the area (supplies in the capital are most reliable) vary from non-existent to occasionally interrupted.

Figure 1: DPRK Electric Power Grid



4. The ROK Grid

South Korea's power system is about thirty times larger than North Korea's current "operable" system. Total ROK generating capacity is about 60 GWe with peak demand rising to about 54 GWe in 2004.[14] South Korea's generating capacity (see Table 1) is split roughly about 27 percent from nuclear power, about 29 percent coal-fired thermal power plants, and about 26 percent gas-fired thermal power plants. South Korea plans to increase its total installed capacity to about 80 GWe by about 2015, and includes about 10 GWe of renewable energy-powered generation (especially wind-powered energy) in its expansion plan.[15] Finding sites for all the new plants required to expand the system is now problematic and will increase construction cost in the future.

Table 1: ROK Electrical Generating Capacity, Megawatts, 2004

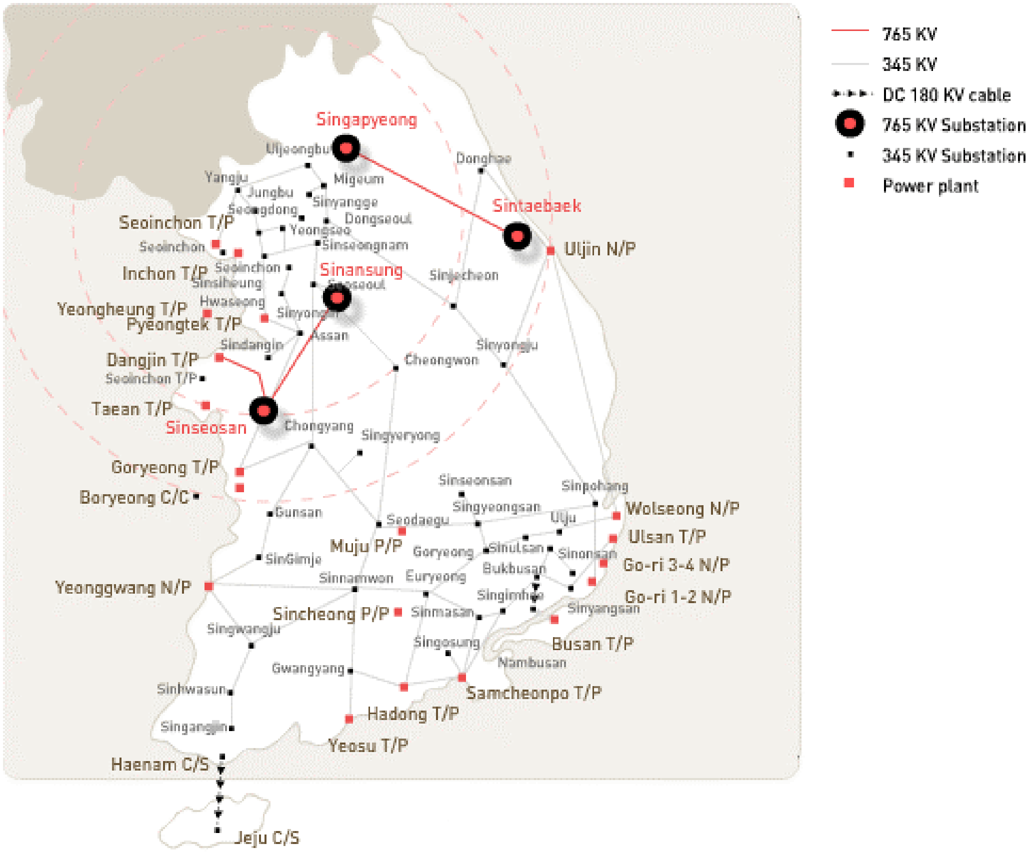
Generation Type	MWe	%
Hydro	3838	6.4
Domestic coal	1139	1.9
Bituminous coal	16309	27.2
Oil	6176	10.3
Gas	15770	26.3
Nuclear	16729	27.9
Total	**59961**	100

Source: Korea Electric Power Corporation, *KEPCO in Brief, 2004.12.31* , at www.kepco.org

The ROK transmission and distribution system is similarly much larger and more complex than that in the DPRK. Total transmission lines run about 25,000 km with an additional 10,000 km to be constructed in the next decade to 2015. The system is built around a backbone of 345kV lines, with local systems operating on 154kV or 66kV lines (with the latter being phased out). A 765kV line is under construction and is partly completed to meet the rapidly increasing power demand in and around Seoul by shipping bulk power from the generation plants in the south to the load center in and around Seoul, which accounts for more than 42 percent of the total load.[16]

Due to reactive power losses[17] incurred in large-scale power transfer by long-distance transmission lines, there are physical limits on the south-north flow inside South Korea of electrical energy to this demand center from the power plants, which, if exceeded, can cause the grid to shut down due to the tripping of circuit breakers in response to voltage collapse. In 2001, that transfer was 10,886 MW in normal operation.[18] In 2001, ROK experts estimated that the maximum DPRK load that could be added to the existing grid system without exceeding these limits was 0.5 GWe. Although the DPRK supply and demand of electric power has grown since then, the ability to transmit power from generator to load centers has not grown commensurately, making it unlikely that the ROK grid can supply more than was estimated in 2001.

Figure 2: ROK Electric Grid



Source: www.**kepco**.co.kr

The ROK power sector represents a major fraction of total ROK investment in industry. From 2001 to 2015, South Korea anticipated investing about $33 billion in new generation plant, and another $14 billion in transmission facilities, for a total of $46.7 billion or about $3 billion per year.

5. Evaluating the ROK Offer

With this background, it is possible to identify three problems that arise from the South Korean offer. These are technical, economic, and political and institutional in nature. We will examine them in that order.

5.1 Technical Problems: Given the vast disparity between the two grids, it is not only difficult but downright hazardous to simply transmit pure power to the DPRK. Not only are the two grids operating on different frequencies (in at least parts of the DPRK), with vast differences in standards such as voltage fluctuation, reserve capacity, etc, and completely different engineering and safety cultures. The two grids are also antithetical in that the ROK cannot afford to put its own grid at risk operating as it does 20 power reactors generating 17.7 gigawatts of electricity, with the potential for forced outages with no warning due to instability being propagated from the

DPRK grid to the South. As was noted above, in 2001 South Korean experts studied carefully the risks associated with connecting South Korea's grid with North Korea, and concluded that the maximum load that could be drawn from the ROK grid and sent to the DPRK grid was about 0.5 gigawatt, or about one quarter of what is now committed to the DPRK by the ROK should it denuclearize over the next year or so (leaving a couple of years to construct supply and the transmission lines to send the power north).[19]

If the power is to be drawn off the existing ROK grid without putting it at risk, then there are only two options:: build power plants north of Seoul to better balance supply and demand in the ROK grid; or build unconnected power plants that supply power directly to the DPRK. The third option--to reduce demand in the Seoul area by two gigawatts in order to free up generating and transmission capacity to send the same amount of power to North Korea—would not be politically palatable in the South.

Ministry of Commerce, Industry and Energy (MOCIE) officials have stated that they intend to expand power generation in the Seoul and Incheon region to achieve the balance in the ROK grid that is necessary to supply 2 gigawatts to the DPRK. Ministry officials state that they have already advanced completion of a 0.8 gigawatt generating unit at Incheon's Yeongheung Thermoelectric Power Plant to June 2008 to this end.[20] It appears that they intend to add an additional 2 gigawatts of generation at this plant in order to supply the power needed for the DPRK, as well as to add other capacity (such as reopening of the Seoul Thermoelectric Power Plant in Dangin-dong, Seoul) in order to keep up with the growth in demand in the Seoul area over the same period.[21]

These power plants would likely be combined cycle gas-fired units and would require that gas pipelines be run to the power plants, either from the Seoul area, or from new or expanded LNG import facilities at Incheon west of Seoul on the coast.

If new or existing power plants were connected to the DPRK grid via the ROK grid, then the latter could be further "insulated" against DPRK grid instability by installing an AC-DC-AC converter at or near the DMZ, but such units are expensive (roughly $125 million per gigawatt). To ensure ROK grid reliability without incurring the expense of converters, KEPCO appears to be assuming that the two grids will be run separately for the foreseeable future.[22] If and when the two grids were connected, this would render converters redundant, suggesting that such an investment would be risky today and reinforcing the trend to use separated lines with dedicated generators to fulfil the commitment to send two gigawatts of power to the DPRK.

5.2 Cost Problems: Our rough estimates (see Table 2) suggest that the cost is likely to be far greater than the implied ceiling of $2.4 billion dollars (see above). The instantaneous capital costs for the power to be delivered to end users amounts to about $3.44 billion. The on-going annual cost of fuel and operating and maintenance costs amounts to another $0.8 billion per year. Over say five years of operation, the fuel costs are about $3.3 billion in present value in 2008.

Table 2: Rough Cost Estimate of South Korea's Power Offer	
Item	**Cost Estimate, US billion $**

Capital Costs	
2.12 GWe of gas-fired power plant	1.06 billion
100 km of cross-DMZ and 400 km of high voltage transmission line to Pyongyang area (including reserve line)	0.58 billion
Half DPRK existing transmission & distribution refurbished in order to use the 2 gigawatt of delivered power	1.8 billion
Operating Costs	
Annual Gas cost for 2.12 GWe of power plant	0.84 billion/year

Source: Authors' estimates

Put another way, the annual cost from 2008 of this $3.44 billion capital investment (assuming the equipment has a 30 year lifetime) is about $0.3 billion per year (assuming an 8 % discount rate). Adding this $0.3 billion to the annual fuel cost of $0.84 billion implies a rough annual cost of about $1.14 billion per year "in perpetuity" (assuming, as we do, that the DPRK cannot afford to import $0.84 billion of gas per year and that the ROK and/or its partners picks up this tab). To put this in perspective, South Korea currently invests on average about $3 billion per year in new generating and transmission plant. South Korea's Chung seems to recognize that there is room at the table for other donors, reportedly stating: "We will carry out this proposal on our own but other countries are requested to respond (to this proposal) by making their own gestures."[23]

South Korean officials recognize the uncertainties in such estimates. "We cannot say a word about the energy offer plan," said one, "as we have little information on the North's power distribution system, which means it will be difficult to calculate the required to costs to supply electricity to the North. ''[24]

We believe that these rough estimates are likely low estimates that do not capture much of the real cost of construction in the DPRK environment. For example, a long transmission line will be needed to connect the line crossing the DMZ to major load centers which will result in reactive power and stability problems due to its length, requiring extra voltage support and additional transmission infrastructure that are not costed above. Nor is the cost included of upgrading DPRK end-use equipment, for example, ancient industrial electric motors in poor condition, which will cause power factor and harmonics problems for a new or upgraded grid if they are not replaced. We have not included interest-during-construction in the capital cost figures, nor likely fuel price increases in the annual operating cost estimate. Thus, the true cost of delivering 2 gigawatts of electric power to the DPRK is likely closer to $1.5 billion per year or more.

We do not object in principle to the ROK or the international community paying this price if it secures a settlement of the nuclear issue. From an ROK economic perspective, even if such a tie-line is a relatively inefficient use of scarce investment resources (not least because the DPRK is likely to drain every kilowatt hour of electricity from such a tie-line, whether the final demand is economically and socially useful or not), the cost of continuing instability on the South Korean economy is also large. Thus, even a small reduction in if the South Korean GNP of about $900 billion due to higher tensions with North Korea will be far greater than the cost of the power offer to the DPRK to settle the nuclear issue.

5.3 Political and Institutional Problems: Grid interconnection is always highly political and difficult to achieve, even between friendly neighbors, let alone between enemy states divided by many fundamental issues.[25] Critical issues (that is, show-stopping issues) include: high front-end transaction costs in negotiating system connection and distribution of gains from cross-border trade; operating standards such as frequency and voltage fluctuations, reserve capacity, and engineering design considerations arising from system connections; and achieving the trust needed to share dispatch and control authority in a system that rests on shared reserves and instantaneous response to shifts in demand on the one hand, and isolating and controlling cascading collapses on the other. Past ROK studies of ROK-DPRK grid interconnection avoided these issues by simply assuming that the grids were unified wholesale. In effect, the South Korean simulations were conducted as if DPRK grid was absorbed into the ROK by "swallowing it alive."[26]

However, the ROK's power play directly poses these issues, which we analyze in the next sections.

5.3.1 Dispatch and Control: If the plants feeding the line are dispatched to meet marginal demand changes from the ROK, but the power lines they (ultimately) feed are controlled by the DPRK, then the separation of responsibility creates a significant coordination problem that would need to be solved. Possible mechanisms would include creating a joint dispatch-and-control center with communications back to the national dispatch centers of each utility, and negotiated agreements as to the control response to various contingencies related to sudden or planned changes in supply (for example, scheduled shutdowns for maintenance if the power plants are in South Korea) and demand (for example, lightning-strike induced transmission failure or sudden surges in demand due to connection of formerly isolated grid lines in the DPRK).

From North Korea's perspective, an even bigger problem is that South Korea can arbitrarily deny supply by "flipping a switch" at the power plant. (That North Korea might turn off its demand for political reason is less of a problem for South Korea in a technical sense. If North Korea persisted in denying itself electricity supply, the South could switch the power to ROK demand with a small marginal cost, although the economic value of the transmission line would not be realized). South Korean politics is notoriously volatile, and in our view, such a fear on North Korea's part would be rational. Alternative ways of delivering this power via a regional tie-line could ameliorate this problem (see section 6.1 below).

5.3.2 Political Sustainability in South Korea: In principle, the cost of sending power to the North should be paid for out of the ROK's central treasury. In practice (based on the KEDO precedent), the ROK government will impose a tax via the power tariff structure to collect the necessary funds. South Korean low-income power consumers may perceive that they are paying higher tariffs to support free electricity sent to the DPRK. Because South Korea is in the midst of dismantling its state-controlled monopolistic utility into an oligopolistic set of privately controlled companies, using the tariff system to collect these funds may prove to be politically problematic in South Korea itself.

5.3.3 Coordination with Other Parties at the Six-Party Talks: The underlying justification of South Korea's power initiative to the DPRK is that it kickstarts the negotiations at the six-party talks. However, a proposal that has not been fully costed and discussed with these partners may not have much credibility in Pyongyang, particularly if there are significant costs to be paid that have not been distributed and accepted by the parties who are likely to be responsible, before they enter the talks. For example, North Korea may much prefer a regional grid inter-connection between the Russian Far East and South Korea that would pay them rent for use of a transmission corridor and would enable them to siphon off power when and where it is needed (rather than absorb a bulk power transfer on a political timeline). This approach would buffer North Korea against political manipulation by South Korea as the South would be much less likely to turn a regional tie-line on or off for domestic or intra-Peninsular reasons than might be the case for an ROK-DPRK tie-line.[27]

5.3.4 Slow Delivery: A North-South tie-line might begin to provide bulk power to the DPRK by 2008, according to government statements in Seoul. However, for North Korea, three years is light years away. Whether this tie-line (or a regional one such as that proposed in the previous section) proceeds or not, it is critical that other, multiple, cheaper, faster, less risky and high impact energy projects are undertaken at the same time that can provide benefits to the DPRK in the same timelines demanded by the United States for its phased dismantlement and complete denuclearization. Three years is simply far too long to wait. Fortunately, substituting such a diverse package for resumption of HFO deliveries is eminently feasible and should be pursued by all parties to the talks.

6. Negotiating Energy for Nukes at the Six-Party Talks

In this section, we propose that the ROK power proposal be treated at the next round of the six-party talks as a way to initiate meaningful talks between all the parties on what makes sense for North Korea's energy economy—above all, with the North Koreans.

First, we should state our working assumptions. We do not believe that the United States will arrive at the talks carrying a detailed and rigorously researched road map for DPRK energy reconstruction that could form the basis of commitments beyond those already made by the ROK to the DPRK. Moreover, for reasons too complicated to expand upon here, we do not believe that mere provision of 2 gigawatts of non-nuclear power and possible resumption of HFO delivery will suffice to substitute either for KEDO's energy assistance package in the past, nor to induce the DPRK to abandon its nuclear weapons capacities. In short, nuclear weapons are too valuable in terms of strategic power and political legitimacy for North Korea to give them up for a return to the *status quo ante* in energy terms.

Thus, we believe that there will be no breakthrough at the next round to a DPRK commitment to denuclearize. Rather, the best that can be hoped for is that the six parties decide to continue to talk in depth about what it would take to bring North

Korea to give up its nuclear weapons capacities. We suggest that a technical working group on DPRK energy needs be convened within days of the high-level talks ending. In particular, additional donors need to come to the table if the ROK offer is to be made meaningful by investing in DPRK power system rehabilitation and industrial reconstruction that make it possible for the DPRK to use 2 gigawatts of power. The only candidate for such a major donor that could play such a role is Japan, and clearly Japan is not about to commit any resources to the DPRK while its bilateral agenda remains unresolved, either at the six-party talks or more likely, in a resumption of bilateral negotiations driven by domestic Japanese politics.

For a working group to succeed, it will need to obtain significant access to information about the DPRK's electric power system. Only China and Russia, especially the latter which supplied much of the power system equipment to the DPRK during the Cold War, can hope to be granted such access. Thus, we suggest that Russia should chair such a working group and China should host its meetings.

We specifically suggest that the working group adopt a three point agenda, as follows:

6.1 Regional, Not North-South Grid Connection? Although an inter-Korean tie-line may appeal to Korean nationalism on both sides of the DMZ, this same appeal also poses many obstacles to the project's success. Thus, we suggest that the working group examine closely the relative attractiveness of a regional tie-line between Russia and South Korea that could substitute for a 2 gigawatt North-South line. This approach has the advantage that the tie-line would be economically and possibly commercially justified and be more attractive to the DPRK by providing a Russian buffer against ROK political manipulation of power supply to the DPRK. Now that the light water reactor project is defunct, KEDO could be the organizational vehicle by which such a project could be implemented.

6.2 North Korean Energy Needs? Any negotiation should be based on mutual interest. For the North Koreans, energy assistance that moves from humanitarian to development assistance is crucial to slow economic recovery. In this regard, we should follow North Korean guidance as to the most urgent and highest priority energy needs. Americans and even South Koreans often assert that so little is known about the North's energy economy that one cannot set priorities or know what to do first.

However, North Korean energy experts have stated clearly their energy and electricity priorities, both in formal communications with KEDO over the years of working on the grid in relation to the light water reactors, in UN projects and channels on energy and the grid, and in private and technical channels of engagement.[28] Thus, there is no excuse for ignoring North Korean energy priorities in approaching the six-party talks. In 2004, North Korean energy experts stated that they wished to increase their energy security by:

- Decreasing coal share of energy supply, diversifying resource use, exploring crude oil and developing nuclear power (similar to Japan and South Korea);
- Developing renewable energy, especially windpower;
- Undertaking international natural gas projects.

The DPRK energy experts also expressed the wish to create a national energy database and to prepare a national energy strategy. They placed human capacity building at the top of their energy goals, seeking to introduce creative thinking along with technologies. They sought training on how to initiate sustainable energy markets and declared that they seek technical and economic training—even in advance of any opportunities for membership in international financial institutions such as the World Bank.

They have also set more specific objectives, including:

- Restore/repair existing thermal and hydro plants, and build new hydro plants;
- Repair, integrate, improve voltage and frequency on T&D network; add modern control facilities;
- Rehabilitate, modernize coal production;
- Adopt energy-efficient technologies in industrial, household/commercial sectors, coal/electricity sectors;
- Develop renewable energy systems, including construction of 5 kW small wind power stations in rural and remote areas and manufacture of 100 kW wind power plants.

Given the DPRK's dire energy predicaments, these are not irrational choices. The trick for delivering energy services in a meaningful time-frame is to shift from large-scale, inter-governmental projects (such as the North-South tie-line) to a basket of diverse, small-scale, rapidly implemented (less than a year) and relatively cheap options that match these priorities. Moreover, it would be irrational to invest in large-scale energy infrastructure development before a new macro-economic framework is set for a reconstructed urban and industrial end-use geography. The DPRK is already conducting feasibility studies of redeploying industry in order to increase efficiency of energy supply and demand. Until a proper national energy sector is completed with technical assistance from agencies such as the IBRD and ADB, projects should be implemented that support bottom-up redevelopment based on market niches and marginal commercial appeal.

6.3 Immediate (6 month to one year) Energy Package: Whether energy is provided through a North-South or a regional tie-line, three years is far too long to wait to deliver energy services to the DPRK as part of the denuclearization process. Therefore, the working group should also examine the relative attractiveness of supplying a package of energy measures that would rapidly provide tangible energy services to the DPRK that, for example, would be the cost equivalent of the ½ million tonnes of HFO (about 21 petajoules) [29] provided annually in the past at a cost of about $100 million/year, but in forms that would be far more useful to the DPRK.

In summary, these options are:

- Build energy planning/capacity via training and technical assistance: $5m/y;
- Rehabilitate the power grid: $30m/y (~ to the cost of 6 PJ/y of oil);
- Rehabilitate coal supply $10m/y (~ to 2.1PJ/y)
- Rehabilitate generation: $20m/y (~ to 4.2 PJ/y)
- Reduce end-use waste: $20m/y (~ 4.2 PJ/y)

- Implement small-scale, rural and renewable energy: \$15m/y (~ to 3.2 PJ/y)

This approach would work within two constraints on delivering energy assistance to the DPRK, namely, that the absorptive capacity of DPRK is limited in institutional and physical ways that cannot be circumvented in short timelines; and diminishing returns in each area while structural transformation of the DPRK economy takes place.

Next, we will outline in more detail each of the priorities, any one of which could be adopted by a participant at the six-party talks, or by a “friend” of the process (such as Canada, Australia, or the EU).

6.3.1 Assistance for Internal Policy and Legal Reforms to Stimulate and Sustain Energy Sector Rebuilding in the DPRK: This priority has five components to build basic energy planning/capacity via training and technical assistance

- Reform of energy pricing practices, and the physical infrastructure to implement them
- Careful energy planning to base aid on need and rational objectives
- Training for energy sector actors
- Strengthening regulatory agencies and educational/research institutions in the DPRK
- Involving the private sector in investments and technology transfer

Implementation of these steps would be undertaken by APEC Energy Working Group and the Asia Pacific Energy Research Center in Tokyo; bilateral aid agencies; multilateral financial and development institutions such as the IBRD, ADB, UNDP and UNDESSA; and by non-governmental organizations including commercial interests in the energy sector.

6.3.2 The Decaying Grid: This activity begins by determining with the North Koreans exactly what it would take to rehabilitate the DPRK grid. Generic categories include provision of:

- New conductors, substation equipment, switching equipment, modern control facilities, new towers or poles in many existing right-of-ways;
- Labor, rebar, channel iron, cement can be supplied locally, but grid-quality conductor, even nuts and bolts may be unavailable in the DPRK without significant retooling of manufacturing industries.

To rehabilitate the roughly ~6000 km of transmission lines and distribution system in the DPRK and its 8 GW of generating plant will cost roughly \$5.5 – 7.5 billion.

Detailed studies for this rehabilitation should be undertaken by the IBRD with Japanese reparations and ROK financing, possibly implemented by KEDO, as follows:

- Work with DPRK engineers to identify, prioritize list of T&D sector improvements and investments;

- Provide limited funding for pilot installations in a limited area—perhaps in the Tumen River area;
- Engage the World Bank as a leader in DPRK power sector refurbishment (with Japanese funding?);
- Focus on projects that would help the DPRK earn foreign exchange in acceptable manner, such as grid repairs to allow key mines to operate.

6.3.3 Redevelopment Priority: Limited Rehabilitation of Coal Supply and Coal Transport Systems: North Korea mines coal resources that are in many cases very low-grade, highly polluting, and uneconomic. Limited rehabilitation of the coal supply system should be undertaken to provide coal during the DPRK's economic transition, as follows:

- Couple coal supply measures with boiler rehabilitation, especially small-medium sized boilers for winter heat in buildings where people have to survive the cold, and especially in large public organizations such as hospitals, orphanages etc.
- Assist with evaluating and upgrading coal mines in the DPRK, including:
- Improvements in mining technologies, mine ventilation systems, mine safety
- Evaluation of coal resources
- Rehabilitation of the coal transport network: Rail infrastructure/parts, fuel supply for trains

6.3.4 DPRK Power Plant Repair: The DPRK does not need new coal-fired power plants. Rather, those plants that can be repaired economically to supply power where demand exists should be considered for repair, bearing in mind that about 10 large thermal plants and 20 large hydro plants account for over 60 percent of national generating capacity. Lack of spare parts, maintenance difficulties, fuel supply constraints, damage from natural disasters and incompetent operating staff have reduced actual operable capacity to ~2 to 3 GWe at present, leaving 7-8 GWe to be refurbished. This work should be undertaken by ROK and private power project companies on a commercial basis.

6.3.5 Reduce the Vast Waste of Supplied Energy: Domestically-produced electric and electronic devices often use 1940s, 50s, and 60s technologies in the DPRK. Coal-fired boilers operate at less than 50 percent efficiency, especially in the 20,000 odd small to medium sized boilers. The DPRK industrial plants that still exist are even less efficient than Soviet counterparts on which they were based. Steam distribution systems are porous and waste much of the available heat supply before it reaches industry or buildings. Assuredly, the fastest effective way to increase the DPRK power and coal supply is to reduce waste. Energy efficiency improvements are easily achieved in lighting, motors, coal stoves/boilers, controls, and building improvements starting with weather-stripping and simple insulation measures.

These measures need material support and technical assistance from China, ROK, Japan, Canada, Australia, the European Union, and Russia.

6.3.6 Alternative Sources of Small-Scale Renewable Energy Coupled with Energy-efficiency Measures: The DPRK has a keen interest in renewable energy, and in energy-efficiency technologies. Assistance in this area should:

- Focus on fast, small, cheap technologies;
- Couple appropriate technology with humanitarian assistance and provide services in areas poorly served with energy now;
- Support small hydro turbine-generator manufacturing, and wind powered water-pumping windmills, especially by cottage industry in provincial towns to serve proto-markets for such products with local farming communities;
- Address sustainability of biomass (agricultural waste, charcoal and woodfuel) used by much of the rural population to heat and feed themselves at a high environmental cost;
- Improve agricultural equipment efficiency to help North Koreans to feed themselves.

The European Union has prepared an aid program in this area as has UNDP while a number of non-governmental organizations are able to deliver these inputs at short notice.

6.3.7: Begin Transition to Gas Use in the DPRK with LPG Networks: Very little gas is used in the DPRK energy sector at this time. LPG (that is, Liquid Petroleum Gas, typically a mixture of propane and butane) is more expensive than natural gas (NG) in the world market, but is much easier to use where piped distribution networks do not yet exist, and the infrastructure required to import LPG by oceangoing tanker is also cheaper than for NG (as liquefied natural gas, or LNG), and LPG storage and transfer facilities are available in smaller capacities than for LNG. LPG is a clean-burning fuel with limited military diversion potential. Setting up LPG networks can be a first step toward use of natural gas in the DPRK. LPG projects should:

- Start experience in the DPRK with operating gas distribution systems, and developing gas use infrastructure.
- Be used as opportunities to explore the feasibility of natural gas pipelines and LNG terminals, as a step toward economic development coupled with regional integration of energy systems.

ENDNOTES

[1] Peter Hayes is Director, Nautilus Institute and Professor, RMIT Melbourne; David von Hippel, Jungmin Kang, and Richard Tanter are Research Associates of Nautilus Institute; Tatsujiro Suzuki is Project Professor at the University of Tokyo Scott Bruce is Program Officer at Nautilus Institute at the University of San Francisco Center for the Pacific Rim. We thank anonymous Korean and American experts for their review comments on earlier versions of this essay. The authors are participants in the East Asia Science and Security Collaborative, a Nautilus initiative funded by the MacArthur Foundation.

[2] John H. Bickel, Evergreen Safety and Reliability Technologies, LLC, "Grid Stability and Safety Issues Associated with Nuclear Power Plants," Workshop on Power Grid Interconnection in Northeast Asia, Hotel New Ohtani, Beijing, China, May 14-16, 2001, http://www.nautilus.org/archives/energy/grid/index.html

[3] In fact, the KEDO reactors could only have operated by being tied into a Russian Far East-South Korea interconnection to trade seasonal energy and capacity surpluses, with an DC-AC converter between the high voltage DC tie-line to the DPRK grid; or

by running two AC lines from the KEDO reactors to the South Korean grid, in effect exporting the power from the DPRK to the ROK grid and making the KEDO LWR's a grid "island." See the technical papers from three East Asia Power Grid Interconnection Workshops in 2001-3 at: http://www.nautilus.org/papers/energy.html#grid

[4] Rhee So-eui, "S.Korea says offered to supply North electricity," *Reuters*, July 12, 2005 , http://www.alertnet.org/thenews/newsdesk/SEO305678.htm

[5] *ibid.*

[6] Joel Brinkley, "Rice gives U.S. credit in Korea talks," *The New York Times*, July 15, 2005, http://www.iht.com/articles/2005/07/14/news/rice.php

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[8] AFX News Limited, "Seoul offers NKorea electricity if Pyongyang renounces nuclear weapons," July 12, 2005, at http://www.forbes.com/home/feeds/afx/2005/07/12/afx2133398.html

[9] Seo Jee-yeon, "Energy Aid to N. Korea Faces Technical Hitch," *Korea Times*, July 15, 2005, http://times.hankooki.com/lpage/biz/200507/kt2005071520084211910.htm

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[11] Communication with US officials.

[12] Lee Joo-hee, "South Korea offers power aid in return for nuclear cleanout, Proposes light-water reactor to be terminated for assistance," *Korea Herald*, July 13, 2005, http://www.koreaherald.co.kr/SITE/data/html_dir/2005/07/13/200507130029.asp

[13] A nearly-completed UNDP-funded project, "Electric Power Management System" was only designed to address control systems at four critical power plants and four substations around Pyongyang.

[14] Korea Electric Power Corporation, KEPCO in Brief, 2004.12.31, at www.kepco.org; see also Park, Dong-wook, "Perspectives on Northeast Asian System Interconnection," Korea Electrotechnology Research Institute, S. Korea, Workshop on Power Grid Interconnection in Northeast Asia, Hotel New Ohtani, Beijing, China, May 14-16, 2001, http://www.nautilus.org/archives/energy/grid/index.html

[15] Woo-jin Chung and Jungmin Kang, "Update On The ROK Energy Sector and The ROK LEAP Model," Asia Energy Security Workshop, Tsinghua University, Beijing, May 17, 2005. http://www.nautilus.org/energy/2005/beijingworkshop/papers.html

[16] Jong-Keun Park, "Power System And Technical Issues In South Korea," Workshop on Power Grid Interconnection in Northeast Asia, Hotel New Ohtani, Beijing, China, May 14-16, 2001, http://www.nautilus.org/archives/energy/grid/index.html

[17] Reactive power requirements account for the losses of energy during transmission of electricity that arise from motors, generators and alternators attached to the system, and by devices such as condensers and capacitors which normalize the electrical current flow by releasing energy when drops in voltage are sensed. If the system is not designed to provide for the reactive power demand, then this energy will be drawn from the transmission lines and will lead to the grid being overloaded and possibly trigger interruption of supply. Reactive power flows are controlled and transmission system voltages are maintained by using voltage regulators and transformers. T. Elliott, K. Chen, R. Swanekamp, *Standard Handbook of Powerplant Engineering*, McGraw Hill, New York, New York, 1989, p. 4.59.

[18] Jong-Keun Park, *op cit*.

[19] Jong-keun Park, "Power System and Stability Issues in the Republic of Korea," Workshop on Power Grid Interconnection in Northeast Asia, Hotel New Ohtani, Beijing, China, May 14-16, 2001, http://www.nautilus.org/archives/energy/grid/papers.html

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[25] See Karsten Neuhoff, "Economic Considerations: An overview & background on power markets and pricing principles, with focus on international trading, institutional considerations for international electricity trade," at Workshop on Power Grid Interconnection in Northeast Asia, Hotel New Ohtani, Beijing, China, May 14-16, 2001, http://www.nautilus.org/archives/energy/grid/papers.html

[26] Based on a simulation, of which Nautilus obtained an informal summary, carried out by ROK power authorities in the mid to late 1990s, and in authors' files.

[27] See studies on regional and Russian Far East-South Korean grid interconnection from the Second Workshop on Power Grid Interconnection in Northeast Asia, May 5-8, 2002, at: http://www.nautilus.org/archives/energy/grid/2002Workshop/material.html

[28] See DPRK Delegation, "*Energy Sector Activities And Plans In The DPRK*," Asian Energy Security Workshop 2005, May 13th - 16th, 2005, Beijing, China, http://www.nautilus.org/energy/2005/beijingworkshop/papers.html; and DPRK Delegation, "Options For Rehabilitation Of Energy System & Energy Security & Energy Planning In The DPR Of Korea," Asian Energy Security Workshop 2004, May 12th - 14th, 2004, Beijing, China, http://www.nautilus.org/archives/energy/AES2004Workshop/index.html

[29] A petajoule is one million gigajoules. A standard barrel of petroleum has the energy equivalent of about 6.1 gigajoules, so a petajoule is about 164,000 barrels of petroleum.