REGIONAL ENERGY INFRASTRUCTURE PROPOSALS AND THE DPRK ENERGY SECTOR: OPPORTUNITIES AND CONSTRAINTS

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1. Introduction

Over the last decade and more, economic growth in Northeast Asia—and particularly in China and the Republic of Korea (ROK)—has rapidly increased regional energy needs. These increased and increasing needs, in turn, have stimulated additional interest in and work on proposals for infrastructure for regional resource sharing and other economic integration. Many of these proposals involve infrastructure for moving fuels—gas, oil, or electricity—from the resource-rich Russian Far East (RFE) or other parts of the former Soviet Union to China, the Republic of Korea, and (in some cases) Japan. In addition to their requirements for investment capital, which range from large to extremely large, energy infrastructure proposals that involve the ROK also usually have a common geographical factor: they traverse the Democratic Peoples' Republic of Korea (DPRK). As a consequence, the status of the DPRK's energy sector, and the politics of the DPRK's relations with its neighbors and with the United States, play and will continue to play a considerable role in determining the degree to which many regional infrastructure projects can in fact be implemented.

In this summary we provide an overview of some of the regional infrastructure proposals that have been suggested, highlighting some of the issues that may "make or break" these proposals. We also provide some background on the DPRK energy sector, including a review of the recent and current status of the sector, the manifold DPRK energy sector problems, and potential means for the international community to assist in addressing those problems. We conclude by briefly offering our views on what types of infrastructure projects are likely, in the short to medium term, to be implementable, and on what types of collaborative activities, including those involving the DPRK, will help to improve the prospects for regional energy cooperation.

2. Regional Infrastructure Proposals

The countries of Northeast Asia already collectively constitute the world's largest market for liquefied natural gas (LNG), and one of the world's largest markets for crude oil and petroleum products. Recent economic growth in the countries of the region, particularly in greater China and in the Republic of Korea, has resulted in a very significant increase in both energy demand and energy imports, with an attendant increase in energy-related environmental problems. Figure 2-1, for example, shows a comparison of one set of carbon dioxide emissions projections for Northeast Asia as compared with projections for the rest of the world. In 1980, the countries of Northeast Asia accounted for just under 15 percent of the world’s total carbon emissions. By 1992, the fraction had grown to nearly 20 percent. By 2010, based on an older projection by Fujime, carbon dioxide emissions from the region will be 23 percent of the global total, with overall emissions double that of 1992. This means that the region will have contributed nearly one-third of the total growth in global carbon emissions between 1980 and 2010[1]. The combination of this growth and its current and future environmental consequences, coupled with the availability of lightly-used energy resources in the Russian Far East and in other areas of the former Soviet Union (Table 2-1 offers a partial listing of these resources) and the need for economic development in Russia have resulted in the development of a number of

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[11] Fujime, K., "Long-Term Energy Supply/Demand Outlook for Asia APEC Nations". Energy in Japan, January 1996. .

proposals for regional energy and transport infrastructure. The discussion below focuses on regional electricity grid proposals, which we consider to be the most viable near-term option, but also touches on proposals for gas pipelines, and for road and rail infrastructure development.

Figure 2-1:

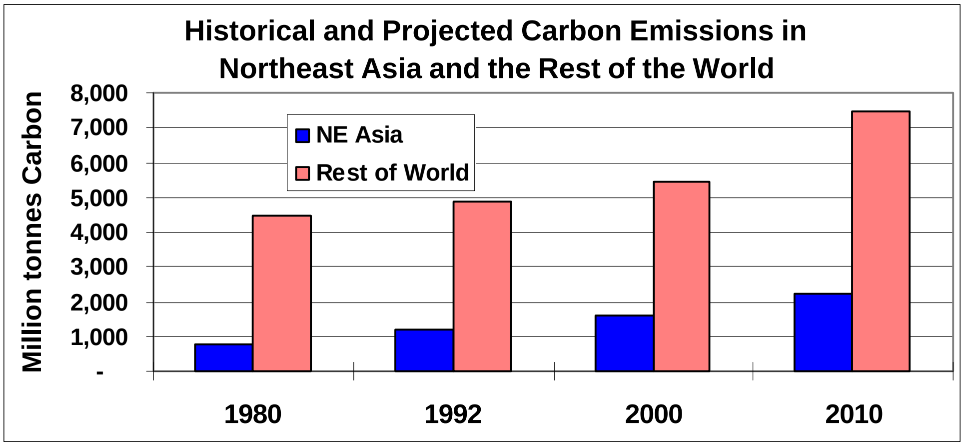

Table 2-1: Discovered Reserves of Primary Energy of the RFE (MTOE)[2]

Area	Coal	Oil	Natural Gas	Hydro	Total
Republic of Sakha	6,700	375	1,200	115.5	8,391
Magadan territory	710	14	13.3	33	770
Kamchatka territory	160	0	20.3	11.6	192
Amur territory	1,150	0	0	17.5	1,168
Khabarovsk territory	1,280	0	1.75	45.5	1,327
Primorskii territory	1,400	0	0	5.8	1,406
Sakhalin territory	1,080	620	850	1.1	2,551
The RFE as a Whole	12,480	1,010	2,085	230	15,802

2.1 Electricity Grid Interconnections

A number of proposals for interconnecting the electricity grids of the ROK, DPRK, China (and sometimes Japan) with the grid of the Russian Far East (and sometimes other regions of Russia) have been developed. These proposals are typically designed to move electricity generated at hydroelectric, nuclear, or natural gas-fired facilities in Russia to consumers in China and/or Korea. Figure 2-2 presents a picture of Northeast Asia from space that conveniently summarizes both the impetus for grid interconnections (intense electricity use in the ROK,

[2] Kalashnikov Victor D. (2000), National Energy Futures Analysis and Energy Security Perspectives in the Russian Far East. Khabarovsk Economic Research Institute, Far Eastern Branch of Russian Academy of Sciences, Paper Prepared for The Nautilus Institute East Asia Energy Futures Project, June, 2000.

China, and Japan, together with low electricity use in the RFE) and one the major technical and political barriers to grid connections (the DPRK and its fragmented electricity grid).

Figure 2-2: Northeast Asia from Space[3]

A number of grid interconnection options have been proposed that would link the RFE with the ROK and the DPRK[4]. Options also include more elaborate transmission line proposals

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[3] A similar image is available from http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=4333.

involving Japan (including a transmission "ring" surrounding the Sea of Japan/Korea East Sea), as well as segments of transmission line linking portions of one or more Chinese regional grids to the RFE or other parts of eastern Russia. Key elements of, and considerations for, grid interconnection include the following:

- *The cost of the transmission line*. Transmission line costs per kilometer vary depending on whether the line is AC (alternating current) or DC (direct current), the capacity of the line, the terrain crossed by the line, and the types of conductors (wires carrying current) and towers used. As a rough rule of thumb, a line capable of carrying on the order of 1000 MW of power might cost $250,000 to $500,000 per kilometer, meaning that a line linking the RFE with the ROK, and passing through the DPRK, would cost on the order of $0.5 to $1 Billion.
- *The cost of converter stations*. If part of the line is DC (superior in cost and performance to AC if the transmission distances are long enough), at least two converter stations must be used to convert AC power to DC for transmission, then back again to AC for use. AC-DC-AC converter stations may also be needed to provide interfaces between systems of different frequencies (see Figure 2-3), and/or to enable the partial isolation of interconnected grids from each other[5]. Converter station cost has been decreasing with improvements in electronics technology, but are on the order of $100 million per 1000 MW of capacity. The technical issues associated with grid interconnection, and with the operation of AC-DC-AC interconnections, are considerable[6].
- *The seasonal availability of generation and generating capacity in the interconnected countries*. For example, the RFE has available capacity (above the amount it needs to provide for its own power needs) in the summer, but little available capacity in the winter. The situation in the ROK is reversed—there is little or no excess capacity in the summer, but available capacity in the winter.
- *The capital costs of the power plants that the long-distance transmission will avoid*. The availability of the power from the transmission link will allow one or more countries to avoid building new power plants to meet peak and/or baseload power needs. The higher these "avoided capacity costs" are, the more economic the link will be.
- *The capital costs of any power plants added specifically to provide power for the link*.
- *The fuel and operating costs of the power plants that will feed into the transmission link relative to the costs for the power plants not run because of the availability of power from the link*. That is, the net generation costs avoided by the interconnection.

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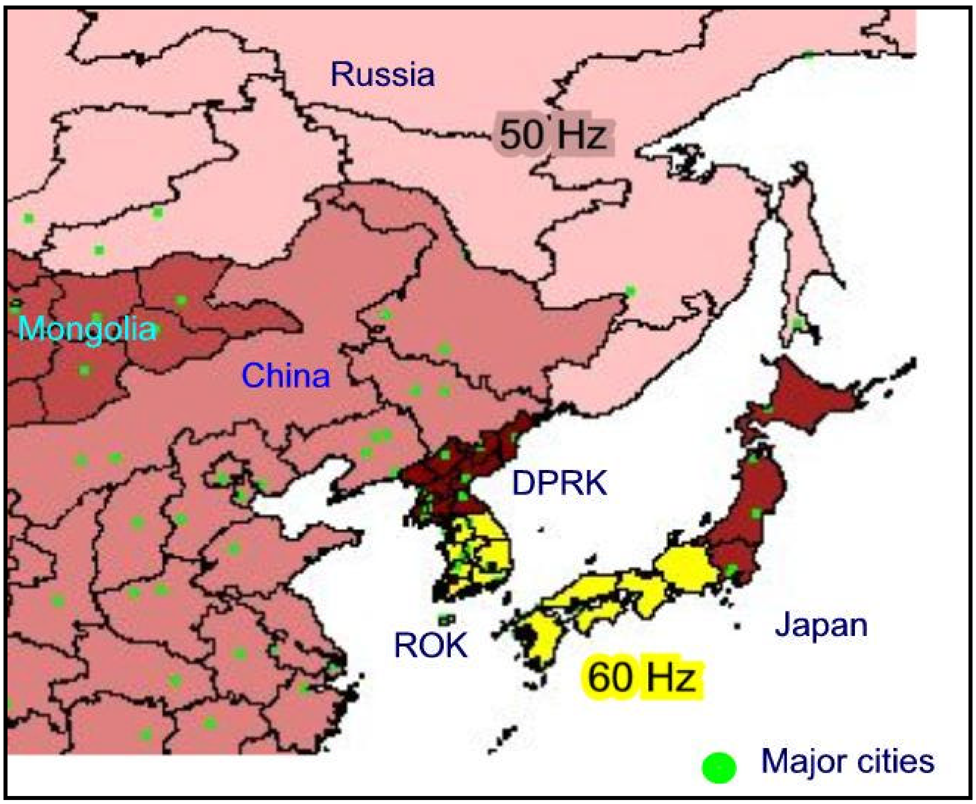
[4] See, for example, S. Podkovalnikov, Study For "Russian Far East–Korea People Democratic Republic–Republic of Korea" Power Grid Connection: Analysis of Current Status. Prepared for the Second Workshop on Regional Power Grid Interconnection in Northeast Asia, May 6th to 8th, 2002 in Shenzhen, China. See section on Second Grid Interconnection Workshop on www.nautilus.org.

[5] Note that while the DPRK electricity grid is designed to operate at a frequency of 60 Hertz (Hz), it in fact in recent years has operated at frequencies varying in time and location. Frequencies ranging from 52 Hz to 48 Hz and lower on the DPRK grid have been measured. Variations in frequency of more than a small fraction of a Hz are rare in most electricity grids today.

[6] For example, see papers by Felix Wu, Lev Koshcheev, and J.K. Park prepared for the First Workshop on Power Grid Interconnection in Northeast Asia, held in May, 2001, in Beijing. See www.nautilus.org.

- *Environmental or other considerations related to transmission line and/or generation siting and operation*. Depending on what power plant operation and/or capacity is avoided, the grid interconnection may be credited with avoided pollutant emissions, transmission bottlenecks, or power plant siting difficulties. For example, providing hydroelectric power from the RFE that avoids coal-fired generation in China or the DPRK will avoid the emissions of greenhouse gases and local/regional air pollutants. Similarly, displacing new peaking capacity in the ROK with the capacity of a transmission line from the RFE avoids the transmission and siting constraints faced by the ROK in expanding its fleet of nuclear reactors.
- *Institutional and pricing arrangements*. The arrangements needed to provide an multi-lateral institution for the operation of a Northeast Asia transmission link are decidedly no-trivial, as are arrangements for agreeing on power pricing (and rents for power transmission across national territories. Some international examples for such arrangements exist, but none operate in a political climate similar to that in Northeast Asia[7].

Figure 2-3: Frequency Distribution of the Electricity Grids of Northeast Asia[8]



[7] For example, see papers by Karsten Neuhoff and Ivar Wangensteen prepared for the First Workshop on Power Grid Interconnection in Northeast Asia, held in May, 2001, in Beijing. See www.nautilus.org.

[8] P. Hayes (2000), Regional Energy Security and the DPRK Electric Power Grid. Briefing to US Under-Secretary of Energy Ernest Moniz dated June 7, 2000.

Initial analyses of the economic potential of grid interconnections between the RFE and the ROK through the DPRK (and in some cases involving China) indicate that may be cost-effective on purely economic grounds, or may be cost-effective ways to reduce overall regional greenhouse gas and other air pollutant emissions[9]. Much depends on what is assumed about the parameters discussed above, and more detailed feasibility studies and modeling of the power systems to be interconnected is needed to better characterize the net benefits (or costs) of the different interconnection schemes.

2.2 The Influence of the KEDO 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 as the Korean Peninsula Energy Development Organization (KEDO), are providing financing for and constructing two 1150 MW reactors at the Kumho site on the East coast of the DPRK. These reactors were intended to help alleviate DPRK electricity shortages, but use of these reactors in the DPRK grid is problematic, at best[10]. 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 are actually currently operable), the grid would be too small to safely operate the KEDO 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 KEDO reactors are ever to generate power. This requirement adds a significant political (and economic) impetus to the development of Northeast Asia grid interconnections.

2.3 Gas Pipeline Proposals

There are probably 20 or more proposals, prepared by various parties and elaborated to different degrees, for exporting gas from Eastern Russia and/or the countries of Central Asia to China, Korea, and/or Japan. These proposals range from relatively short pipelines linking Sakhalin Island to Japan, to pipelines covering many thousands of kilometers to link Central Asia with the Far East. Figure 2-4 summarizes some of these proposals[11]. What virtually all gas pipeline proposals have in common is high capital cost (a range of $1.2 to 20 billion has been

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[9] See the paper Estimated Costs and Benefits of Power Grid Interconnections in Northeast Asia, prepared by David F. Von Hippel for the First Workshop on Power Grid Interconnection in Northeast Asia, held in May, 2001, in Beijing, and the 2002 paper by S. Podkovalnikov (prepared for the Second Grid Workshop) referenced above. See www.nautilus.org.

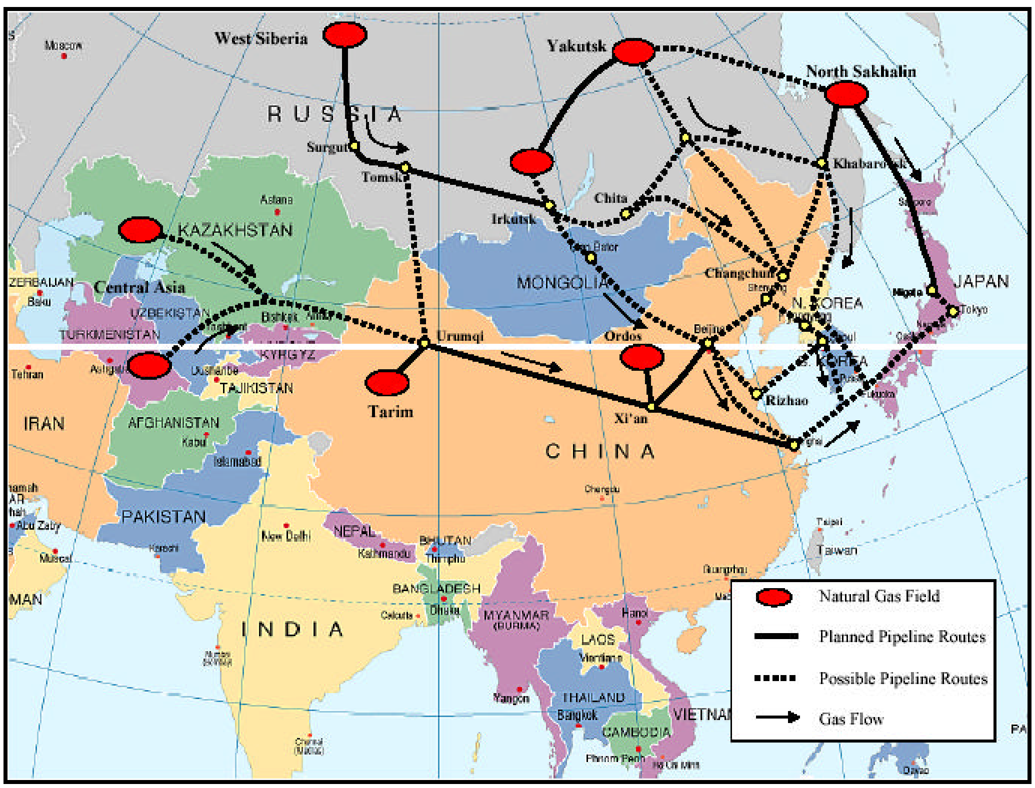
[10] For more detailed discussions of issues related to operation of the KEDO reactors, see John H. Bickel (2001), Grid Stability and Safety Issues Associated with Nuclear Power Plants. Paper prepared for the Workshop on Power Grid Interconnection in Northeast Asia - May 2001, Beijing, China, and available at http://www.nautilus.org/energy/grid/papers/bickel.pdf; David Von Hippel and Peter Hayes (2001), Modernizing the US-DPRK Agreed Framework: The Energy Imperative. Nautilus Institute Report, February, 2001, available at http://www.nautilus.org/papers/energy/ModernizingAF.pdf.

[11] Figure taken from Kazuaki Hiraishi, Development of natural gas pipeline network in Northeast Asia, prepared for the World Energy Council 18th Congress, Buenos Aires, October 2001, and available at http://www.worldenergy.org/wec-geis/publications/default/tech_papers/18th_congress/dsessions/ds7/ds7_9.asp.

cited, and costs of $1-2 million per kilometer of pipeline[12, 13]), long lead times for completion (typically five years or more), and formidable technical and (especially) political barriers to implementation.

In addition, to be economic, the availability of gas has to coincide with the development of gas demand. In China, gas distribution infrastructure remains undeveloped in many areas. Japan's gas industry is based on local distribution systems for liquefied natural gas (LNG), but lacks a national trunk pipeline system that would allow the use of substantial pipeline gas imports. The ROK has a relatively well-developed national gas transmission and distribution system, which is likely to provide a competitive economic advantage (relative to Japan), if and when pipeline gas imports are available, but the degree to which significant expansion of gas use is in fact likely in the industrialized ROK (as in Japan) remains to be seen. The DPRK, whose economy has traditionally been dependent on coal, has essentially no gas distribution infrastructure. All of these factors argue that any development of gas pipelines in Northeast Asia is unlikely in the near-term, particularly without a breakthrough in relations with the DPRK.

Figure 2-4: Several Proposed International Natural Gas Pipeline Routes



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[12] Multilateral Cooperation in Northeast Asia's Energy Sector: Possibilities and Problems by Mark J. Valencia and James P. Dorian (probably 1996). University of California Institute on Global Conflict and Cooperation Policy Paper 36, available as

http://www-igcc.ucsd.edu/publications/policy_papers/pp3604.html

[13] As another reference to the costs of gas pipeline, the US Department of Energy's Energy Information Administration, as part of its International Energy Outlook 2002, cites (in "China's West-to-East Natural Gas Pipeline") the cost of China's proposed domestic 4300 km gas pipeline development at $4.8 billion . The pipeline will have a throughput of 12 to 20 billion cubic meters annually. See http://www.eia.doe.gov/oiaf/ieo/chinaboxtxt.html.

2.4 Oil Pipeline Proposals

Oil pipelines have been proposed to link oil fields of Siberia to terminals in northern China[14], to link the oil fields of Russia's Sakhalin area with Japan, and even to connect the Caspian region with consumers in China and beyond. Uncertainties in future oil market conditions, coupled with formidable technical barriers and capital costs reaching easily into the billions of dollars, have thus far severely limited major pipeline development, though some Russian and multinational companies remain interested.

2.5 Road and Rail Interconnections

Road and rail interconnections are not a major focus of this summary, but will likely, practically speaking, accompany any grid or pipeline proposal. Road and rail connection (or re-connection) projects were underway to link the ROK and the DPRK, until these projects were recently put on hold. A rail link does, of course, exist between the Russian Far East and the DPRK, but at least one group has contemplated a major expansion in this link (including adjustments to the present gauge of part of the link) to allow large flows of freight to move to between the ROK and Russia through the DPRK, even connecting to Western Europe[15]. It is likely that the international arrangements necessary to accomplish such a link would benefit the negotiation of arrangements for a grid or pipeline interconnection, and vice-versa.

3. The DPRK Energy Sector: Status, Problems, and Cooperation Opportunities

During the decade of the 1990s, continuing through these early years of the 21st century, and particularly in recent weeks, a number of issues have focused international attention on the DPRK. Most of these issues—including nuclear weapons proliferation, 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. Below we review the recent history and current status (based on our estimates) of the DPRK energy sector, list some of the key energy sector problems facing the DPRK, and offer suggestions as to opportunities for international cooperation on DPRK energy sector problems,

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[14] A near-term $1.7 billion pipeline development linking oil fields in Eastern and Western Siberia with Daqing in China is described in "Developments in Projects to Export Oil and Gas from Russia to Asia" by Julia Nanay (2002), available as http://www.mees.com/news/a45n45d01.htm.

[15] See, for example, the report on the Eurasian Railways Symposium, Helsinki, 3 - 4 April 2002; "The Eurasian Dimension - the Role of Railways in Northern European -Northeast Asian Relations", organized by the Finland - Northeast Asia Trade Association in cooperation with VR Ltd. Finnish Railways. http://www.geocities.com/kaky_ry/symposium/toc.html.

highlighting those opportunities with the potential to encourage the development of regional infrastructure[16].

3.1 Recent History and Current Status of the DPRK Energy Sector

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[17]. 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.

Among the energy-sector changes on the supply side in the DPRK since 1990 have been a vast drop in imports of fuels from the Soviet Union and Russia. Crude oil imports from Russia in 1993, for example, were on the order of one-tenth what they were in 1990[18], and have fallen to practically zero since. Oil import restrictions have further reduced the availability of refined 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 probably 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 assistance and/or technology in the 1970s.

In the years since 1990 there has been a virtual halt in economic aid, technical assistance and barter trade on concessional or favorable terms from Russia and other Eastern European nations. This reduction, coupled with a sharp decline in similar types of assistance from China, had resulted in a total estimated loss of aid to the DPRK economy of more than $ US 1 billion per year[19] by the mid-1990s.

These overall economic and energy-sector trends provide the backdrop to the assessment of the current status of the DPRK energy sector, discussion of future energy sector problems, and international approaches for energy sector assistance that are provided below.

Changes in the DPRK energy sector between 1996 and 2000 have, for the most part, been of a substantially more incremental nature than the changes in experienced during the first half of

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[16] For additional information on the topics covered in this section of this summary paper, please see D. Von Hippel and P. Hayes, The DPRK Energy Sector: Current Status and Options for the Future, prepared for the International Workshop on "Upgrading and Integration of Energy Systems in the Korean Peninsula. Energy Scenarios for the DPR of Korea", Como, Italy, September 19-21, 2002; and D. Von Hippel, P. Hayes, and T. Savage (2002), The DPRK Energy Sector: Estimated Year 2000 Energy Balance and Suggested Approaches to Sectoral Redevelopment. These and other DPRK-related papers and reports are available at www.nautilus.org.

[17] Far Eastern Economic Review (1995), 1995 Asia Yearbook, North Korea.

[18] U.S. Bureau of the Census (1995a), The Collapse of Soviet and Russian Trade with the DPRK, 1989-1993: Impacts and Implications. Prepared by N. Eberstadt, M. Rubin, and A. Tretyakova, Eurasia Branch, International Programs Center, Population Division, U.S. Bureau of the Census, Washington, D.C., USA. March 9, 1995.

[19] United States Department of Energy Energy Information Administration (UDOE/EIA, 1996), Country Analysis Brief, North Korea. Part of USDOE/EIA World-wide Web site, WWW.eia.doe.gov/emeu/cabs/nkorea.html.

the 1990s. Among the key changes (or continuing processes) for the energy sector between 1996 and 2000 are:

- A continuing **decline in the supply of crude oil** from China, significantly reducing the overall output of the DPRK's remaining major (Northwest Coast) refinery.
- 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 of electricity** in most parts of the country away from Pyongyang.
- Continuing **degradation of industrial facilities**, and the damage to industrial electric motors from poor quality electricity (electricity with highly variable voltage and frequency).
- Evidence of significant international trade in **magnesite (or magnesia)**.
- Continuing difficulties with **transport of all goods, especially coal**.
- Difficulties in **coal production** related to lack of electricity, as well as mine flooding (in the Anju region).
- Some **economic revival**, but mostly, it seems, associated with foreign aid and/or with areas of the economy that are not energy intensive.

Figure 3-1 compares estimated final energy demand by sector for the years 1990, 1996, and 2000, and Figure 3-2 provides the same comparison for energy demand by fuel category. In addition to the marked decrease in overall energy consumption, there are two notable features of these comparisons. The first is the continuation of the trend of 1990 to 1996 whereby the residential sector uses an even larger share (now more than half) of the overall energy budget by 2000, while the industrial sector share shrinks to under a quarter of the total. This change is the combined result of continued reduction in fuel demand in the industrial sector, 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 decade, while the importance of commercial fuels has decreased.

Figure 3-1:

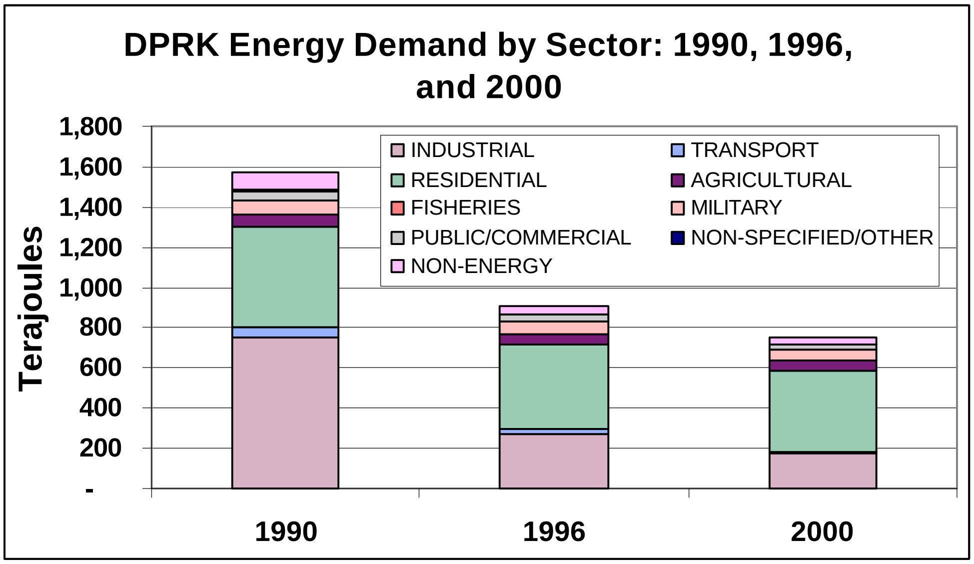
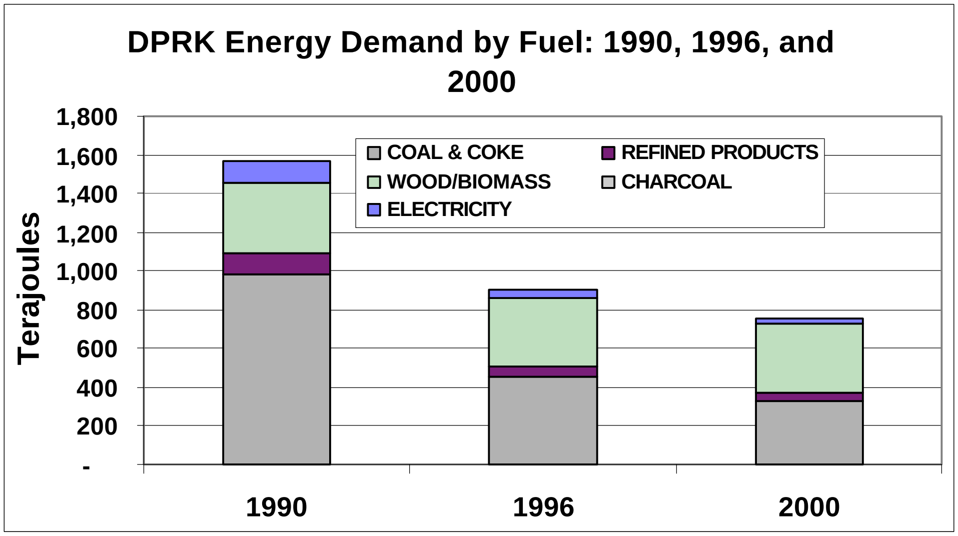


Figure 3-2:



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 has important political implications related to the KEDO Light Water Reactor (LWR) project, and to electricity grid interconnection options[20]. Analysis of the current status of the DPRK electricity sector suggests that:

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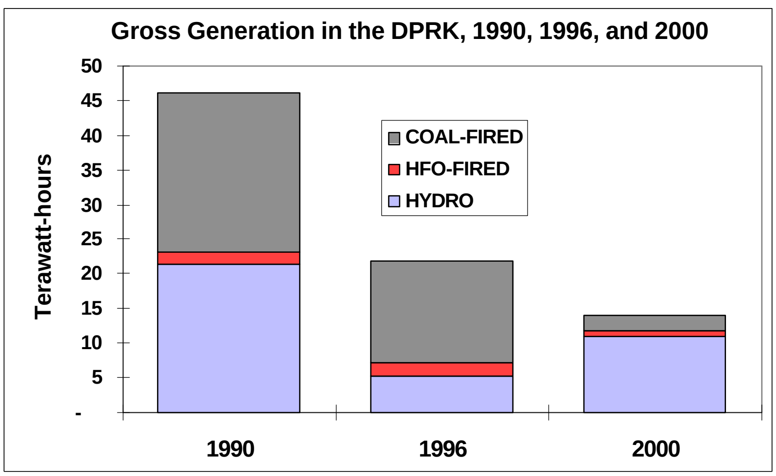
[20] For a more thorough discussion of this issue, see the Nautilus essay Modernizing the US-DPRK Agreed Framework: The Energy Imperative (D. Von Hippel, P. Hayes, M. Nakata, T. Savage, and C. Greacen, 2001), available as http://www.nautilus.org/papers/energy/ModernizingAF.pdf.

- The **thermal power generation** system in the DPRK is rapidly eroding. In virtually all of the large power stations, only selected boilers and turbines are operating, and those that are still in use operate at low efficiency and low capacity factors[21] 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.

Figure 3-3 shows the estimated structure of electricity supply in the DPRK in 1990/1996 (for comparison) and in 2000, broken down as generation in hydroelectric plants, generation fueled with heavy fuel oil (HFO, independent of whether the plant was designed to use oil), and thermal plants fueled with coal. Note that this figure displays gross generation: some of the electricity produced is used in the power plant itself, some is lost as a result of "emergencies", and more is lost during transmission and distribution. The total estimated supply of electricity decreased substantially between 1990 (46 terawatt-hours, or TWh[22]) and 1996 (24 TWh), and fell still further (by our estimate) by 2000 (to 14 TWh). Reflected in Figure 3-2 is the significant drop in hydroelectric output as a result of damage the floods of 1995 and 1996, and a considerable drop in thermal plant output between 1996 and 2000[23].

Figure 3-3: Estimated Sources of Electricity Supply: 1990, 1996, and 2000



[21] 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.

[22] One terawatt-hour is equal to 3600 terajoules, 3.6 million gigajoules, or one billion kilowatt-hours (kWh).

[23] It is clear that the degradation of the electricity sector has not gone unnoticed by DPRK authorities. Reports in the media and elsewhere indicate that the DPRK is actively seeking both low-cost and longer-term (for example, contacts on T&D infrastructure refurbishment with the Swiss multinational ABB) "fixes" to its problems. How these upgrades will be paid for remains unclear.

3.2 Key DPRK Energy Sector Problems

Key energy-sector problems in the DPRK include:

- *Inefficient and/or decaying infrastructure*: Much of the energy-using infrastructure in the DPRK is reportedly antiquated and/or poorly maintained, including heating systems in residential and other buildings. Industrial, power supply (as noted above), and other facilities are likewise either aging or based on outdated technology, and often (particularly in recent years) are operated at less-than-optimal capacities (from an energy efficiency point of view).
- *Suppressed and latent demand for energy services*: Lack of fuels in many sectors of the DPRK economy has apparently 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.
- *Lack of energy product markets*: Compounding the risk of a surge in the use of energy services is the virtual lack of energy product markets in the DPRK. Without fuel pricing reforms, there will be few incentives for households and other energy users to adopt energy efficiency measures or otherwise control their fuels consumption.

3.3 Opportunities for International Cooperation on DPRK Energy Sector Problems

Key economic resources for the DPRK include a large, well-trained, disciplined, and eager work force, an effective system for dissemination of technologies, the ability to rapidly mount massive public works projects by mobilizing military and other labor, and extensive reserves of minerals. What the DPRK lacks are modern tools and manufacturing methods, fuel, arable land, and above all, capital and the means to generate it (other than weapons sales). As a consequence, given the energy sector problems outlined above, a coordinated program of assistance from the ROK, the United States, and other countries that builds upon these skills will be needed. Providing key assistance in a timely manner will enhance security in Northeast Asia, accelerate (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[24]. 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. In our own experience working on the ground in the DPRK, visitors working hard to help and to teach North Koreans has great effectiveness in breaking down barriers between peoples.

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[24] This argument should <u>not</u>, however, be interpreted to mean that the KEDO LWR project should be abandoned (at least without the negotiated agreement of the DPRK). For all of its many faults, the reactor project provides one of the few (and dwindling) remaining avenues for constructive communication with the DPRK.

- *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.
- *Promote better understanding of the North Korean situation in the ROK*. South Koreans have a deep and natural interest in what goes on in the DPRK, but generally have no better access to information on the DPRK than those in other countries. It will be important in particular to involve South Korean actors in the types of assistance activities described here.
- *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:

- *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 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.
- *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.

4. Conclusions: Near-term Regional Cooperation Options

With the possible exception of relatively short-distance road and rail links, most options for regional infrastructure development in Northeast Asia are extensive, long-term propositions, with a host of formidable technical, economic, political, and sometimes environmental barriers to be overcome. Regional cooperation on energy facilities, however, provides an important "hook" for the substantive engagement of the DPRK in constructive, peaceful, and mutually beneficial activities with the countries of the region (and beyond).

Although hardly either a quick fix or a short-term project, it is imperative and attractive, from the perspectives of virtually all of the countries in the region, to move ahead with the consideration of electricity grid interconnections involving the ROK, the DPRK, Russia, and possibly China as well. The driving force for the implementation of such interconnections, in the short-to-medium term, will be, as noted above, the need to provide a means of safely "turning on" the KEDO reactors once they are complete (in, for example, the 2007 to 2010 time frame). The consideration of grid interconnection options is, as noted above, a complex matter, and one requiring cooperation from all parties. Here, however, the needs of the DPRK may be sufficiently in line with the needs and aspirations of its neighbors as to provide an opportunity for a breakthrough in cooperation. A detailed cooperative study of interconnection options involving researchers and data from each of the countries will be needed to move ahead with grid interconnections.

Natural gas and oil pipelines from Central Asia and/or Russia to the Far East are particularly expensive, and face both competition from LNG providers and uncertainties about the availability of gas demand. Though little or no gas is used in the DPRK at present, the keen interest in Russia and the ROK in extending a gas pipeline from the vast resources of Siberia and the Russian Far East to the consumers of South Korea, may make it worthwhile to start to establish an appreciation for the benefits of gas on the part of the DPRK. Initial steps might be to build very small demonstration power plants fired, for example, with liquefied petroleum gas imported to small storage facilities, and also to use gas piped from such facilities to provide essential humanitarian services and residential fuel to a small surrounding area. At the same time, representatives of parties from these three countries can begin to work out the issues associated with the construction of a gas pipeline from the RFE to Korea.