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

Prepared by

David Von Hippel and Peter Hayes

Nautilus Institute for Security and Sustainability

125 University Avenue, Berkeley, CA 94710, USA

October 1, 2002

The authors may be contacted at:
dvonhip@igc.org **(David Von Hippel; 910 E 23rd Ave., Eugene, OR 97405 USA) and**
phayes@nautilus.org **(Peter Hayes; 125 University Avenue, Berkeley, CA 94710, USA)**

TABLE OF CONTENTS

1. Introduction

During the decade of the 1990s, and continuing through these early years of the 21st century, a number of issues have focused international attention on the Democratic People's Republic of Korea (the DPRK). Most of these issues—including nuclear weapons proliferation, military disagreements, economic collapse, transboundary 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.

Despite signs of recent economic improvement, the energy situation in the DPRK remains difficult at best, and focused and coordinated international assistance is likely to be a key ingredient for any substantial energy sector development/redevelopment in the DPRK.

The paper that follows summarizes Nautilus Institute research and analysis related to the DPRK energy sector, and is designed to provide background and input to the deliberations of the International Workshop on "Upgrading and Integration of Energy Systems in the Korean Peninsula. Energy Scenarios for the DPR of Korea", held in Como, Italy, September 19-21, 2002. As such, this paper provides discussions of current estimates of energy sector activity in the DPRK, and of the potential pole of energy-efficiency improvements in DPRK energy sector development, of future energy "Paths" for the DPRK, and concludes with some ideas for consideration in formulating cooperative, coordinated international approaches for aiding in DPRK energy sector development.

1.1. Background

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[1]. 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. Recently, observers of the DPRK economy have suggested that at least a modest improvement has taken place in recent years—ROK sources, for example, say that the DPRK economy grew approximately 6 percent in 1999, and another 1.3 percent in 2000[2]. Other observers, however, tend to argue that most of any economic upturn in the DPRK economy appears to be driven by food and other aid from abroad[a].

Among the energy-sector changes on the supply side in the DPRK since 1990 have been:

- A vast drop in imports of fuels (particularly crude oil and refined products, but coal and coke as well) from the Soviet Union and Russia. An index of these imports declined from a value

---

[a] For example N. Eberstadt (2001), If North Korea Were Really "Reforming", How Could We Tell—And What Would We Be Able To See? states "...official claims of 'turning the corner' and 'completing the Forced March' notwithstanding, the DPRK remains in dire economic straits.". Eberstadt goes on to cite the UN Food and Agriculture Organization's finding that DPRK cereal production in 2000/2001 "is expected to be fully a third below the level of 1995/96", and asserts, based in part on the DPRK's meager reported export earnings in the first half of 2001, that "The country's export capabilities are likewise in a state of virtual collapse…".

of over 140 in 1987 to 8.7 in 1993, and crude oil imports from Russia in 1993 were on the order of one-tenth what they were in 1990[3], and have fallen to practically zero since.

- Oil import restrictions that 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.

Contributing to the decline in the country's economic fortunes has been the inability (again, partly due to lack of foreign exchange, and partly due to Western economic sanctions) to obtain key spare parts 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 (including, in the last several years, a reduction in crude oil shipments to the DPRK), had resulted in a total estimated loss of aid to the DPRK economy of more than $ US 1 billion per year[4] by the mid-1990s. The DPRK's trade deficit as of 2000 stood at $US 857 million[5].

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 prospects and possibilities, and international approaches for energy sector assistance that are provided in the remainder of this paper.

1.2. Contents of this Paper

The remaining sections of this paper are organized as follows:

- **Section 2** provides a discussion of Nautilus Institute's work on analysis of the DPRK energy sector, including a summary of the history of Nautilus work on DPRK issues, and an overview of the general analytical approach used.
- **Section 3** provides a summary of the most recent (year 2000) Nautilus DPRK Energy Balance Update, including summaries of the procedure used to prepare the update, and overviews of results for electricity supply and demand as well as the supply of and demand for other key fuels.
- **Section 4** discussed the potential role of energy efficiency in the development of the DPRK energy sector, including estimates of the energy benefits, costs, and environmental impacts of a limited set of potential demand- and supply-side energy efficiency measures.
- **Section 5** summarizes recent Nautilus work on future energy paths for the DPRK, and their implications for policy approaches to DPRK energy sector assistance.
- **Section 6** provides some initial ideas for cooperative, coordinated approaches for the international community to consider in planning assistance for DPRK energy sector development.

2. DPRK Energy Analyses--History and Analytical Approach

2.1. Nautilus Projects

Nautilus experience drawn upon in carrying out the analyses summarized in this paper spans much of the last two decades, and includes:

- Analyses of Korean security, including nuclear armaments, issues starting during the 1980s[b].
- Several consulting missions to the DPRK, on energy sector and environmental (including greenhouse gas) issues, undertaken during the early 1990s for the United Nations Development Programme (UNDP).
- An analysis of the DPRK's energy situation as of 1990, and an assessment of the degree to which energy efficiency measures could result in improved performance of the DPRK energy sector (Von Hippel, D. F., and P. Hayes, The Prospects For Energy Efficiency Improvements in the Democratic People's Republic of Korea: Evaluating and Exploring the Options, Nautilus Institute Report, December, 1995)[c].
- A review of the demand for and supply of heavy fuel oil in the DPRK as of 1996, with demand scenarios for the year 2000, prepared for the Korean Peninsula Energy Development Organization (KEDO).
- Research, focusing on the DPRK electricity system, updating Nautilus' estimate of the status of the DPRK energy sector to 1996, and elaborating and evaluating energy scenarios for the DPRK to 2005 (D.F. Von Hippel, and P. Hayes (1997), Demand and Supply of Electricity and Other Fuels in the Democratic Peoples' Republic of Korea (DPRK): Results and Ramifications for 1990 through 2005, Nautilus Institute prepared for Northeast Asia Economic Forum)[d].
- A discussion of the rural energy crisis in the DPRK, and of measures that might be taken to rebuild rural energy and agricultural infrastructure in the country (J. Williams, D.F. Von Hippel, and P. Hayes, Fuel and Famine, Rural Energy Policy Options in the DPRK, Nautilus Institute, March 2000)[e].
- A long-term project, which to date has included three missions by U.S. engineers to the DPRK, to provide wind-powered electricity generation, electricity storage, efficient electric end-use equipment, and water pumping windmills to a flood-affected village in a rural area of the DPRK. In the latter project, Nautilus engineers have worked (and played) side-by-side with North Korean counterparts to construct facilities in the village. The project has also

[b] See, for example, Hayes, Peter (1990), Pacific Powderkeg: American Nuclear Dilemmas in Korea (Free Press, New York, 1990; Han-ul Press, Seoul, 1991).

[c] A summary version of this report is available as an HTML document on the Nautilus Institute World-wide Web site at http://www.nautilus.org/papers/energy/dvh_hayesENEF.html.

[d] A summary version of this report, http://www.nautilus.org/papers/energy/dvh_hayesscenarios.pdf, is available on the Nautilus Institute World-wide Web site. The complete report can be provided upon request.

[e] The Fuel and Famine report was prepared for the Institute on Global Conflict and Cooperation (IGCC) of the University of California, and an HTML version of the report is available at http://www-igcc.ucsd.edu/publications/policy_papers/pp46.html.

included what is to Nautilus' knowledge the first systematic survey of rural energy use ever carried out in the DPRK[f].

- Modernizing the US-DPRK Agreed Framework: The Energy Imperative (D. Von Hippel, P. Hayes, M. Nakata, T. Savage, and C. Greacen, 2001), providing a summary of the issues and options surrounding the Agreed Framework—the 1994 agreement between the United States and the Democratic People's Republic of Korea (DPRK) under which the DPRK is to be supplied with two light-water nuclear reactors for electricity generation in exchange for abandoning its existing nuclear reactors[g].
- An update of the DPRK energy balance to the year 2000 (D. Von Hippel, P. Hayes, and T. Savage (2002), The DPRK Energy Sector: Estimated Year 2000 Energy Balance and Suggested Approaches to Sectoral Redevelopment, prepared for the Korea Energy Economics Institute (KEEI)).

2.2. Analytical Approach

In the 1995 report referenced above, an estimated energy supply/demand balance for the DPRK for the year 1990 was prepared that synthesized the information available on the North Korean economy and energy sector. In the 1995 report, the energy balance results were used to estimate the potential for and potential benefits of energy-efficiency improvements in the DPRK. Preparation of the 1997 report Demand and Supply of Electricity and Other Fuels in the Democratic Peoples' Republic of Korea (DPRK): Results and Ramifications for 1990 through 2005 included the preparation of an estimated energy balance for 1996, and used the 1996 balance as the starting point for the development quantitative energy "paths" for the DPRK for 2000 and 2005.

In preparing the 1990 and 1996 energy balance estimate, we:

- Collected available energy and other data on DPRK. The documents assembled included international and regional publications providing statistics (energy, industrial and agricultural output, infrastructure) on the DPRK; documents (in Korean) on the DPRK energy and economic situation obtained from South Korean (ROK) studies and other sources such as Russian analysts; official statistics provided by the DPRK government; historical documents on energy use in ROK; and other documentation from the authors' files.
- Collected energy statistics and other energy-sector data on economies that are likely to be similar, in some ways (such as types of infrastructure) to that of the DPRK. This process included collection of energy sector intensity data from the international literature[h] for the People's Republic of China, the Former Soviet Union, and the countries of Eastern Europe.
- Synthesized the information available and organized it by balance element (supply, transformation, demand), by fuel, and by subsector (when possible). We further categorized the types of information we collected as direct data on the energy system of the DPRK,

---

[f] J. Williams et al (1999), "The Wind Farm in the Cabbage Patch", Bulletin of the Atomic Scientists, May/June 1999 provides an overview of the wind power project. The rural energy survey carried out as part of the wind power project is described in D.F. Von Hippel et al (2001), Rural Energy Survey in Unhari Village, The Democratic People's Republic of Korea (DPRK): Methods, Results, and Implications. This Nautilus Institute Report is available as http://www.nautilus.org/dprkrenew/Unhari_Survey.pdf.

[g] Available as http://www.nautilus.org/papers/energy/ModernizingAF.pdf.

[h] In particular, the Energy Analysis Program at Lawrence Berkeley Laboratory, Berkeley, California, USA.

including the *amount of energy produced or consumed*, and capacities of key infrastructure; data on *activities* relevant to energy use in DPRK, including the physical output (tonnes of steel produced, for example) in key subsectors, and other physical, social, and demographic factors such as population and agricultural land area; and data on the *intensity* of energy use. In the case of energy intensities in particular, very little information specific to the DPRK was available, so analogous and "placeholder" data from other countries, usually China or the former Soviet Union, were often used.

The approach used to update the 1990 and 1996 energy balances to a 2000 base year, and the estimates for the year 2000 thus derived, are presented below. Although the process that Nautilus has followed in evaluating energy supply and demand in the DPRK was and is bound to produce energy balances that "fits" the DPRK poorly in some areas, it is our hope that in future collaboration with DPRK energy experts we will be able to use the balance described and presented below as a starting point to develop better information for use by both the international community and by the DPRK itself.

3. DPRK Energy Balance Update

The overall goal in preparing an estimating energy supply-demand balance for the DPRK for the year 2000 was the same as motivated previous analytical research on the DPRK energy sector, namely, to provide an internally-consistent analysis of the energy sector using all available data, so as to be able to use the analytical results to formulate and focus cooperative approaches for energy sector assistance. The overall approach used in preparing a DPRK energy supply-demand balance for 2000 included:

- Starting with the estimates of demand and supply prepared as above for 1990 and 1996.
- Modification of the 1990/96 estimates of demand for fuels to reflect reports of recent changes in conditions in the DPRK. These included changes in population, continued reduction in the availability of oil products, observed changes in the transport system, and reported or implied reductions in industrial, agricultural and fisheries output. Reports as to the availability of electricity in different parts of the country also played a role in the estimation of year 2000 electricity demand.
- Revision of 1996 estimates of electricity supply to meet 2000 electricity demand and to reflect information about recent changes in thermal and hydroelectric generating capacity (and its availability).
- Estimation of 2000 oil supply in a way that reflects available information, including the capacities, product slates, and utilization of the oil refineries in the DPRK, and quantities of refined products reported to be imported during 2000 (including product trades recorded in official statistics and products reportedly imported "unofficially").
- Revision of oil products demand as initially estimated to meet the overall supply for each of the major classes of oil products (heavy fuel oil, diesel oil, gasoline, and kerosene).
- Setting the level of coal and biomass supply to meet demand, and re-adjusting supply of other fuels as necessary to produce a rough balance in overall supply and demand.

Overall, the approach used in preparing the year 2000 energy balance, in keeping with the paucity of information available (both inside and outside the DPRK) about the DPRK in general and about its energy sector in particular, was to obtain all the information remotely germane to the problem, sift through the information to see which pieces made sense, and fit with other data, and to try and use what was available to prepare an internally consistent energy balance. In so doing information was collected from reports by others, media reports, official statistics of DPRK trading partners, information on the DPRK from ROK government agencies, and the reports of visitors to and observers of the DPRK. In updating our 1990/96 energy balance to 2000, we contacted a number of specialists in DPRK (and broader Northeast Asian) energy issues and economics, including those who visit the country, to obtain their data, thoughts, and observations on recent developments the DPRK.

3.1. Summary of Key Changes in the DPRK Energy Sector Between 1996 and 2000

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 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. Figure 3-1 presents a view of the lights of Northeast Asia from space in which it is clear that electricity is available in the DPRK only in limited areas.
- Continuing **degradation of industrial facilities**, and the damage to industrial electric motors from poor quality electricity (electricity with highly variable voltage and frequency).
- Some **imports of used motor vehicles** (which are more efficient than existing DPRK vehicles).
- A continued decline in **production of cement and steel**.
- Evidence of significant international trade in **magnesite (or magnesia)**.
- Some increase in **military activity**, relative to 1996.
- 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: Northeast Asia from Space[i]

3.2. Summary Electricity Sector Results

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 Korean Energy

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

Development Organization (KEDO) Light Water Reactor (LWR) project[j]. Some of the highlights of the updated analysis of the DPRK electricity sector are provided below.

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, if any are operating at all. The (nominal) 200 MW heavy fuel oil-fired plant near the (East Coast) Sonbong refinery apparently did not operate at all in 2000, and at least three other 100 MW plants also did not operate. Those plants that do operate are reportedly plagued by problems with "air heaters"—devices that extract heat from exhaust gases to heat incoming combustion air. These air heaters have in most plants been degraded to the point of inoperability by acid gases from the combustion of high sulfur fuels. Boiler tubes in many power plants have been degraded from the outside by acid gases from high-sulfur fuels, and from the inside by inadequately-treated, or untreated boiler feed waters. The lack of spare boiler tubes—and in many cases it may be that boiler tubes to fit these generators, which were built in the 1950s and 1960s, are not available—means that it is very difficult to repair the boiler tube degradation. In total, it is estimated that less than 800 MW of thermal capacity were operable as of 2000, though it is possible that some other units were technically operable, but did not operate due to lack of fuel. For those power plants that are operable, an average capacity factor in the range of 50 percent or less seems plausible, 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. Information from industry sources indicate that any difficulties associated with the 1995/1996 flood damage to the shared power stations (China/DPRK) along the Chinese border has been repaired, and those plants are operating normally. Normally, however, apparently means that those plants—about 700 MW of capacity each for China and for the DPRK—are used largely in a peaking mode to conserve river water, and operate at full capacity only during the rainy mid-July to mid-August period. Of the approximately 4000 MW of other hydroelectric plants, 80 percent of capacity was estimated to be operable, and those operable hydro plants had a capacity factor in 2000 (a low water year) of about 38 percent overall. This could, in fact, prove an over-estimate.

The above assumptions as to electricity generation imply a gross output of about 14 terawatt-hours in 2000. Based on reports of the continuing erosion of the transmission and distribution (T&D) grid, it was assumed that T&D losses were 5 percent higher in 2000 than in 1996, totaling over 24 percent of net generation.

Table 3-1 and Figure 3-2 show 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 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 (including electricity exports to China) decreased substantially between 1990 (46 terawatt-hours, or TWh[k]) and 1996 (24 TWh), and fell still further (by our estimate) by 2000 (to 14 TWh). This

[j] For a more thorough discussion of this issue, see the Nautilus essay Modernizing the US-DPRK Agreed Framework: The Energy Imperative, referred to in section 2 of this paper.

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

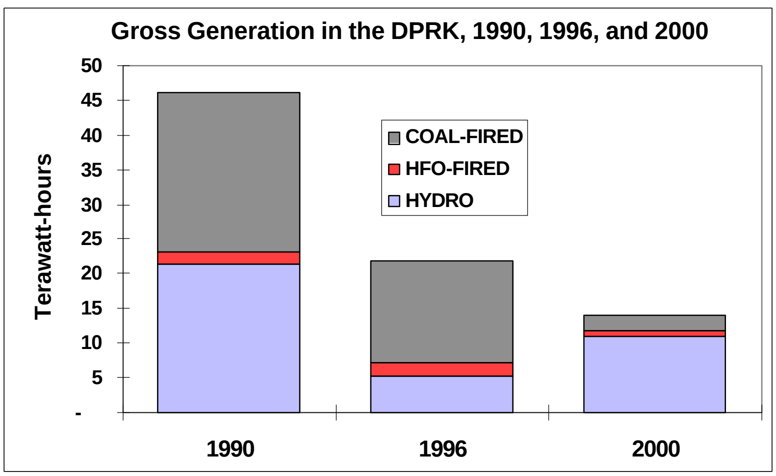
estimate for 2000 is considerably lower than other estimates[l], but is more likely to be close to actual 2000 generation, as it is built up based on information as to the status of generation facilities. Reflected in Figure 3-2 is the significant drop in hydroelectric output as a result of damage the floods of 1995 and 1996, and a considerable drop in thermal plant output between 1996 and 2000[m].

Table 3-1:

Supply Summary for Electricity: Terawatt-hours of Gross Generation

GENERATION	YEAR 1990	1996	2000
HYDRO	21.3	5.3	10.8
HFO-FIRED	1.7	1.9	1.0
COAL-FIRED	23.0	14.6	2.2
TOTAL	46	22	14
HYDRO	46%	24%	77%
HFO-FIRED	4%	9%	7%
COAL-FIRED	50%	67%	16%
TOTAL	100%	100%	100%

Figure 3-2: Estimated Sources of Electricity Supply: 1990, 1996, and 2000



The estimated structure of demand for electricity is shown in Figure 3-3 for 1990, 1996, and 2000. The fractions of demand by sector are shown in Figure 3-4 . Industrial demand for electricity accounted for a slightly larger fraction of the total in 2000 than it did in 1996, with the

[l] For example, data provided to Nautilus by KEEI (and based on data from the ROK National Statistics Office) shows 19.2 TWh of total generation in 2000, of which 10.2 TWh (slightly less than our estimate) is hydro generation, and 9.2 TWh (about three times our estimate) is thermal generation.

[m] 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.

residential share declining (as a result of lack of availability of electricity in many areas) and shares used by agriculture (for example, irrigation and crop processing, a national priority) and the military increasing.

Figure 3-3: DPRK Electricity Consumption by Sector: 1990, 1996, and 2000

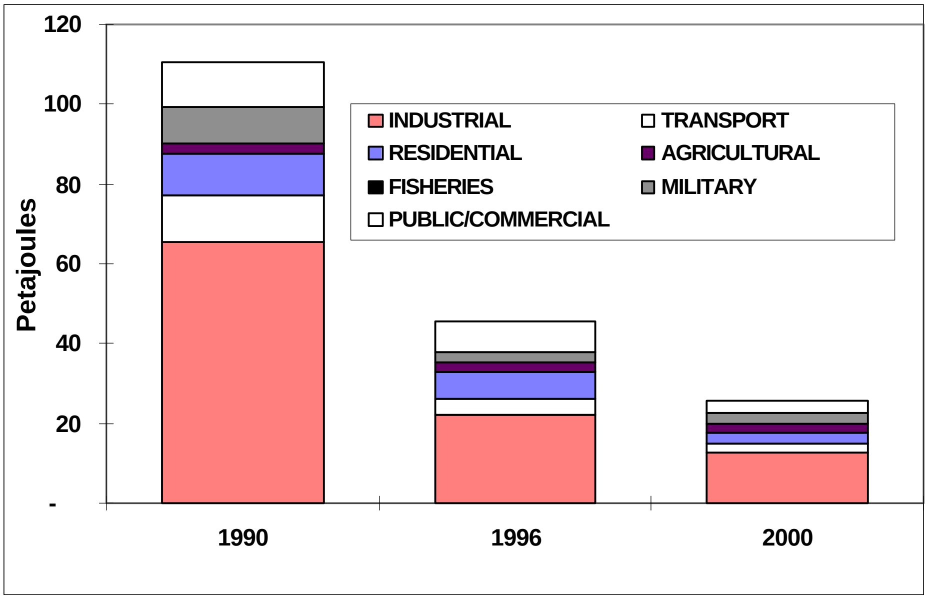
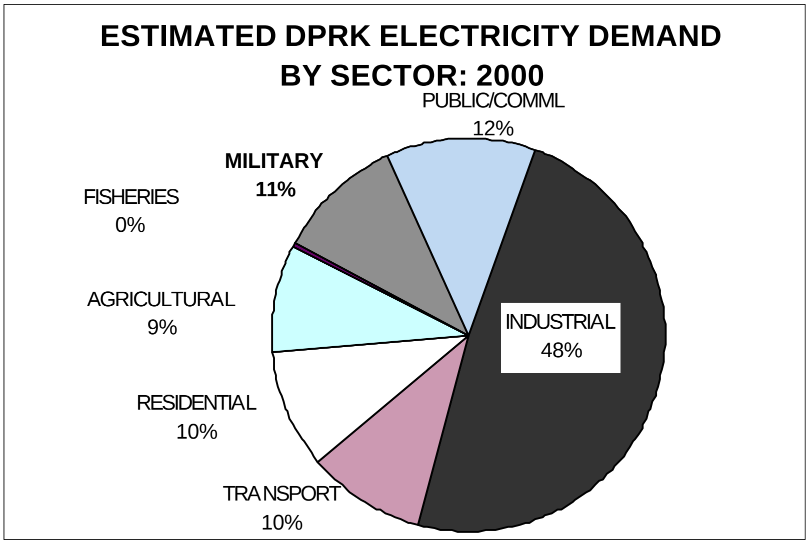


Figure 3-4:



3.3. Estimated Supply and Demand for Non-Electric Fuels

Table 3-2 presents a summary version of an estimated 2000 energy balance for the DPRK. Figure 3-5 shows the supply for energy by fuel in 2000, underscoring the overwhelming importance of both wood and biomass and coal-based fuels to the DPRK economy. Figure 3-6 shows the breakdown of overall energy use by sector in 2000. Here the residential sector uses more than half of the overall energy budget by 2000, while the industrial sector share is under a quarter of the total. Figure 3-7 shows the pattern of final fuels demand by fuel, which shows a similar pattern to overall fuels supply. Figures 3-8 and 3-9 show the pattern of demand for coal and for oil products in 2000, respectively. The industrial sector is the largest end-user of coal products, while the military sector is estimated to consume the largest share of petroleum products.

Table 3-2: Summary Estimated Supply/Demand Balance for the DPRK in 2000

UNITS: PETAJOULES (PJ)	COAL & COKE	CRUDE OIL	REF. PROD	HYDRO/ NUCL.	WOOD/ BIOMASS	CHAR-COAL	ELEC.	TOTAL
ENERGY SUPPLY	387.3	24.8	40.0	39.0	358.6	-	(8.3)	841.3
Domestic Production	385.8	-	-	39.0	331.9	-	-	756.6
Imports	9.3	24.8	43.0	-	26.7	-	-	103.8
Exports	7.8	-	3.0	-	-	-	8.3	19.1
Stock Changes	-	-	-	-	-	-	-	-
ENERGY TRANSF.	(57.4)	(24.8)	5.9	(39.0)	(7.7)	2.5	34.0	(86.3)
Electricity Generation	(33.9)	-	(16.3)	(39.0)	-	-	50.4	(38.7)
Petroleum Refining	-	(24.8)	23.6	-	-	-	(0.1)	(1.4)
Coal Prod./Prep.	(18.7)	-	-	-	-	-	(2.5)	(21.2)
Charcoal Production	-	-	-	-	(7.7)	2.5	-	(5.1)
Own Use	-	-	(1.4)	-	-	-	(2.0)	(3.4)
Losses	(4.8)	-	-	-	-	-	(11.8)	(16.5)
FUELS FOR FINAL CONS.	329.9	-	45.9	-	350.9	2.5	25.7	755.0
ENERGY DEMAND	329.9	-	45.9	-	350.9	2.5	25.7	755.0
INDUSTRIAL	152.1	-	11.7	-	0.3	-	12.5	176.5
TRANSPORT	-	-	7.7	-	0.5	-	2.5	10.7
RESIDENTIAL	107.6	-	2.6	-	280.3	2.5	2.5	395.6
AGRICULTURAL	8.8	-	1.8	-	40.5	-	2.3	53.3
FISHERIES	-	-	0.8	-	-	-	0.0	0.8
MILITARY	38.3	-	16.6	-	-	-	2.7	57.6
PUBLIC/COMML	21.2	-	-	-	-	-	3.1	24.4
NON-SPECIFIED			-					-
NON-ENERGY	1.9		4.8		29.3			36.0
Elect. Gen. (Gr. TWhe)*	3.04	-	0.15	10.82	-	-	-	14.01

**Note: Gross terawatt-hours for coal-fired plants includes output for plants co-fired with coal and heavy fuel oil.*

Figure 3-5:

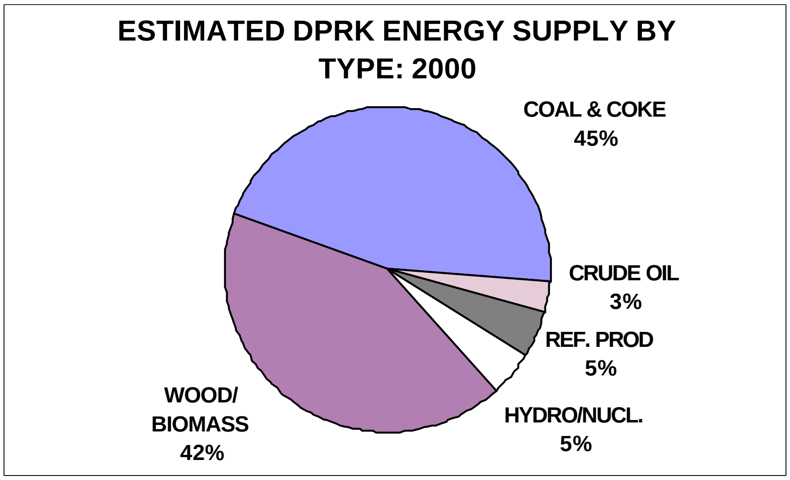


Figure 3-6:

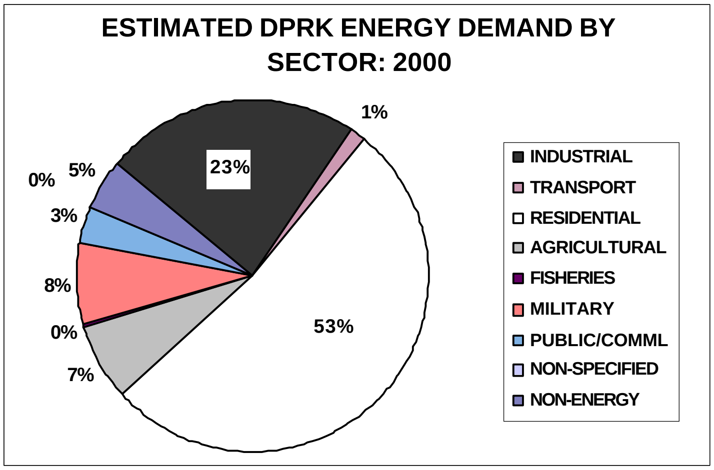


Figure 3-7:

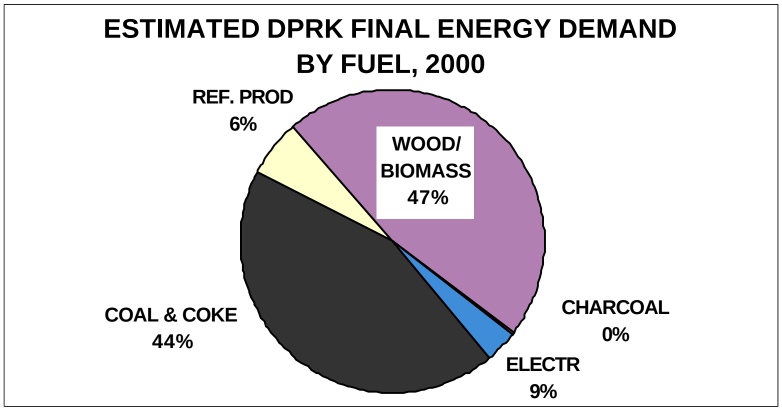


Figure 3-8:

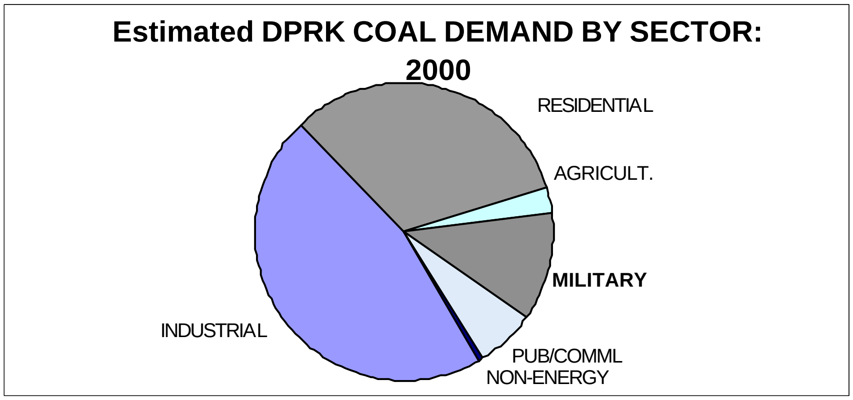


Figure 3-9:

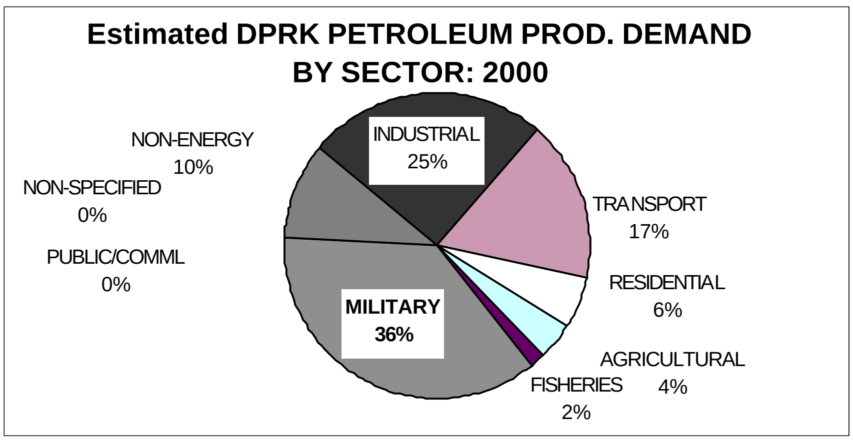


Figure 3-10 compares estimated final energy demand by sector for the years 1990, 1996, and 2000, and Figure 3-11 provides the same comparison for energy demand by fuel category. In addition to the marked decrease in overall energy consumption, there are two notable features of these comparisons. The first of these features 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 3-10:

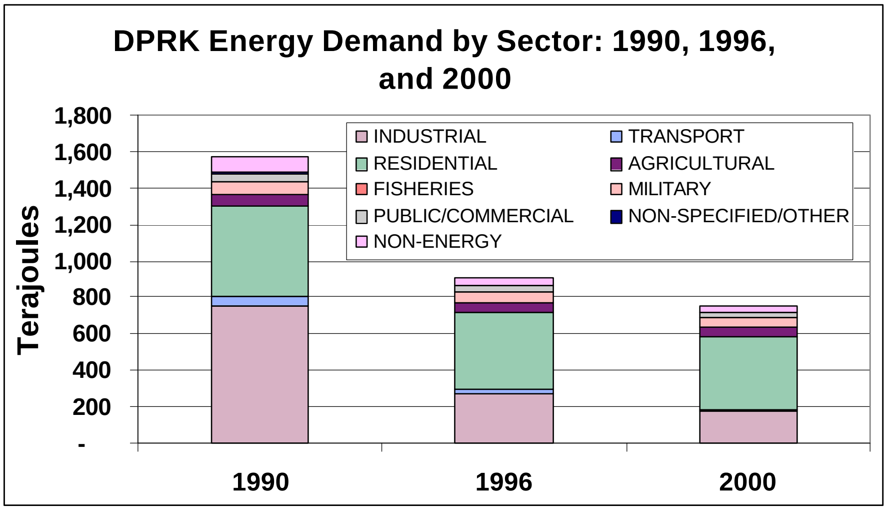
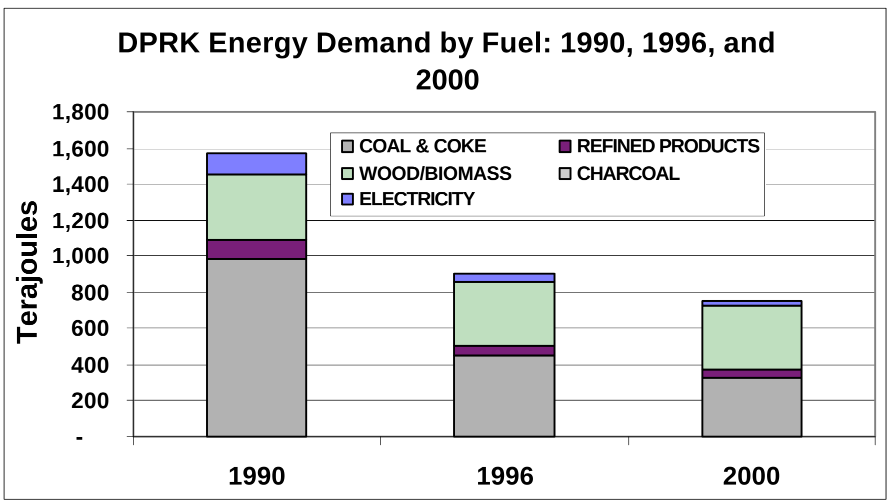


Figure 3-11:



3.4. Environmental Impacts of Energy Sector Activities

The DPRK energy sector has historically been a major source of environmental problems both within and—in the case of regional and global pollutants—outside the country. As such, the status of the environment has a significant bearing on the future development of the DPRK electrical system and other elements of the energy system. Among these problems are industrial pollution of rivers; urban air pollution (including sulfur and nitrogen oxides, the precursors of acid precipitation) from industrial facilities and virtually uncontrolled combustion of coal in residential, industrial, and power plant boilers; indoor air pollution from domestic combustion of coal and biomass fuels; pollution of surface- and ground-water from agricultural practices (fertilizer and pesticide application, irrigation); high per-capita greenhouse gas emissions (from high per-capita coal use); pollution of waters by drainage from mines; and erosion from over harvesting of forests and inadequate soil conservation practices. Some of these problems (as shown by the trends in estimated pollutant emissions shown in Table 3-3) have abated somewhat as a result of decreased activity in the energy and industrial sectors, while other problems (notably deforestation) have likely been exacerbated in recent years. The environmental considerations associated with energy sector activities need to be addressed as at least a part of any cooperative activities to assist energy sector development in the DPRK.

Table 3-3:

SUMMARY OF ACID GAS AND CO_2 EMISSIONS

YEAR	Sulfur Oxides (thousand tonnes)	Nitrogen Oxides (thousand tonnes)	Carbon Dioxide (million tonnes)
1990	803	545	129
1996	415	301	66
2000	237	189	38

The litany of environmental problems described above is hardly unique to the DPRK. It is the confluence of these problems, high population densities, limited resources of arable land, and political and economic isolation, that leave the DPRK arguably in a much worse position than most countries to deal with environmental problems. North Korea suffers from a lack of sufficient trained personnel and analytical equipment for use in enforcing existing environmental laws, meaning that environmentally-sound practices are likely to be sporadic at best. In the short run, the absence of an effective regulatory infrastructure means that the extent to which the DPRK takes environmental considerations of any kind into account in planning and operating its energy system is likely to be externally, rather than internally, motivated, even though North Korean leadership have declared that environmental protection is to be of paramount importance[6].

4. Energy Efficiency Opportunities in the DPRK

In the 1990 energy balance study (conducted in 1995) described in section 2 of this paper, the estimated energy balance was used as a starting point for a indicative—though admittedly very approximate and not at all exhaustive—quantitative analysis of a subset of the energy efficiency and renewable energy options that could be implemented in the DPRK. This analysis was intended to illustrate the significant potential for energy efficiency as a crucial component to energy sector development in the DPRK. Since 1990, based on the observations of the authors and others who have visited the DPRK, there have been relatively few changes in end-use equipment that would substantially affect the overall conclusions of the 1995 study[n]. An

[n] For a more complete discussion of the analysis of the energy efficiency opportunities described in this section, as well as a more qualitative discussion of some of the additional opportunities available, see P. Hayes and D.F. Von Hippel (1997), "Engaging North Korea on Energy Efficiency", Chapter 9 in Peace and Security in Northeast Asia: The Nuclear Issue and the Korean Peninsula, Young Whan Kihl and Peter Hayes, editors, M.E. Sharpe, Armonk, NY; and D.F. Von Hippel and P. Hayes (1996) "Engaging North Korea on Energy Efficiency", The Korean Journal of Defense Analysis, Volume VIII, No. 2, Winter 1996, pages 177 - 221.

energy-efficiency analysis using the same measures included in the 1995 study, but updated to take into account the year 2000 estimated energy consumption, is presented below. Note that the use of the 2000 energy balance as a starting point reduces both the costs and savings from the energy efficiency measures. This may in fact be an artificial reduction, as any economic improvement that also includes an improvement in the availability of electricity and other commercial fuels is likely to increase demand for energy, and thus would increase the savings potential of the measures described below.

4.1. Analytical Approach

The general approach used in preparing the analysis of energy efficiency opportunities can be described as follows:

- Use the estimated DPRK energy balance data as a guide to indicate key sectors and subsectors where fuel demand could be significantly reduced by energy efficiency measures.
- Use the energy balance results, together with data from the international energy literature and rough estimates of key parameters to estimate end-use shares for key technologies.
- Use cost and performance data on energy efficiency and renewable energy technologies data from international literature sources to estimate the potential achievable fuel savings available in key subsectors, and the investment costs required to achieve those savings[o]. In many of these cases, the cost and performance data are based on actual Chinese experience obtained during the 1980s.
- Evaluate and aggregate the potential impacts and costs of the energy efficiency and renewable energy technologies quantified, and suggest other key measures that are likely to be broadly applicable in the DPRK.
- Evaluate, briefly, the potential environmental and other impacts of implementing energy efficiency measures.

A full-fledged analysis of the achievable potential for energy efficiency measures requires a host of assumptions about the future. Population growth rates, economic growth rates, and underlying, ongoing structural changes such as changes in the housing stock, shifts in industrial output, and changing patterns of personal consumption (among many others) form the backdrop against which energy efficiency opportunities should be considered. For this analysis, however, the choice has been to let estimates of potential energy sector improvements stand for the achievable savings over the next decade. Reasons for this assumption, in addition to the paucity of reliable data include:

- The relatively static present state of the DPRK economy, suggesting that a complete and immediate turnaround less likely than a slow recovery and thus that a 10-year analysis based on a current year's data might not entirely unreasonable.
- Though complete implementation of a particular energy efficiency measure in a subsector is unlikely, the pathways for technology dissemination in North Korea—if there is committed support from national leaders and the financial and technical support from the international

[o] In many cases, this analysis has drawn upon the large body of work on energy efficiency programs in the People's Republic of China that has been published by the by the Energy Analysis Program of Lawrence Berkeley National Laboratory (LBNL or LBL) and their Chinese collaborators.

community—have the potential to allow the rapid implementation of energy efficiency measures.

- We believe that our assumptions as to the energy savings achievable from the technologies we address (quantitatively) are more likely to prove to be under- than over-estimated. This belief is informed by the large number of anecdotal reports of extremely high energy intensities in the DPRK, even when compared with early 1980s conditions in China.

4.2. Overall Results for Energy Efficiency Measures Evaluated

The following set of energy efficiency and renewable energy measures have been chosen for initial analysis:

Measures that Save Coal

- Industrial boiler improvements
- Residential (multi-family) and public/commercial military boiler improvements
- Domestic coal stove/heater improvements
- Residential (multi-family) and public/commercial/military building shell improvements
- Electric Utility boiler improvements

Measures that Save (or Generate) Electricity

- Industrial electric motor improvements
- Electric motor improvements in other sectors
- Residential Lighting improvements
- Non-residential Lighting improvements
- Reduction in "Own Use" at coal-fired Electric Utility plants
- Reduction in "Emergency Losses" at coal-fired Electric Utility plants
- Reduction in electricity transmission and distribution losses
- Wind powered electricity generation

A Measure to Save Petroleum Products

- Replacement of the existing fleet of 2 1/2 tonne trucks

The details of the process used in estimating the impacts and costs of these measures are provided in studies referenced previously in this paper[7].

Table 4-1 shows the overall results of our evaluation of these measures. It has been assumed that under an aggressive program with both strong leadership commitment inside the DPRK and technical and financial cooperation from other countries, these measures (or some of these measures and others with similar per-unit costs and impacts) could be implemented over the next 10 years[p]. In total (that is, in year 10 of an aggressive program), they annually save approximately 114 Petajoules (PJ, equal to 1000 terajoules or 1 million gigajoules) of coal (about 29 percent of estimated 2000 DPRK coal supply) at a cost of about $US 415 million (2000 dollars), plus over 14 PJ/yr (about 28 percent of 2000 generation) of electricity supply (electricity saved plus 500 MW of new wind-powered generation) at a cost of approximately $660 million. Replacement of the DPRK fleet of 2 1/2 tonne trucks, as it has been modeled, is unlikely to be cost effective in saving energy alone, but would save approximately 3.4 PJ of refined products (somewhat under 8 percent of total estimated national petroleum use in 2000 and 57 percent of road transport use at an investment cost of $710 million.

A key assumption made in estimating the costs and performance of most of the coal- or electricity-saving energy efficiency measures is that the costs and performance of these measures, when implemented in the DPRK, will be similar to the cost and performance of the measures as experienced in the People's Republic of China during energy efficiency programs carried out there in the 1980's. It could be argued that the costs of the measures in China might be lower than in the DPRK, due to lower labor rates and a larger manufacturing base in China. It could, however, equally be argued that the opportunities for savings with the measures we have evaluated are likely to be greater in the DPRK than they were in China, due to the older capital stock in the DPRK.

The environmental benefits of measures such as those described above would be substantial. The measures to save coal would avoid the emissions of approximately 56 thousand tonnes of sulfur oxides, 35 thousand tonnes of nitrogen oxides, and 8.7 million tonnes of carbon dioxide. Using the year 2000 ratio of thermal to hydroelectric generation, the electricity-saving measures described above (not including the wind power generation) would avoid emissions of another 5.5 thousand tonnes of sulfur oxides, 3.5 thousand tonnes of nitrogen oxides, and 0.9 million tonnes of carbon dioxide. These emissions reductions represent on the order of 20 percent of total national emissions in 2000.

Together, the energy savings and environmental benefits of these few energy efficiency measures, as evaluated, underscore the very important role that energy efficiency can, and indeed, must play in any DPRK energy sector development/redevelopment effort. By way of comparison, the electricity savings from the limited package of measures described above (excluding wind power systems) amounts to about the same amount of electricity that would be produced by a 400 to 500 MW thermal power plant at approximately the same capital cost, but with no fuel costs, arguably higher reliability, and no environmental impacts. Plus, each individual investment in energy efficiency measures is smaller, and thus arguably more manageable and sustainable, than investments for the larger elements that are avoided by energy-efficiency investments.

[p] Note that figures in Table 4-1 have been rounded for presentation, and are likely to be accurate to only one or two significant digits.

Table 4-1: Results of Energy-Efficiency Analyses for the DPRK

MEASURES TO SAVE COAL:

Measure	**Estimated Energy Energy Savings Potential, TJ/yr**		**Total Estimated Investment Cost, $US 2000**
Industrial Boiler and Furnace Improvements	41,000		$ 208,800,000
Residential and Public/Commercial/Military Boiler Impr.	26,000		$ 72,500,000
Building Envelope Improvements	17,000		$ 44,500,000
Domestic Stove/Heater Improvements	14,000		$ 13,100,000
Electric Utility Boiler Improvements	15,000		$ 76,400,000
TOTALS	113,000	TJ/yr	$ 415,400,000
Avoided Losses of Coal During Transport:	1,100	TJ/yr	
TOTAL COAL SUPPLY SAVINGS	114,000	TJ/yr	
Fraction of 1990 Total Coal Supply	29.4%		
Investment required, $ per GJ/yr of Coal Supply Savings			**$ 3.65**
Investment required, $ per tce/yr of Coal Supply Savings			**$ 107**

MEASURES TO SAVE/GENERATE ELECTRICITY:

Measure	**Estimated Energy Energy Savings Potential, TJ/yr**		**Total Estimated Investment Cost, $US 2000**
Industrial Motors and Drives	1,310		$ 67,300,000
Motors and Drives in other Sectors	290		$ 15,100,000
Residential Lighting	470		$ 24,300,000
Non-residential Lighting	1,770		$ 64,700,000
Own Use reduction in Power Plants	510		$ 31,600,000
Reduction of Emergency Use in Power Plants	740		$ 28,400,000
Transmission and Distribution Improvements	4,410		$ 169,600,000
TOTALS	9,510	TJ/yr	$ 401,000,000
Additional Avoided T&D Losses (based on 2000 Rates)	930	TJ/yr	
TOTAL ELECTRICITY SUPPLY SAVINGS/GENERATION	10,440	TJ/yr	
Fraction of 2000 Total Electricity Generation	20.7%		
Investment required, $ per GJ/yr of Electricity Supply Savings/Generation			**$ 38.41**
Investment required, $ per MWh/yr of Electricity Supply Savings/Generation			**$ 138**

MEASURE TO SAVE PETROLEUM PRODUCTS:

Measure	**Estimated Energy Energy Savings Potential, TJ/yr**		**Total Estimated Investment Cost, $US 2000**
Improvements in 2 1/2 tonne truck fleet	3,430		$ 709,800,000
Fraction of 2000 Total Refined Products Use	7.5%		
Fract. of 2000 Total Refined Prod. Use in Road Transport	56.8%		
Investment required, $ per GJ/yr of refined products Savings			**$ 207**
Investment required, $ per toe/yr of petroleum products Savings			**$ 8,655**

5. Future Energy Paths for the DPRK

No one can pretend to see into the future of any country with any kind of clarity, and the future of the DPRK in general seems as uncertain as any. Nonetheless, the formulation of effective approaches for cooperation on energy sector development in the DPRK requires the consideration of what could happen in the future, and indeed, in multiple futures. By considering multiple possible futures, the cooperation strategies formulated can be designed to be robust—that is, that the strategies will be effective under a wide range of possible future conditions. Nautilus has applied two complementary approaches to the consideration of different "futures" for the DPRK. The first tool is scenario analysis, a consideration of the major uncertainties and drivers of key relationships involving the DPRK are used to focus the development of different "stories" or "scenarios", which are then used to test different policy approaches[q]. The second tool starts with a consideration of current (estimated) energy sector conditions in the DPRK (or any other country) and evaluates the potential implications of different energy "paths"—quantitative estimates of future energy sector activities[r]. The paragraphs below provide a discussion of the results of a set of energy paths analysis carried out for the DPRK. As with other elements of this paper, this discussion is meant to inform the consideration of different cooperative strategies for assisting in DPRK energy sector development.

5.1. Overview of Paths Considered

The starting point for the DPRK energy paths analysis described below has been the 1995-97 DPRK energy sector analyses referenced earlier in this paper, and previous "Recovery" and "Decline" paths to 2005 carried out as a part of Nautilus' 1997 DPRK energy sector analysis. Although the paths analysis described below is a quantitative analysis , it represents a subjective, illustrative update of paths prepared previously. The update takes into account DPRK changes since 1996, and prospects for change in the near future, but is NOT based upon the quantitative analysis of recent DPRK data, that is, it does not take into account the year 2000 energy sector analysis summarized in Section 3 of this paper (because the paths analysis described here was carried out before the year 2000 energy balance update was complete).

Three primary paths were considered: "Recovery", "Continued Decline", and "Sustainable Development". Each of these paths is described briefly below.

"Recovery" Path

The premise of the Recovery path is that with a combination of some political and economic opening to other nations, coupled with increased and effective foreign aid, the DPRK economy starts to rebuild in approximately 2003. As a consequence:

- Industrial production increases, with an emphasis on lighter industries manufacturing goods for internal consumption and for export.
- There is increased demand for transport (goods and people).

---

[q] Nautilus Institute organized two scenario workshops, held during the first half of 2002, focusing on the DPRK and DPRK-related policies. The outcome of these workshops is described in Scenarios for the Future of US-North Korean Relations: Engagement, Containment, or Rollback? Scenario Workshop Report, Nautilus Institute, Berkeley, CA, April 30-May 1, 2002, prepared by Nautilus Institute, June 2002.

[r] Nautilus is working with colleagues from the countries of Northeast Asia (China, the DPRK, Japan, the Republic of Korea, and Russia—specifically the Russian Far East) to prepare energy paths for each country of the region, and to evaluate the costs, benefits, and implications of coordinated action on energy sector issues. This work is organized as the Nautilus East Asia Energy Futures project.

- An increase in household energy use takes place, as households are able to afford and acquire new appliances and other goods. This increase in household energy use includes a trend toward electricity, LPG, and kerosene use, and, generally, a trend away from the use of coal and biomass fuels in households.
- A considerable increase in commercial sector activity and energy use occurs, with a relatively small increase in military sector energy use.
- Refurbishment of electricity transmission and distribution systems, as well as hydroelectric plants, takes place, along with the commissioning of new (particularly smaller-scale) hydro plants. This path also includes the re-starting and expansion of the DPRK's east coast refinery, and partial retirement of existing coal-fired generation capacity.
- Modest improvements in energy efficiency take place, but energy efficiency is not a major focus of policy.

"Continued Decline" Path

The Continued Decline Path implicitly assumes that there is no significant DPRK economic or political opening to other countries, and that there is only modest rapprochement with the US, and the Republic of Korea (ROK). As a result, the DPRK economy doesn't really decline relative to 2000, but continues stagnating, as foreign aid and domestic policies keep the economy operating at a low level, and there is little (if any) growth in per-capita energy use. Energy supply and industrial infrastructure is maintained just enough to keep the economy operating at near-2000 levels, and as a results there is no significant increase in energy efficiency.

"Sustainable Development" Path

The Sustainable Development Path is based on, and provides the same energy services as, the Recovery Path, but also includes:

- Aggressive implementation of energy efficiency measures to reduce coal and electricity use per unit of energy service delivered (including, for example, those measures described in section 4 of this paper).
- A more rapid phase-out of existing coal-fired power plants.
- The addition of an LNG (liquefied natural gas) terminal and gas CC (combined cycle) generating plant in approximately 2011.
- The addition of an integrated-gasification combined-cycle (IGCC[s]) generating plant in 2015.
- Aggressive wind power development along with a focus on refurbishment of existing hydroelectric plants and development of new (including small local) hydroelectric facilities.

[s] An IGCC generating facility is a type of (typically) coal-fired power plant now being commercialized that combines high efficiency with low emissions of sulfur oxides and other pollutants.

All three paths assume that the nuclear power plants (approximately 2 gigawatts—thousand megawatts—of light water reactor capacity) being built under the auspices of the Korean Peninsula Energy Development Organization (KEDO) in the DPRK will:

- Be on line in 2007 (although 2010 may be more likely at this point[t]),
- Operate reliably, and
- Largely export power (to the ROK or China).

No assumptions made about national or regional nuclear waste disposition arrangements.

5.2. Energy Paths Results

Summaries of the energy supply and demand trends over time, and of the pollutant emissions trends, implied in each of the three DPRK energy paths are provided below.

"Recovery" Path

In the Recovery Path, overall fuels demand returns to approximately 90 percent of year 1990 demand by 2020. In addition:

- There are increasing shares of oil products and electricity used in the DPRK. The rapid growth of electricity use, especially in the residential and public/commercial sectors, can be seen in Figure 5-1.
- Primary fuel requirements rise nearly to 1990 levels by 2020, with coal lower than 1990 levels, but oil, hydroelectric energy, and nuclear energy (starting in 2007) higher than in 1990.
- Electricity output is about 50 percent higher by 2020 than it was in 1990 (see Figure 5-2), but much of this difference in output is exported.
- Emissions of greenhouse gases (measured in terms of global warming potential—GWP, or as CO_2), and NO_x (nitrogen oxides) emissions are about 15 percent lower in 2020 than in 1990, and SO_x (sulfur oxides) emissions are about 25 percent lower.

[t] Recent discussions with colleagues familiar with the KEDO LWR project suggest that the current target year for completion of the LWRs in the DPRK is 2008.

Figure 5-1:

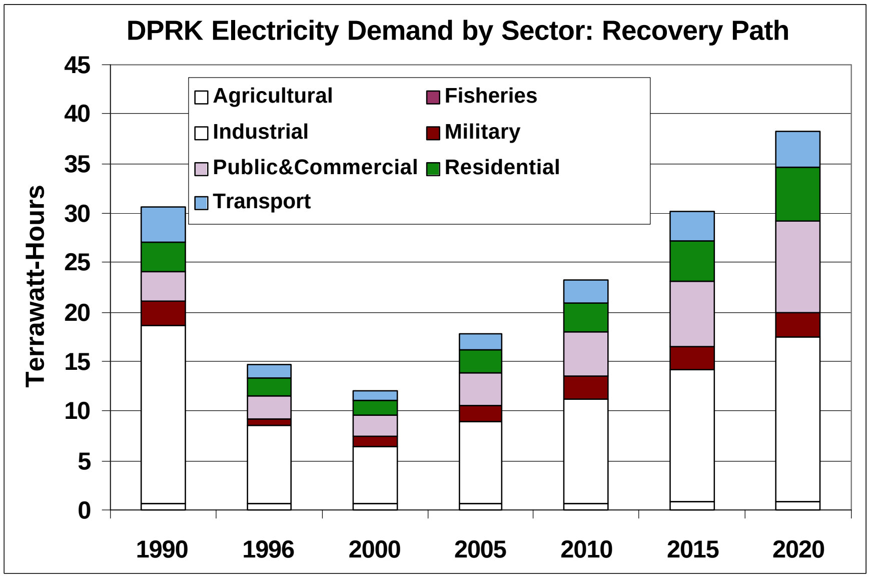
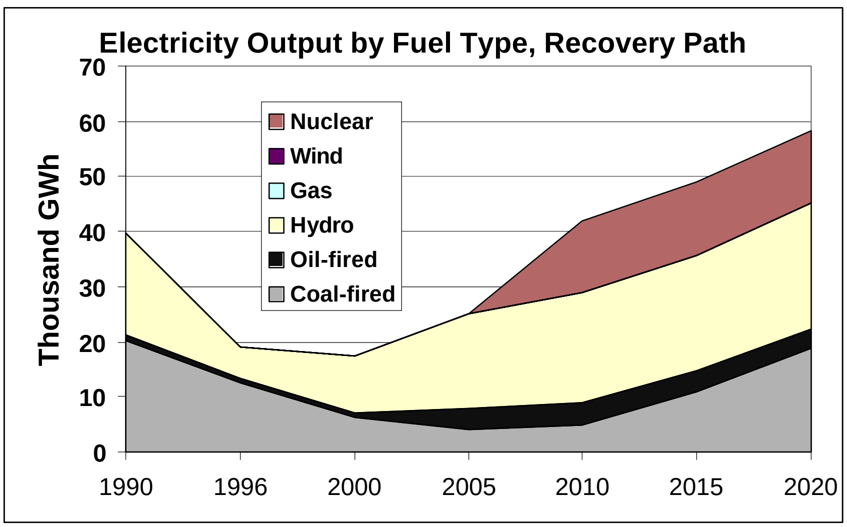


Figure 5-2:



"Decline" Path

In the "Decline" path, overall fuels demand rises gradually after 2000, reaching about 60 percent, of 1990 demand by 2020, but nearly half of the fuel used is in the form of wood, crop wastes, and other biomass. Electricity demand returns to only just greater than half of its 1990 level by 2020 (see Figure 5-3). Industrial energy demand remains low throughout the path. Other key results of the "decline" path include:

- The shares of high-quality fuels such as oil products (particularly), and electricity are lower by 2020 than they were in 1990.

- Primary fuel requirements rise slowly from 2000 levels to about 62 percent of 1990 levels by 2020, but of the "commercial" fuels, coal consumption reaches only 40 percent of its 1990 level by 2020, and oil and oil products use reach only 47 percent of 1990 levels by 2020.
- Even with the KEDO reactors running, electricity output in 2020 less than it was in 1990, as shown in Figure 5-4, and 35 percent of electricity output is exported.
- Air pollutant emissions, including GWP/CO_2, NO_x, and SO_x emissions, are 60 or more percent lower in 2020 than in 1990.

Figure 5-3:

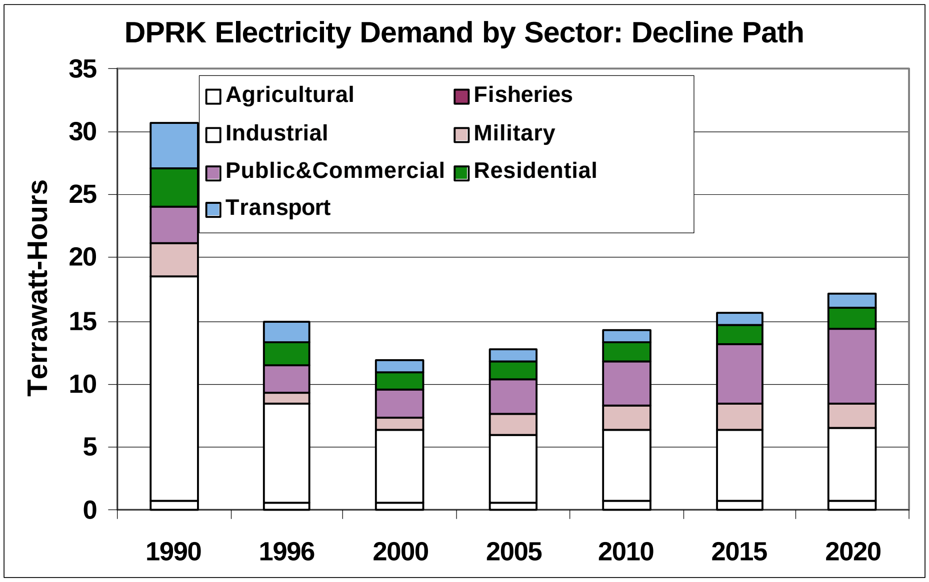
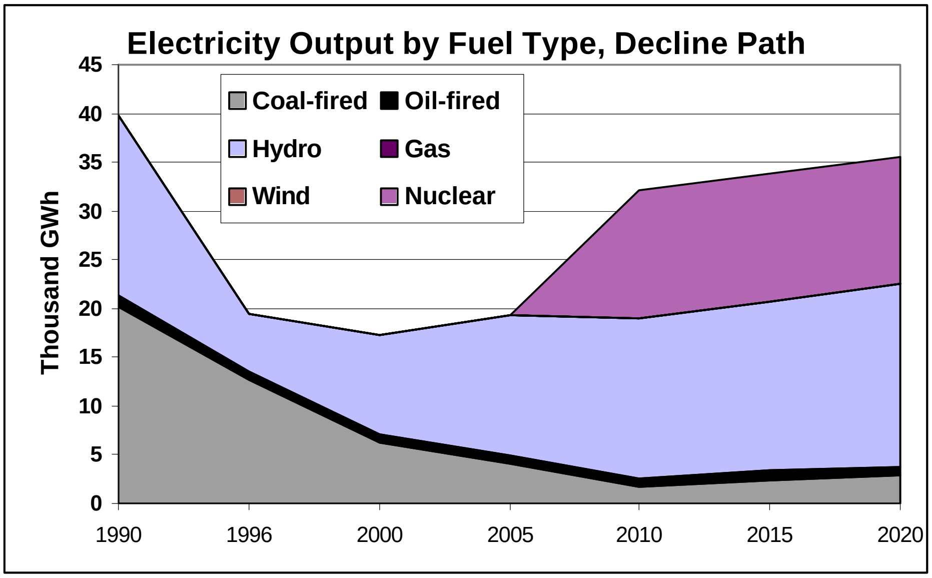


Figure 5-4:



"Sustainable Development" Path

In the Sustainable Development path, overall fuels demand rises gradually after 2000, but reaches only about 70 percent of "Recovery" path levels by 1990. Relative to the Recovery path, the Sustainable Development path includes substantial reductions in energy use in the industrial, residential, and public/commercial sectors, while providing the same goods and services. Figure 5-5 shows the electricity consumption in the Sustainable Development path relative to the Recovery path, with substantial reductions in electricity use in residential and public/commercial sectors, and especially in the industrial sector. The overall reduction in electricity use in 2020 relative to the Recovery scenario is more than 25 percent. Other key results from analysis of the Sustainable Development path include:

- The shares of oil products and of electricity in final energy demand rise significantly toward the end of the analysis period, reflecting a preference for cleaner and more convenient end-use fuels.
- Primary fuel requirements are 65 percent of "Recovery" levels by 2020, and 60 percent of 1990 levels, but this reduction is distributed unevenly across fuel types, with coal demand in 2020 being 42 percent of its level in 1990, and 2020 oil demand 134 percent of 1990 levels.
- Electricity output higher in 2020 than in 1990 (see Figure 5-6), but output for domestic use remains lower than 1990 (as the bulk of the energy from the KEDO LWRs is exported).
- The overall emissions of greenhouse gases (measured either as GWP or CO_2) are approximately half of 1990 levels, and only 60 percent of the levels in the "Recovery" path, by 2020.

Figure 5-5:

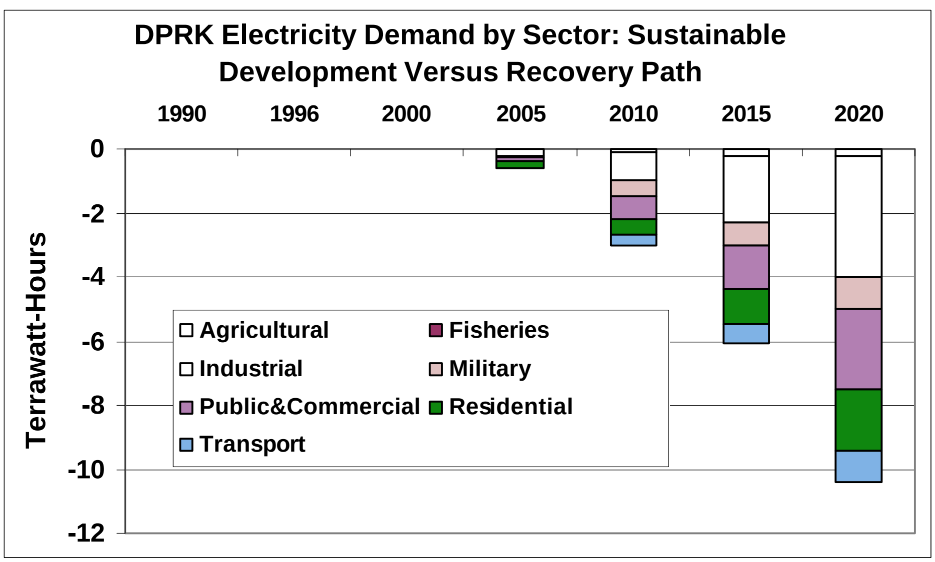
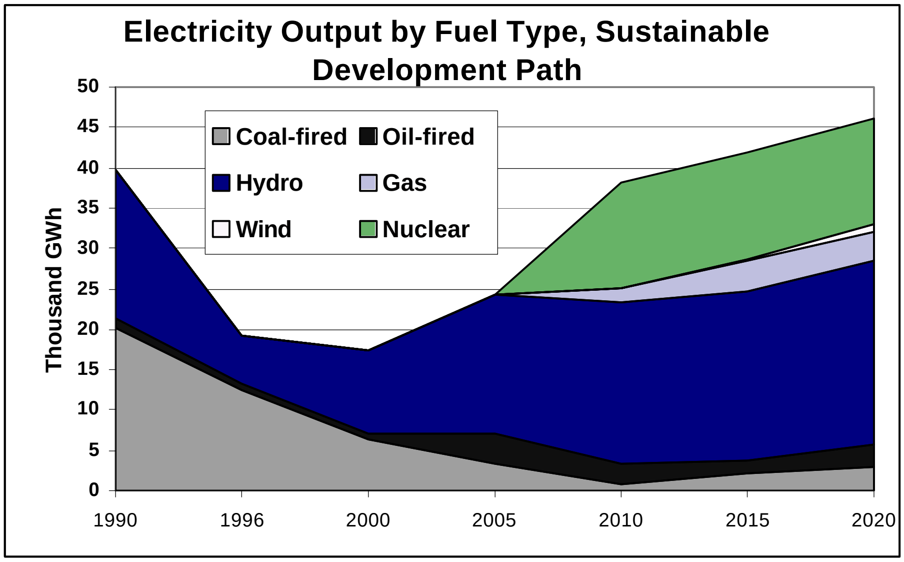


Figure 5-6:



5.3. Comparison of Path Results

Figure 5-7 summarizes the difference in electricity demand between the three paths described above. The key features to note is the substantial difference, by 2020, in electricity demand between the Recovery and Sustainable Development paths, underlining the importance of energy efficiency measures for the DPRK economy. In addition, the relatively modest difference, even in the Recovery path, between year 2020 demand and year 1990 demand suggests that significant net additions of generating capacity will not be needed even in the most optimistic of outlooks. Considerable expenses (perhaps bordering on the level of the expenses for outright replacement), however, would be needed to refurbish power sector infrastructure in the DPRK to allow it to meet Recovery path-level demand by 2020.

Figure 5-8 looks at the difference between the three paths in terms of emissions of greenhouse gases. Here the most striking result is that the Sustainable Development path, which produces the same goods and services as in the Recovery path, does so with greenhouse gas emissions that are on the order of 40 percent less than in the Recovery path, and only slightly above the level of the Decline path, by 2020.

Overall, a comparison of the paths described above, rough as they are, clearly shows the benefits of policy approaches—on the part of the DPRK government and the international community—that promote an approach to DPRK economic "recovery" that emphasizes improving energy efficiency and renewable energy as the economy retools. An emphasis on energy efficiency and renewable energy would seem to be very much in keeping with both ongoing (self-reliance) and more recent (more market-oriented) economic philosophies expressed by DPRK officials.

Figure 5-7:

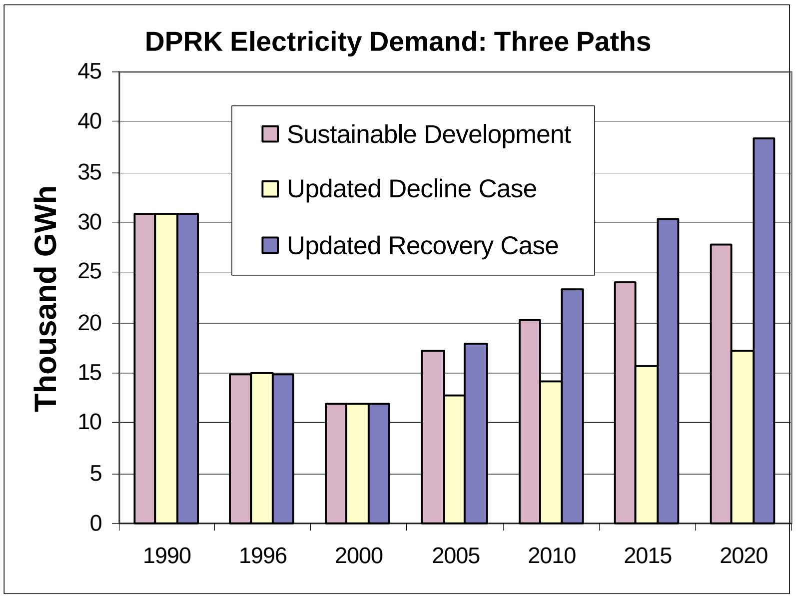
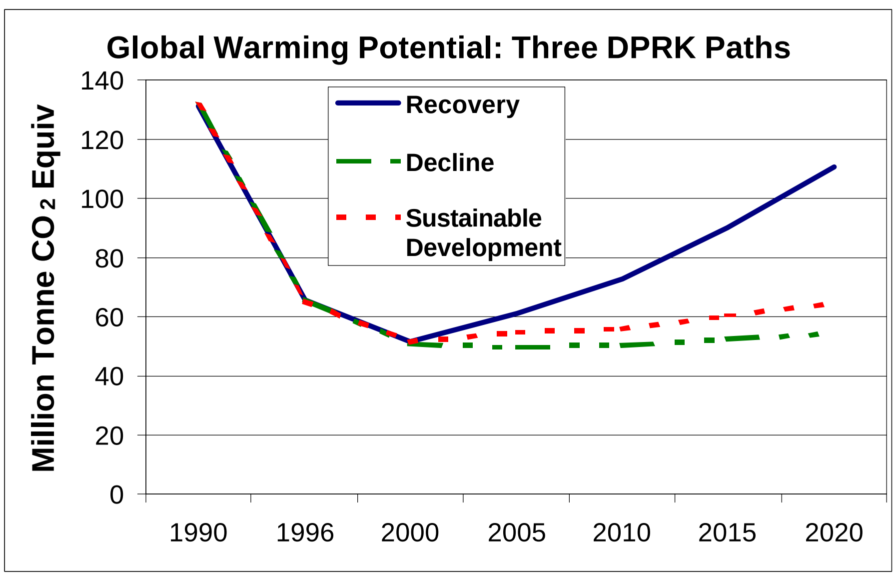


Figure 5-8:



5.4. Next Steps and Possible Path Variants

The next steps in the analysis of energy sector paths for the DPRK include:

- A reconsideration of existing paths based on the year 2000 energy balance analysis described in Section 3 of this paper, as well as thoughts about the future that take into account recent events in the DPRK and Northeast Asia. The existing paths should also be reconsidered taking into account the scenarios developed during the recent Nautilus Institute workshops on the "Future of U.S.-Korean Relations"[8].

- Add the element of costs—including costs of demand devices, supply infrastructure, energy resources, and fuels imports—to the analysis to more concretely show the cost implications of different paths.
- Refine the estimates of environmental emissions from the different paths, including adding estimates of particulate and indoor air pollutants.
- Debug the data set, and iterate the analysis as necessary.

In pursuing further work on DPRK energy paths, Nautilus Institute would like to have the opportunity to work with other colleagues, and in particular, with colleagues from the DPRK, in order to provide additional information and fresh perspectives to the paths analysis[u].

6. Future Prospects and Suggestions for DPRK Energy Sector

6.1. Introduction

Despite a few outward signs of economic recovery in recent years—including more activity in the capital and a population that looks, in general, better nourished—it is clear, if the estimates of energy sector activity presented in Section 3 of this paper are close to correct, that the DPRK energy sector is a long way from good health. What does the near- and medium-term future hold for the DPRK, and what can be done by the international community to assist the DPRK in energy sector development? This final section of this paper examines these questions, and provides some ideas for initiatives that could assist the DPRK in building a sustainable energy sector.

6.2. The DPRK Under a Medium-Term "Recovery" (or "Rebuilding") Pathway

It is taken as a given that the peaceful engagement of the people and economy of the DPRK with the people and economies of neighboring nations, and of the world as a whole, is a key goal of international assistance to the DPRK. What kind of pathway from the present to the medium-term future would make the DPRK receptive to and able to use such assistance? Below we describe, in a very qualitative way, what a medium-term "Recovery" or "Rebuilding" path might look like for the DPRK economy and, by extension, for the DPRK energy sector. This qualitative sketch augments the initial estimates of the quantitative attributes of such a path—what the path might mean in terms of future terajoules, tonnes of coal, and megawatts—that are provided above.

First and foremost, the Recovery/Rebuilding pathway implicitly assumes a major breakthrough in relations with the ROK (and probably the United States as well), resulting in some investment in the industrial and energy infrastructure in the DPRK from outside the country, and much increased foreign development aid. (Initial steps along such a pathway seem, in fact, to have been made by the DPRK government over the last few months.) The Recovery/Rebuilding path also assumes, however, that the DPRK government essentially

[u] Nautilus hopes to continue working with DPRK colleagues, as well as other colleagues from the Northeast Asia region, in its East Asia Energy Futures project, in which teams from each country have adopted the same energy paths methodologies shown here, share results and data, and work together to evaluate both national and regional approaches to energy sector issues in Northeast Asia.

maintains its integrity. If the current DPRK government loses power, rapid reunification of North and South Korea may result, which probably means very large, very fast changes for the DPRK energy sector, providing that the unified Korea can obtain internal and external financing for infrastructure reconstruction in the North.

A **Recovery/Rebuilding** pathway for the DPRK would likely, as noted above, be built upon the following assumptions:

- With some political and economic opening, coupled with increased foreign aid, the DPRK economy starts to rebuild (for example, in 2003).
- Industrial production increases, particularly in the lighter industries; and there is increased demand for transport.
- There is an increase in household energy use, with trends toward using more electricity, LPG, and kerosene in homes.
- There is a considerable increase in commercial sector activity, and a relatively small increase in military sector energy use.
- Refurbishment of electric transmission and distribution infrastructure takes place, coupled with refurbishment of existing hydro plants, building of new hydro capacity, the re-starting and expansion of the DPRK's east coast refinery, and partial retirement of coal-fired electricity generating capacity.
- Modest improvements in energy efficiency take place as older equipment is refurbished.

This pathway, or one very much like it, may in fact be one of the only ways that DPRK infrastructure can recover enough to use even some of the power from the nuclear reactors being built by KEDO within the DPRK. There is at present no way to use the reactors, when they are complete, within the existing DPRK grid[v], so interties to other countries must be constructed, and preferably, from a political and practical perspective, the DPRK grid must be totally rebuilt as well. The disposition of the KEDO reactors is therefore both a huge problem that could lead to poor relations between the DPRK and the outside for years to come, or, if handled correctly, a huge opportunity for building of economic links (and better relations) between the countries of the region.

The last several sections of this paper focus on the types of reforms, and options for international assistance, that would likely be needed to make the Recovery/Rebuilding path, or a path with similar attributes, a reality for the DPRK.

---

[v] Nuclear safety concerns (back-up power for coolant pumps and controls) and the attributes of a large-capacity nuclear unit operating in a small power grid (the DPRK grid is far below the minimum size to support the KEDO reactors) are key reasons why these reactors cannot operate under current conditions. See D. Von Hippel et al (2001), "Modernizing the US-DPRK Agreed Framework: The Energy Imperative" as referenced earlier in this report.

6.3. Internal Policy and Legal Reforms to Stimulate and Sustain Energy Sector Rebuilding in the DPRK

There are a number of areas in which DPRK policies must be revised if the DPRK energy sector is to be rebuilt within a more open economy. The ROK and other nations could assist in the process of learning and phasing in the types of reforms that will be necessary. Some of the areas in which policy reform is called for are described briefly below.

6.3.1. Reform of energy pricing practices and the physical infrastructure to implement them

Hand in hand with rebuilding of energy supply infrastructure should go the rebuilding of end-use equipment, but accomplishing the former in a cost-effective manner is in large part dependent on making sure that new end-use equipment is purchased and operated with an eye toward efficiency. The economic levers of prices, in a market economy, are important tools for helping to make sure that energy is used wisely.

Before adopting market style pricing of energy commodities, ***the modification of existing incentives facing plant managers and relevant officials*** to encourage more efficient use of energy. Although inappropriate to a market economy, a well-designed program of administrative measures would effectively utilize the strengths of North Korea's current form of government, and would be a first step toward a more efficient energy economy.

Reforming energy pricing is a longer-term goal. Before market forces of any kind can help to spur the implementation of energy efficiency measures (or choices of efficient, rather than the cheapest, equipment on the supply side), the prices for energy products in the DPRK must be adjusted towards their actual costs of production. Pricing of some energy products, particularly electricity, will require the implementation of metering and billing systems. To be effective, parallel reforms that sensitize local decision-makers to prices (that is, that allow them to benefit from cost savings) must be implemented.

One way to modify existing disincentives for energy efficiency is to ***promote changes in physical infrastructure that will facilitate energy decision-making.*** In previous reports (and in brief below), we have discussed some of the types of energy-using equipment and other infrastructure in the DPRK that could be targeted for replacement or rehabilitation. What has been emphasized relatively less, but is at least as important, is the need to invest in equipment that allows flows of energy to be controlled and quantified adequately. Such equipment includes electricity, heat, and hot water meters; steam and process control valves and shunts; and dimmers and other equipment for controlling lighting. Without such equipment—which typically is inexpensive and relatively easy to install and operate—any attempt to institute price signals in energy markets, or even to reward reduced energy use in other ways, will be futile, as end-users will lack the ability to control energy flows, the quantitative feedback that tells them whether efforts to reduce energy use have succeeded, or—worst of all—both.

6.3.2. Training for energy sector actors

Recovery of the DPRK economy, and modification of the DPRK's energy and industrial infrastructure, will require that a wide spectrum of energy sector actors—from analysts in planning institutions to building maintenance personnel—receive training on topics varying from long-range energy planning (as noted above) to operation and maintenance of commercial boilers. Here, regional cooperation will be helpful in making experienced personnel available to train their counterparts in the DPRK.

In particular, given stated interest on the part of the DPRK government in energy efficiency and renewable energy and the potential small unit size of assistance efforts in these areas, it will be possible to start energy cooperation with the DPRK–it will be necessary to ***provide specific information and training to local actors.*** Training of a very specific and practical nature must be provided to personnel at the local level. Examples here are factory energy plant managers, boiler operators in residential and commercial buildings, power plant and heating system operators, and new job classifications such as energy-efficiency equipment installers and energy auditors. The departure of Soviet/Russian assistance left a vacuum of technical expertise that, according to some observers, very much persists to this day. The sort of training described above is therefore both badly needed and a necessary complement (or, more probably, precondition) for any other type of technical assistance to the DPRK energy sector.

6.3.3. Strengthening regulatory agencies and educational/research institutions in the DPRK

There is a definite need to strengthen a variety of the DPRK's government institutions through a combination of provision of information, persuasion of leaders, training of personnel, and supplying institutions with needed equipment. Many of these tasks have been started (or at least attempted) by initiatives of the United Nations Development Programme (UNDP) and other ongoing programs.

One general area in which DPRK institutions could be strengthened is in their ability to ***implement standards, and enforce them.*** DPRK officials have made general statements about their support for energy efficiency and environmental protection. The next step is to codify these in terms of quantitative standards for the efficiency of new appliances and equipment, as well as effluent standards for new—and perhaps eventually, existing—factories, power plants, residential heating boilers, vehicles and other major sources of pollution. Once standards are set, it will be necessary to create the capability to enforce them by recruiting and training enforcement personnel and supplying them with the tools necessary to do their job (testing equipment and adequately equipped labs, for example) and the high-level administrative support needed for credible implementation of sanctions.

Standards for specific energy consumption (for example, the amount of energy needed to produce a unit of physical output) have long been used in China to gauge performance of and within industrial and other enterprises. Issued nationally, and often tailored to conditions specific to individual enterprises, these standards have been used to measure progress in improving efficiency, and have formed the basis of a system of financial and other awards. It is, in effect, a system of performance evaluation that parallels that based on output levels and product quality. This system is losing its effectiveness as China's transition to a market-oriented economy progresses and the central planning apparatus weakens, but it may still be quite appropriate for the DPRK at this time.

There is not as yet in the DPRK, a single ***center of technical excellence*** that is devoted to the study and promotion of *energy efficiency and renewable energy* opportunities. We would encourage the formation of such an institution, which could be modeled on existing institutions like the Beijing Energy Conservation Center and a similar Center in Russia. The Center in China was established jointly with the Battelle Pacific Northwest Laboratory and the Lawrence

Berkeley National Laboratory (both U.S. government-sponsored organizations with extensive experience in energy demand issues), and the Center in Russia was founded with Battelle[9]. It is possible that the Center for the Rational Use of Energy (CRUE), formed during the early 1990s within the existing DPRK Institute of Thermal Engineering under a UNDP project, could be strengthened through a combination of North Korean and extramural support into such a center of excellence. The first step will be to start training current CRUE staff in the fundamentals of energy-efficient technologies and analysis.

6.3.4. Involving the private sector in investments and technology transfer

Much of the money and other assistance necessary to help the DPRK toward recovery will have to come from the more flexible and fast-moving private sector. If substantial private-sector financing for DPRK projects is to be forthcoming, it is likely that inducements and guarantees—possibly supplied by other governments of the region—will be necessary in order to mediate, at least initially, the risk of dealing with the DPRK.

One way that the governments of the region, including the DPRK government, and governments of other countries with an interest in what happens in Korea (including the United States) can help in this regard is to *promote joint ventures and licensing agreements*. The government of the DPRK, and other interested parties, should promote joint ventures and licensing agreements between DPRK concerns (governmental or otherwise) and foreign firms with energy-efficient technologies to produce. Compact fluorescent light bulb factories are a commonly cited example of potential energy technology transfers[10]. A wide variety of efficient industrial equipment and controls (including adjustable speed drive motors and improved industrial and utility boilers), efficient household appliances and components, and efficient building technologies have already been introduced to China through commercial channels are being or will be manufactured there.

Wind turbine-generators are another intriguing possibility, given the apparent success of such ventures in former East-bloc nations[11] and the North Koreans' historical emphasis on machinery manufacture. Foreign firms that have successfully transferred efficient and renewable technologies to China, Russia, and Eastern European nations represent a valuable repository of experience that could be applied to similar efforts in North Korea. Depending on how fast the Tumen River Economic Development Zone develops (infrastructure in the area is not yet adequate to support major industry), this area could be the location most acceptable to the DPRK for the first such ventures. It is likely that the first few foreign companies to participate in joint ventures in the DPRK will require guarantees not only from the DPRK government, but also from their own government or another industrialized-nation or a multilateral donor.

Before any of these types of ventures can be initiated, however the DPRK will have to implement, and show the international community that it is adequately enforcing, laws to protect the intellectual property and investments of foreign companies doing business in the DPRK. A description of all of the areas in which such laws are required, and the reasons why they are needed, is, however, well beyond the scope of this paper.

6.4. Potential for International Cooperation to Assist in the Redevelopment of the DPRK Energy Sector

Key economic resources for the DPRK include a large, well-trained, disciplined, and eager work force, an effective system for dissemination of technologies, the ability to rapidly mount massive public works projects by mobilizing military and other labor, and extensive reserves of minerals. What the DPRK lacks are modern tools and manufacturing methods, fuel, arable land (though the land it does have might be just sufficient to feed its population with some improvements in agricultural methods), 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 the process of North Korean rapprochement, and help to position the countries and firms as major suppliers for the DPRK rebuilding process.

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

Below, we identify priority areas where we see DPRK energy sector assistance as both necessary and in the best interests of all parties. 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 our peoples. Actions speak louder than words or missiles in negotiating with the DPRK.

6.4.1. 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***. Since these items will probably, at least initially, be imported, this will entail a loosening of restrictions on imports. China, already one of North Korea's largest trading partners, would be a good source of efficient technologies and equipment that may be more easily absorbed (and more affordable) than those available from already developed countries. China has been a major energy supplier to North Korea in the past, and may have an interest not only in marketing equipment, but also in reducing North Korea's dependence on energy imports. European firms and governments may also be able to provide assistance in this area.
- ***Pursue sector-based implementation of energy efficiency measures.*** One point made forcefully by studies of East European economies “in transition” is the need to pursue energy efficiency opportunities on a sector-by-sector basis, as opposed to through an overarching "Least Cost Planning"-style of analysis as has been practiced for electric and gas utility

service areas[w]. It is people at the sectoral level who must work with energy-using equipment daily to do their jobs, rather than planners in a central ministry, who are most likely to be interested in energy-efficiency opportunities.

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

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

6.4.2. 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—to the extent allowed and desired by the North and South—in the types of research and training activities mentioned above. This suggestion follows partly from the proximity of the two countries, and from the considerable economic support and technical know-how that the South can offer the North. In addition, we believe that the more contact officials from the two countries have, and the more they know about each other, the more rapidly the process of reconciliation is likely to go.

6.4.3. Work to open opportunities for IPP companies to work in the DPRK

As noted above, the scale and complexity of the energy sector problems in the DPRK mean that the most reasonable way to address those problems is on a local and regional level.

---

[w] Schipper and Martinot (Schipper, L. and E. Martinot (1993), Energy Efficiency in Former Soviet Republics: Opportunities for East and West, International Energy Studies, Energy Analysis Program, Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, California, USA; report # LBL-33929, prepared for U.S. Department of Energy) point out two disadvantages of least-cost planning in the context of the former Soviet Union that are probably equally relevant to North Korea. First, stable energy markets and prices (which are inputs to Least Cost Planning) do not exist as they do (for the most part) in the West, and data on energy end-uses, as noted above, as well as cost data for domestic and imported equipment, are problematic. Second, Least-cost planning is sufficiently similar to the system of planning formerly in use in the USSR (and still used in the DPRK) that it would provide a comfortable and familiar retreat for central planners, and thus could be considered a step away from, rather than towards, economic reform

Though the ROK (and U.S. or European, for example) governments might reasonably provide technical assistance and limited direct humanitarian aid, as well as support for international efforts, it is probably unreasonable to expect other countries to directly underwrite the renovation of DPRK infrastructure on even a county scale. What the other governments can do, however, is pave the way for companies such as Independent Power Producers (IPPs) to operate in the DPRK. In this liaison role, the governments could provide assistance to firms in identifying, negotiating with, and working with DPRK counterparts, underwrite performance guarantees, and provide low-interest financing. The governments can also help by providing North Korean counterparts with training in the economics of project evaluation and in international contract law, both of which are at present largely alien concepts in the DPRK. The goal would be to assist IPP firms in working with DPRK authorities to set up with local and regional infrastructure (for example, power plants of less than 50 MWe) using small hydro installations, wind farms, or mid-sized coal-fired plants. In most cases, infrastructure projects would need to be coupled with the initiation or re-establishment of local revenue-generating activities so that IPP services can be compensated.

6.4.4. Cooperation on technology transfer for energy efficiency, renewable energy

A number of suggestions for beginning to work with the DPRK on confidence-building measures in the realm of energy efficiency and renewable energy are listed in our 1995 report on the topic[12]. Briefly, these include:

- Provide information and general training in energy efficiency to high-level government officials;
- Provide specific information and training to local actors (such as power plant managers, industrial energy plant overseers, and building boiler operators;
- Encourage and support implementation and enforcement of energy efficiency standards;
- Assist in establishing a program of grants and concessional loans for energy efficiency investments to industrial organizations and others;
- Encourage the modification of existing incentives that thwart energy efficiency improvements
- Assist in and encourage the reform (or establishment) of energy pricing;
- Promote and support joint ventures and licensing agreements between the DPRK and foreign firms, possibly as part of development of the Rajin-Sonbong or other Free Trade Zones;
- Initiate a program of exchange focused around methods of and training in energy planning, including consideration of the environmental impacts of energy choices.

Many of these technology transfer options, of course, overlap with the areas where assistance is needed that have been identified earlier in this paper.

6.5. Key/Attractive Energy Sector Technologies and Processes for Energy Sector Redevelopment in the DPRK

In the following paragraphs we focus on specific energy sector technologies and processes where infrastructure redevelopment is needed in the DPRK. In many cases, the assistance approaches outlined above are applicable to many of these energy sector needs.

6.5.1. Rebuilding of the T&D system

The need for refurbishment and/or rebuilding of the DPRK T&D system has been touched upon briefly 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. Ultimately, it will be necessary to engage the World Bank as a leader in DPRK power sector refurbishment, likely with funding from the Japanese government. In the short-to-medium term, local solutions could be focused on projects that would help the DPRK earn foreign exchange in acceptable manner, such as repairing T&D infrastructure and local power plants in particular areas so that facilities such as key mines can operate.

6.5.2. Rehabilitation of power plants and other coal-using infrastructure

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

An initial focus, in the area of boiler technology, should be on improvements in small, medium, and district heating boilers for humanitarian end-uses such as residential heating and provision of heat and hot water for hospitals, schools, and orphanages. If possible, it would be optimal to provide such upgrades in areas of the country away from Pyongyang, those hardest hit by the DPRK's economic malaise.

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

Another early focus should be on rehabilitation of boilers in key industries that could help the DPRK to "bootstrap" the civilian economy. As a specific example, the DPRK has one of the world's largest deposits of the mineral magnesite, which is used in making refractory (furnace-lining) materials. Helping to rebuild the boilers or kilns that are used to produce magnesia, the oxide of magnesite, along with the fuel and ore-supply chains that feed them, would bring much-needed foreign exchange into the country. We suspect that with international and ROK government participation and guidance, a private sector partner from the ROK or elsewhere could be found to assist with this type of rehabilitation, and to share in the profits of a joint-venture firm.

In the short run, it may also be useful for the international community States to provide the DPRK with coal for selected power plants (to the extent that they are operable) in areas now poorly served by the existing coal and electricity supply systems. Providing such supplies, perhaps in an agreed-upon exchange for reduced HFO deliveries, would help restore humanitarian services and assist in economic revival while other energy sector upgrades are underway, and could reduce U.S. and KEDO exposure to high HFO prices.

6.5.3. Rehabilitation of coal supply and coal transport systems

Strengthening of the coal supply and transport systems must go hand in hand with boiler rehabilitation if the amount of useful energy available in the DPRK is to increase. Foreign coal industries—in the United States and Australia, for instance, as well as China, Russia, and some European nations—have significant expertise to assist with evaluating and upgrading coal mines in the DPRK, including improvements in mining technologies, evaluation of coal resources, mine ventilation systems, and (we guarantee) mine safety. Coal processing to remove ash and improve fuel value could be another focus of assistance.

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

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

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

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

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

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

- Residential lighting improvements: Three or four times as many households can be supplied with much higher quality light with the same amount of electricity if DPRK incandescent bulbs are replaced with compact fluorescent light bulbs (CFLs). Ultimately, joint venture manufacturing (or at least assembly) of CFLs in the DPRK could be undertaken, but until then provision of CFLs of robust quality should accompany any local power supply, renewable power, or T&D improvement initiative. We have found this measure to be invaluable for securing grassroots support, as it provides a direct and tangible improvement in the lives of ordinary Koreans.
- Industrial and irrigation motors: The opportunities for efficiency improvement in large electric motors and motor drive systems are estimated to be considerable. Imports of efficient motors, pumps, air compressors, and other motor-related equipment may be the first step (once power quality has been improved sufficiently), followed by assistance in setting up facilities to manufacture or assemble equipment in the DPRK. Improving the reliability and efficiency of irrigation pumps will help the DPRK move toward feeding its populace.
- Humanitarian measures: Even the best orphanages, hospitals, and schools in the DPRK are cold and bleak today. Providing on-site power, preferably with renewable energy systems, water purification equipment, and efficient lighting and other end-use devices are necessary and highly visible first steps toward meeting humanitarian needs in the DPRK.

6.5.5. Rehabilitation of rural infrastructure

The goal of a rural energy rehabilitation program would be to provide the modern energy inputs necessary to allow North Korean agriculture to recover a sustainable production level and the basic needs of the rural population to be met. The priority areas would be those for which energy shortfalls most seriously affect agricultural production, human health, and fundamental quality of life. These areas include maintenance of soil fertility, farm mechanization, irrigation and drainage, and lighting, heating, cooking, and refrigeration for households and essential public institutions such as clinics and schools.

A comprehensive rehabilitation program for rural areas would feature a combination of short to medium-term energy supplies from imports and medium to long-term capital construction and rehabilitation projects. Components of an import program would include fertilizer, tractor fuel, and electricity at levels sufficient to enable agricultural recovery in the shortest attainable time. The capital construction program would include projects necessary to achieve the sustainable rehabilitation of the North Korean rural energy sector in the medium term (approximately 5 years). It is possible to outline some of the main elements of such a program: rehabilitation of the rural electricity transmission and distribution grid, development of reliable local power generation, improving the energy efficiency of the irrigation and drainage system, modernizing fertilizer and tractor factories, and improving the transportation of agricultural inputs and products. Many of these projects have already been proposed in the context of UN-sponsored agricultural reconstruction studies.

6.5.6. Electricity grid interconnections

Although hardly either a quick fix or a short-term project, it is imperative and attractive, from the perspectives of virtually all countries in the region, to move ahead with the consideration of electricity grid interconnections involving the ROK, the DPRK, Russia, and possibly China as well. 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).

6.5.7. Gas supply/demand infrastructure

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

6.6. Summary Implementation Policies and Activities for Consideration by the European Union and Other Potential Sources of Assistance

Drawing upon the discussions above, we present the following non-exhaustive list of potential policies and activities that the European Union or other parties might consider in planning energy-sector assistance possibilities to work on with the DPRK.

- Set up or agree upon a **coordinating agency or coalition** to make sure that the various parties providing assistance to the DPRK energy sector work together and in a complementary fashion. This type of coordination is needed to assure efficient, effective assistance.
- Provide **expert missions/seminars/study tours** on basic and applied energy pricing and collections and provide assistance with selection and implementation of metering technologies for electricity and other fuels.
- Work with the DPRK government to establish **consistent ground rules for business transactions/investments.**
- Consider **low-interest loans and/or financial guarantees** to investors/projects that meet specific requirements (as to application, financing, or other appropriate criteria).
- Set up a **Renewable Energy/Energy Efficiency Technology Center** to serve as a focus for training, demonstration projects, and contact with outside experts in these fields, as well as to serve as a repository of technical materials and know-how.
- Co-finance **light-industrial initiatives** in energy sector (including, for example wind power hardware, small hydroelectric equipment, and CFL manufacture) in partnership with the private sector. Ideally, an export component (providing the opportunity for the DPRK to export goods to earn foreign exchange, as well as to repay investors) should be built into such initiatives.

- Assist the DPRK government in **identifying and evaluating options for infrastructure redevelopment**, with a focus on transferring analytical and technical capabilities

6.7. Conclusion

In this paper we have provided our best estimate of DPRK energy supply and demand in the year 2000, and several illustrative (but quantitative) "energy paths" for the DPRK economy through 2020. Despite what some observers report as a turn-around in the DPRK economy, our estimates are that the DPRK's energy infrastructure continues to erode, and on a nationwide basis, supplies of commercial fuels, and probably wood and biomass as well, are extremely tight. In addition, key infrastructure, especially in the power sector, continues to erode, with only modest improvements in isolated cases running counter to the trend. We have also provided a rough, incomplete estimate that nonetheless shows that an extremely substantial potential for and benefit from applying energy efficiency measures in the DPRK. These benefits are underlined by the comparison between two future (to 2020) energy sector "paths" for the DPRK; the "sustainable development" path produces the same goods and services as the "recovery" path, but does so while using much less fuel and producing much lower emissions. We have suggested a number of initiatives and cooperative activities that we believe, assuming the right approach and open, consistent dealings on the part of all of the nations and agencies involved, could provide a means of confidence-building while providing tangible benefits at the local level to DPRK citizens.

7. Endnotes

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

[2] Korea Trade-Investment Promotion Agency (KOTRA) data (from http://www.kotra.or.kr/main/info/nk/eng/main.php3, visited 6/3/02) in "South/North Korea's Trend of Real (GDP) Growth Rate", which lists the Bank of Korea as a Source. Similar growth in the North Korean "GNI" was also cited in data provided to Nautilus by the Korea Energy Economics Institute.

[3] 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.

[4] 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.

[5] Joongang Ilbo, Lee Young-jong, "North Korea Overseas Trade Reaps $1.97 Billion For Last Year," Seoul, 06/04/01, summarized in NAPSNet Daily Report, http://www.nautilus.org/napsnet/dr/0106/jun05.html. The figures come from the ROK's Korea Trade Investment Promotion Agency (KOTRA).

[6] P. Hayes, *Cooperation on Environmental Issues with the DPRK* (Berkeley, California, USA: Nautilus Institute, October 29, 1993).

[7] Von Hippel, D. F., and P. Hayes (1995), The Prospects For Energy Efficiency Improvements in the Democratic People's Republic of Korea: Evaluating and Exploring the Options. Nautilus Institute for Security and Sustainable Development, Berkeley, CA, USA. December, 1995. P. Hayes and D.F. Von Hippel (1997), "Engaging North Korea on Energy Efficiency". Chapter 9 in Peace and Security in Northeast Asia: The Nuclear Issue and the Korean Peninsula, Young Whan Kihl and Peter Hayes, editors. M.E. Sharpe, Armonk, NY. Von Hippel, D.F., and P. Hayes (1996) "Engaging North Korea on Energy Efficiency". The Korean Journal of Defense Analysis, Volume VIII, No. 2, Winter 1996. Pages 177 - 221.

[8] Nautilus Institute (2002), Scenarios for the Future of U.S.-North Korean Relations: Engagement, Containment, or Rollback?. http://www.nautilus.org/security/Korea/DPRKScenarios.html, August, 2002.

[9] Chandler, W. U., Z. Dadi and J. Hamburger (1993), U.S .- China Cooperation for Global Environmental Protection. Pacific Northwest Laboratory, Richmond, Washington, USA.   Chandler, W. U. (1993), AISU's China Program Update June 1993. Battelle, Pacific Northwest Laboratory, Richmond, Washington, USA.

[10] Sathaye, J., R. Friedmann, S. Meyers, O. de Buen, A. Gadgil, E. Vargas, and R. Saucedo (1994), "Economic Analysis of Ilumex: A Project to Promote Energy-Efficient Residential Lighting in Mexico". Energy Policy, February, 1994, pp. 163 - 171.

[11] Martinot, E. (1994), Technology Transfer and Cooperation for Sustainable Energy Development in Russia: Prospects and Case Studies of Energy Efficiency and Renewable Energy. Energy and Resources Group, University of California at Berkeley, Berkeley, California, USA. [Summary of a Ph.D. Dissertation - Draft]

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