Future Northeast Asian Regional Energy Sector Cooperation Proposals and the DPRK Energy Sector: Opportunities and Constraints

VON HIPPEL David, Senior Associate, Nautilus Institute for Security and Sustainable Development
HAYES Peter, Executive Director, Nautilus Institute for Security and Sustainable Development

SUMMARY

Over the last two decades, economic growth in Northeast Asia―and particularly in China and the Republic of Korea (ROK)―has rapidly increased regional energy needs. As a recent, eye-opening example of these increased needs, China added more than 100 GW of generating capacity―equivalent to 150 percent of the total generation capacity in the ROK as of 2007―in the year 2006 alone, with the vast bulk of that added capacity being coal-fired. These increased and increasing needs, in turn, have stimulated additional interest in and work on proposals for infrastructure for regional resource sharing and other economic integration. Many of these proposals involve infrastructure for moving fuels―gas, oil, or electricity―from the resource-rich Russian Far East (RFE) or other parts of the former Soviet Union to China, the Republic of Korea, and (in some cases) Japan. In addition to their requirements for investment capital, which range from large to extremely large, energy infrastructure proposals that involve the ROK also usually have a common geographical factor: they traverse the Democratic Peoples' Republic of Korea (DPRK). As a consequence, the status of the DPRK's energy sector, and the politics of the DPRK's relations with its neighbors and with the United States, play and will continue to play a considerable role in determining the degree to which many regional infrastructure projects can in fact be implemented.

At the same time, concern about global climate change and other environmental problems (largely) associated with fossil fuels use continues to mount. The countries of Northeast Asia, along with most of the rest of the world's nations, are seeking ways of reducing (or reducing the growth in) the greenhouse gas emissions associated with their economies. This concern is increasingly being translated into an emphasis on developing and implementing renewable energy systems and increasing energy efficiency.

The countries of Northeast Asia―including the huge sub-country that is the Russian Far East―possess among them both the incentives and many of the inputs ―including technologies and technological know-how, energy and mineral resources, financial resources, and labor ―to significantly address the coupled problems of fueling development while reducing the environmental burden of that development (and of the regional economy in general). Doing so successfully, and on a time scale sufficient to address global climate change, will require significant coordination and cooperation between nations, as well as strong policies within all of the countries of the region.

In this article, we provide an overview of the recent changes in energy use and environmental emissions in the countries of the region, and review some of the regional energy infrastructure proposals that have been suggested, highlighting some of the issues that may "make or break" these proposals. We also provide some background on the DPRK energy sector, including a review of the recent and current status of the sector, of some of the current DPRK energy sector problems, and of some potential means for the international community to assist in addressing those problems. We briefly review the potential impacts of regional infrastructure proposals on regional and global environmental problems, and conclude by offering our views on what types of infrastructure and other (for example, renewable energy and energy efficiency) cooperation projects are likely, in the short to medium term, to be implementable and to provide significant environmental benefits, and on what types of collaborative activities, including those involving the DPRK, will help to improve the prospects for regional energy cooperation.

1.Introduction[1]

Over the last two decades and more, economic growth in Northeast Asia―and particularly in China and the Republic of Korea (ROK)―has rapidly increased regional needs for energy services, and thus for the fuels―gasoline, coal, electricity, natural gas, and others―that are used to supply those needs. Increased fuels use has brought with it a raft of environmental problems, including rapidly mounting greenhouse gas emissions, and increased emissions of other air pollutants with significant impact on local and regional air quality.

Increased and increasing energy needs, in turn, have stimulated additional interest in and work on proposals for infrastructure for regional resource sharing and other economic integration. Many of these proposals involve infrastructure for moving fuels―gas, oil, or electricity―

[1] This article is based in part on, and updates, a paper entitled Regional Energy Infrastructure Proposals and the DPRK Energy Sector: Opportunities and Constraints prepared by the authors for the KEI-KIEP Policy Forum on "Northeast Asian Energy Cooperation", Washington, DC, January 9, 2003. Please see http://www.keia.org/2-Publications/2-6-Other/NortheastAsiaEnergy/northeastAsiaEnergy.html for the full workshop paper. This article is based on a presentation entitled "Future Northeast Asian Regional Energy Sector Cooperation Proposals and the DPRK Energy Sector: Opportunities and Constraints", prepared by D. Von Hippel for the 2008 Northeast Asia International Conference for Economic Development, Niigata, Japan, January 21-22, 2008 (see http://nice.erina.or.jp/en/pdf/C-HIPPEL.pdf).

Table 1: Primary Energy Use in Northeast Asia and the World, 2006

Country/Area	Primary Energy Use in Northeast Asia and the World, 2006* Unit: Million tonnes of Oil Equivalent							
	Oil	Natural Gas	Coal	Nuclear Energy	Hydro-electric	Total	Fraction of NE Asia	Fraction of World
China	349.8	50.0	1,191.3	12.3	94.3	1,697.8	64.8%	15.6%
Chinese Taipei	52.5	10.7	39.5	9.0	1.8	113.6	4.3%	1.3%
DPRK（North Korea）	1.0	-	9.7	-	0.8	11.4	0.4%	0.1%
Hong Kong（China SAR）	13.2	2.2	7.5	-	-	22.9	0.9%	0.3%
Japan	235.0	76.1	119.1	68.6	21.5	520.3	19.9%	6.1%
Mongolia	0.6	-	1.5	-	-	2.0	0.1%	0.0%
ROK（South Korea）	105.3	30.8	54.8	33.7	1.2	225.8	8.6%	2.6%
Russian Far East	10.6	2.9	11.5	-	1.1	27.0	1.0%	0.3%
Total Northeast Asia	768	173	1,435	124	121	2,621	100.0%	24.1%
NE Asia Fraction of World	19.7%	6.7%	46.4%	19.4%	17.5%	24.1%		
Total Rest of World	3,122	2,402	1,655	512	567	8,258		75.9%
TOTAL WORLD	3,890	2,575	3,090	636	688	10,878		100.0%

from the resource-rich Russian Far East (RFE) or other parts of Russia (and or other Republics of the former Soviet Union) to China, the Republic of Korea, and (in some cases) Japan. In addition to their requirements for investment capital, which range from large to extremely large, and their technical and organizational complexity, energy infrastructure proposals that involve the ROK also usually have a common geographical factor: they traverse (or conspicuously circumvent) the Democratic Peoples' Republic of Korea (DPRK). As a consequence, the status of the DPRK's energy sector, and the politics of the DPRK's relations with its neighbors and with the United States, play and will continue to play considerable technical, political, and economic roles in determining the degree to which many regional infrastructure projects can in fact be implemented, though DPRK issues are hardly the sole determinate of the success or failure of infrastructure projects. Further, the Six-Party Talks process of negotiating the removal of nuclear weapons from the DPRK intertwines consideration of providing assistance in rebuilding the DPRK's economy and energy sector with nuclear weapons issues, such that regional energy cooperation, the solution to the DPRK nuclear weapons dilemma, and perhaps even partial solutions to global and regional environmental problems.

In the remainder of this article, we begin with an overview of the dynamic recent and projected growth of economic activity and energy needs in Northeast Asia, then review some of the opportunities for regional conventional energy supply infrastructure integration, and for coordination on development and implementation of renewable energy and energy efficiency technologies, highlighting some of the issues that may "make or break" these proposals, and noting their potential impact on global environmental problems. We then discuss the potential role of the DPRK in Northeast Asian energy cooperation, including a review of some of the challenges and opportunities associated with DPRK energy issues, and providing some background on the DPRK energy sector, including a review of the recent and current status of the sector, of some of the current DPRK energy sector problems, and of some potential means for the international community to assist in addressing those problems. We briefly offer our views on what types of infrastructure projects are likely, in the short to medium term, to be implementable, and on what types of collaborative activities, including those involving the DPRK, will help to improve the prospects for regional energy cooperation. We conclude by briefly offering our thoughts on what role the United States might play in encouraging—or inhibiting—Northeast Asian regional collaboration and/or coordination on energy issues.

2.Energy Use and its Impacts in Northeast Asia

Rapid economic growth, coupled with a human population of greater than 1.5 Billion makes the Northeast Asian region a major energy user. Recent years have seen a vast expansion in the need for energy services[2] , and an expansion in the demand for the fuels and electricity that help to supply these services. To cite a single, telling example of the impact of recent economic growth on energy needs, China added over 100 GW (gigawatts) of electrical generation capacity—most of which is coal-fired —in the year 2006 alone. To put this total in perspective, this one year of power plant construction yielded capacity approximately equal to150 percent of the ROK's total

[2] "Energy services" are the services that humans receive through the use of energy. Boiling of a liter of water for tea, lighting of a room, a passenger-km of travel, and the production of a tonne of cement are all examples of energy services.

generation capacity as of 2006. Overall, the regional share of world primary energy use has been increasing rapidly. From 1999 through 2006 the share of world primary energy used by the countries of the region rose from18.6 percent to 24.1 percent, which is particularly impressive given that energy use in other regions grew as well.

Many of the major resources that could be used to feed the growth in demand for energy services−including deposits of fossil fuels and major remaining sites for new hydroelectric development−are far from population centers. The Russian Far East (RFE) and Western China are examples of resource-rich areas remote from major cities. Tapping these resources will require substantial long-term investments in energy transport infrastructure.

Table 1 shows the distribution of primary energy use by fuel in the countries of Northeast Asia[3]. Northeast Asia already collectively constitute the world's largest market (64 percent of 2006 global exports[4]) for liquefied natural gas (LNG), and one of the world's largest markets for crude oil and petroleum products (nearly 20 percent of global demand). It also uses nearly half (over 46 percent−up from about 33 percent in 1999) of global coal production, with about two-thirds of regional coal use being in China. The countries of Northeast Asia consumed slightly under 20 percent of the world's petroleum and nuclear energy, 17.5 percent of hydroelectric generation, and 6.7 percent of natural gas use, up from 5.5 percent in 1999.

Table 2 provides 2006 estimates of population in each of the countries (or, in the case of the Russian Far East and Hong Kong, sub-country region) of Northeast Asia, and shows the use of primary energy per capita by country. The DPRK consumed approximately 0.8 tonnes of oil equivalent (TOE) of primary commercial fuels per capita in 1996, and China use about 0.6 TOE/capita in 1999, while South Korea used 3.9 TOE per capita, and Japan used 4.0 TOE per capita in 1999.[5] Since that time, as shown in Table 1, energy use per capita has increased slightly in Japan, significantly in the ROK, and more than doubled in China, while decreasing in the DPRK.

The major point here is that energy use in Northeast Asia−and particularly in China, North Korea, and Mongolia −would seem to have substantial "room to grow" before it reaches the levels currently maintained by Japan, the ROK, and other developed nations. The consumption of transport services, which Chinese and North Koreans currently use relatively lightly and very lightly, respectively, is one of the key areas of growth (as any recent visitor to a major Chinese city will attest), and in all probability will result in a significant increase in transport energy use in these countries.

Table 2: Population and Energy use Per Capita in Northeast Asia, 2006

Country/Area	Population（million）*	Primary TOE/cap*
China	1,313.8	1.29
Chinese Taipei	22.8	4.98
DPRK（North Korea）	22.4	0.51
Hong Kong（China SAR）	6.9	3.30
Japan	127.6	4.08
Mongolia	2.9	0.71
ROK（South Korea）	48.9	4.62
Russian Far East	7.3	3.70
Total Northeast Asia	1,553	1.69

***Estimates for 2006 except DPRK, Mongolia, RFE, which are for 2005**

Growth in demand for energy services in Northeast Asia, and for the fuels used to provide those services, have had (and, as growth continues, will continue to have) significant implications in a number of areas. Expansion in energy use is causing and, based on current trends, will continue to cause major consequences for:

- Global and regional fuels markets, as the countries of the region require increasing amounts of energy-oil, natural gas, and even coal-from outside the region.
- Global financial markets, as funds are increasingly needed to obtain energy and build needed energy infrastructure, and thus may be less available for other investments (within the region and elsewhere).
- Local, regional, and global "criteria" air pollutants, including particulate matter ("smoke", sulfur oxides, nitrogen oxides, and volatile organic compounds, emissions of which are increasingly of concern, and requiring increasing investments in control technologies, in China and elsewhere in the region.
- Global greenhouse gas emissions, which are increasingly of concern worldwide.
- Local land use for energy infrastructure, including land requirements for hydroelectric reservoirs (which have

[3] Data for this table were compiled from a number of sources including British Petroleum Co. (2007), BP Statistical Review of World Energy June 2007 (see details in following footnote) for most countries; United States Department of Energy, Energy Information Administration (USDOE/EIA, 2008) figures from http://tonto.eia.doe.gov/country/index.cfm for Mongolia; D.F. Von Hippel and P. Hayes (2007), Fueling DPRK Energy Futures and Energy Security: 2005 Energy Balance, Engagement Options, and Future Paths (Nautilus Institute Report, available as http://www.nautilus.org/fora/security/07042DPRKEnergyBalance.pdf) for the DPRK; and Russian Far East data from R. Gulidov, V. Kalashnikov and A. Ognev, (2006), draft chapter for Asian Energy Security Project Final Report (manuscript in preparation).

[4] British Petroleum Co. (2007), BP Statistical Review of World Energy June 2007. Downloaded as Excel workbook "statistical_review_full_report_workbook_2007.xls" from http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2007/STAGING/local_assets/downloads/spreadsheets/statistical_review_full_report_workbook_2007.xls.

[5] Population figures used for these calculations are from USDOE Energy Information Administration International data file "tableb1.XLS" "Table B1 World Population, 1980-2005", downloaded from http://www.eia.doe.gov/emeu/iea/wecbtu.html, except for the DPRK, which is from Von Hippel and Hayes, 2007 (see above), and the RFE, which is based on an estimate for 1997 from "National Energy Futures Analysis and Energy Security Perspectives in the Russian Far East", by V. Kalashnikov, prepared for The Nautilus Institute East Asia Energy Futures Project, June, 2000, and available as http://www.nautilus.org/archives/energy/eaef/Reg_RFE_final.PDF.

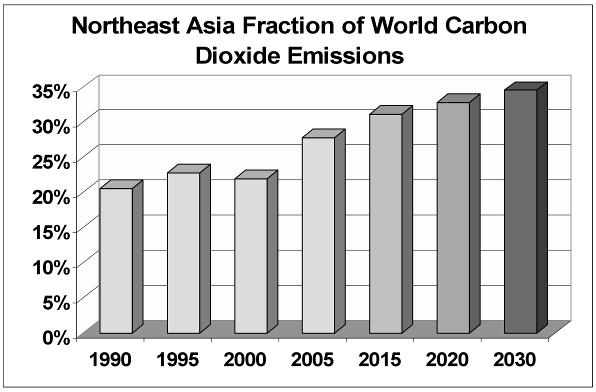
Table 3: Historical and Projected Emissions of Carbon Dioxide in Northeast Asia

	Carbon Dioxide Emissions Unit: Million tonnes of Carbon Equiv.						
Country/Area	1990	1995	2000	2005	2015	2020	2030
China	611	776	794	1,452	2,143	2,558	3,318
Chinese Taipei	32	49	68	78	95	106	130
DPRK (North Korea)	126	63	32	38	82	87	83
Hong Kong (China SAR)	11	13	15	20	[Included in China total]		
Japan	275	293	325	336	363	372	381
Mongolia	3	2	2	2	3	4	5
ROK (South Korea)	66	103	120	136	166	190	225
Russian Far East	80	71	71	80	98	105	135
Total Northeast Asia	1,204	1,371	1,427	2,142	2,950	3,421	4,278
NE Asia Fraction of World	20.6%	22.9%	22.0%	27.9%	31.2%	32.9%	34.6%
Total Rest of World	4,631	4,627	5,051	5,547	6,492	6,974	8,072
TOTAL WORLD	5,835	5,997	6,478	7,689	9,442	10,394	12,350

displaced millions of people in the region in recent years), as well as for thermal power plants and energy transport infrastructure.

For one of the implications above, global greenhouse gas emissions, Table 3 and Figure 1 provide, respectively, a summary of historical estimates and projections for emissions in the countries of Northeast Asia, and a view of the increasing importance of emissions of carbon dioxide (CO_2) from the region relative to the rest of the world. Northeast Asia's share of world CO_2 emissions increased from 20.6 percent to nearly 28 percent by 2005, and, based on a variety of estimates, will account for over a third of global emissions by 2030[6,7].

Figure 1:



3. Opportunities for Energy-sector Cooperation in Northeast Asia

The growth in energy use in the region, and its attendant problems, together with the energy, financial, human, and technological resources available in the countries of the region, create opportunities for energy-sector cooperation in Northeast Asia. These opportunities include integration of conventional energy supply infrastructure (gas and oil pipelines, LNG terminals, and electricity grid interconnections), cooperation on energy efficiency and renewable energy development, cooperation on regional emergency and strategic fuel storage, and cooperation on nuclear fuel-cycle facilities.

3.1 Integration of Fossil Fuel Supply Infrastructure

Perhaps the most obvious type of regional energy cooperation for implementation in Northeast Asia is in connecting remaining oil and gas resource areas to markets. Most of the remaining available oil and gas resources in Northeast Asia are located in the Russian Far East, though

[6] Historical data on carbon dioxide emissions by country for 1990 through 2005 are taken from Energy Information Administration USDOE EIA (2007) International Energy Annual 2005, table H.1, "World Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels, 1980-2005", with the exception of data for the DPRK (from D. Von Hippel and P. Hayes, 2007) and RFE (rough estimates from data from R. Gulidov, V. Kalashnikov and A. Ognev, (2006), and V. Kalashnikov (1997), Electric Power Industry of the Russian Far East: Status and Prerequisites For Cooperation In North-East Asia, Draft Report Prepared for the Working Group Meeting on "Comparisons of the Electricity Industry in China, North Korea and the Russian Far East", Organized by the East-West Center, Honolulu, Hawaii, 28-29 July 1997). Projections for future global CO_2 emissions taken from USDOE EIA International Energy Outlook 2006, "Table A10: World Carbon Dioxide Emissions by Region, Reference Case", available as http://www.eia.doe.gov/oiaf/ieo/pdf/ieoreftab_10.pdf. Projections for individual countries/areas within Northeast Asia are a composite of estimates from country teams participating in the Nautilus Institute "Asian Energy Security" (AES) project, as presented at the 2006 and 2007 AES Project Meetings (see, for example, http://www.nautilus.org/energy/2006/beijingworkshop/papers.html and http://www.nautilus.org/energy/2007/beijingworkshop/papers.html. Projections for the DPRK are preliminary estimates by Nautilus Institute.

[7] The apparent decline, in 2000, in the fraction of global emissions from Northeast Asia, may be in large part an artifact of a change in reporting of coal production and use in China in the years around 2000.

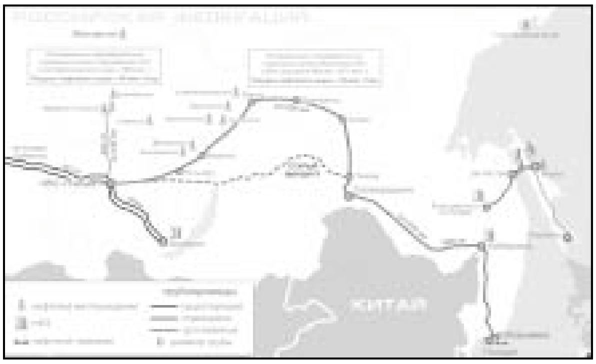
there is evidence that some oil also exists in other areas, including offshore of the DPRK. A number of different oil and gas pipeline routes have been proposed and, to varying degree, studied for feasibility, including routes linking the RFE with the ROK, China, and Japan, in some cases via Mongolia or the DPRK. Another area of oil and gas infrastructure development not directly related to resources is the sharing of existing or new oil refineries and/or LNG (liquefied natural gas) terminals.

The main near-to-medium-term oil pipeline options in Northeast Asia seem to be those from fields in the Russian Far East and East Siberia to Northeast China and to Japan. The route to Japan probably would not, in fact, go all the way to Japan, but would go from Eastern Siberia to the Pacific port of Nahodka in the RFE, just across the Sea of Japan from Japan. A key oil transport infrastructure option currently under active development is the Eastern Siberia to Pacific Ocean Oil Pipeline (ESPO). In its first phase (scheduled for completion in late 2008), the project will have a capacity of 30 million tonnes/yr (Mte/yr) of crude oil, will span a distance of 2800 km, and have a capital cost of approximately USD 11 billion. Figure 2 shows the pipeline route.[8] Approximately half of the capacity of the first phase of the ESPO project is scheduled to go to China (through Daqing), with the other half routed to the Pacific terminal of the pipeline (Kozmino Oil Port) for export to Japan and other countries. The second, post-2008 phase of the ESPO project, with an estimated capital cost of about USD 9 billion, is expected to include expansion of pipeline capacity to 80 Mte/yr, and expansion of the capacity of the Pacific terminal to 50 Mte/yr.

Other oil pipelines, including pipelines from areas west of the RFE to China, have also been considered, but have not reached the stage of development of the ESPO project. Development of oil and gas production and export facilities in the Sakhalin area (the "Sakhalin-1" and "Sakhalin-2" projects, for example) continue, but these projects have largely (except as noted below) focused on supplying RFE internal demand and general exports of oil and LNG, rather than specifically on infrastructure to be shared with the countries of the region.

The ESPO project described above, and most of the other potential regional oil pipeline projects that have been and are being considered, may well provide economic (depending on oil prices and infrastructure costs), political (in the form of closer cooperation between nations sharing infrastructure), and energy supply security (broadening the base of import sources for the ROK and Japan, and broadening the base of export customers for Russia) benefits, but these benefits should be considered in

Figure 2: Route of the Eastern Siberia - Pacific Ocean (ESPO) Oil Pipeline



perspective. First, even 100 Mte/yr is only about 15 percent of 2006 Northeast Asia oil demand, and about 10 percent of projected 2020 oil demand in China alone. Thus, while such projects can play an important role in the overall fuel supply picture for the region, they are hardly a substitute for existing oil supply sources. Second, with regard to global environmental problems, oil pipelines are unlikely to have significant greenhouse gas emissions reduction benefits, as any energy consumption displaced by reducing oil tanker traffic to the region will be at least partially offset by oil and gas used to pump oil through pipelines.

There have been numerous proposals for gas pipelines linking the countries of Northeast Asia. Most involve moving gas from the Russian Far East or West Siberia into China, Japan, and/or the ROK, but some schemes suggest bringing gas from as far west as Kazakhstan and Turkmenistan to China and even further east, as well as linking in fields in Northern and Northwest China. Figure 3 summarizes some (but hardly all) of the gas pipeline proposals that have been described recently.[9] What virtually all gas pipeline proposals have in common is high capital cost (a range of $1.2 to 20 billion and more has been cited, and costs of $1-2 million per kilometer of pipeline[10]), long lead times for completion (typically five years or more), and formidable technical and (especially) political barriers to implementation.

In addition, to be economic, the availability of gas has to coincide with the development of gas demand. In China, gas distribution infrastructure remains undeveloped in many areas. Japan's gas industry is based on local distribution systems for liquefied natural gas (LNG), but lacks a national trunk pipeline system that would allow the use of substantial pipeline gas imports. The ROK has a relatively well-developed national gas transmission and distribution

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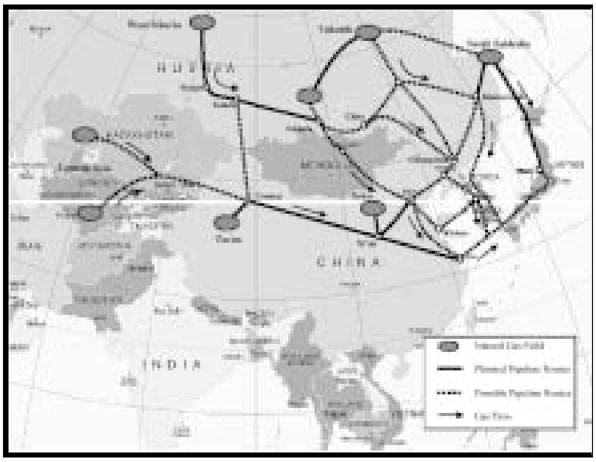
[8] Figure 2, and the details of oil and gas infrastructure projects and proposals presented here, are taken from a presentation by R. Gulidov, V. Kalashnikov and A. Ognev, (2007), "Update on the RFE Energy Sector and on the RFE LEAP Modeling Effort", prepared for the 2007 Asian Energy Security Project Meeting "Energy Futures and Energy Cooperation in the Northeast Asia Region", Tsinghua University, Beijing, China, October 31 - November 2, 2007. This presentation will be available at http://www.nautilus.org/energy/2007/beijingworkshop/papers.html.

[9] Figure taken from Kazuaki Hiraishi, Development of natural gas pipeline network in Northeast Asia, prepared for the World Energy Council 18th Congress, Buenos Aires, October 2001.

[10] As a reference to the costs of gas pipeline, the US Department of Energy's Energy Information Administration, as part of its International Energy Outlook 2002, cites (in "China's West-to-East Natural Gas Pipeline") the cost of China's (then) proposed domestic 4300 km gas pipeline development at $4.8 billion . The pipeline was to have a throughput of 12 to 20 billion cubic meters annually. See http://www.eia.doe.gov/oiaf/archive/ieo02/chinaboxtxt.html.

Figure 3: Several Proposed International Natural Gas Pipeline Routes to Northeast Asia



system, which is likely to provide a competitive economic advantage (relative to Japan), if and when pipeline gas imports are available, but the degree to which significant expansion of gas use is in fact likely in the industrialized ROK (as in Japan) remains to be seen. The DPRK, whose economy has traditionally been dependent on coal, has essentially no gas distribution infrastructure. All of these factors suggest why development of gas pipelines in Northeast Asia has been, and may continue to be, a slower-than expected process, though solution of the political impasse with the DPRK over its nuclear weapons programs could serve as a spur to gas pipeline development (see the next section of this article).

More recent, proposals for regional gas resource sharing include: [11]

- Additional multi-phase projects for gas (and oil) production in the Sakhalin Island and, Sea of Okhotsk areas, many currently in the exploration phase, but potentially drawing on probable Sea of Okhotsk shelf reserves estimated at 1.6 billion tons of oil and 5.0 trillion cubic meters of natural gas. Development of these projects will likely involve international consortia of state, non-state companies, and may involve. Gas extraction and transport infrastructure projects for the (existing) first two phases of work in Sakhalin will require investments of about $40 billion, with total maximum output of about 25 billion m^3 (cubic meters) of gas (and 21 Mte of oil) annually.
- The "Eastern Gas Program", which proposes an integrated system of gas production and transport within Siberia/RFE, and to other NE Asian consumers. The potential output of this program is projected to be 140-160 billion m^3 gas/yr by 2020-2030. As shown in Figure 4, four centers of gas production (Northern Sakhalin, South-Western Yakutia, the Irkutsk area and the Krasnoyarsk area) may potentially be involved, and there are at least 15 possible routes that pipelines might take. The investment requirements for the program have been estimated at $40 to $85 Billion. Pipelines shown in Figure 4 circumvent the DPRK, but pipeline routings from the RFE through (and to) the DPRK and into the ROK have been under discussion in the region for many years.

As with regional oil supply infrastructure, regional gas infrastructure proposals have the potential economic, political, and energy supply security benefits—and, to the extent that gas from the pipelines displace oil and coal fuel use, potential local, regional, and global environmental benefits as well—but these benefits should be considered in perspective. Even 160 B m^3 gas/yr is only 5 percent of total 2006 NEA energy demand, thus representing a substantial resource, but not offering a solution, in and of itself, to looming regional energy supply shortfalls. In addition, even if 160 billion m^3 gas/yr displaces coal use (for example, in power plants in China or the ROK), the greenhouse gas emissions benefits would be about 380 Mte CO_2, or about 5 percent of Northeast Asia's regional emissions in 2006[12].

3.2 Electricity Grid Interconnections

Similar to the situation with gas pipelines, a number of different electricity interconnection schemes have been proposed for Northeast Asia. Here again the emphasis is on moving electricity generated using resources in the Russian Far East to the population centers of Korea, China, and (possibly) Japan. More elaborate transmission line proposals involving Japan include a transmission "ring" surrounding the Sea of Japan/Korea East Sea, while more modest initiatives would build segments of transmission line linking portions of one or more Chinese regional grids to grids in the RFE. In some cases variations among potential electricity trading partners in the season of peak electricity demand (and supply) may make it possible for power to be routed north at some times of year[13] . Key elements of, and considerations for, grid interconnections include the following:

- *The cost of the transmission line*. Transmission line costs per kilometer vary depending on whether the line is AC (alternating current) or DC (direct current), the capacity of the line, the terrain crossed by the line, and the types

[11] As with the ESPO oil pipeline project described above, Figure 4, and the details of gas infrastructure projects and proposals presented here, are taken from a presentation by R. Gulidov, V. Kalashnikov and A. Ognev, (2007), "Update on the RFE Energy Sector and on the RFE LEAP Modeling Effort", prepared for the 2007 Asian Energy Security Project Meeting "Energy Futures and Energy Cooperation in the Northeast Asia Region", Tsinghua University, Beijing, China, October 31 - November 2, 2007. This presentation will be available at http://www.nautilus.org/energy/2007/beijingworkshop/papers.html.

[12] A true accounting of net benefits related to end-use reduction of greenhouse gas emissions through use of natural gas from pipeline project must, of course, also consider any emissions of methane (a much more potent greenhouse gas then CO_2) during natural gas production and transmission, as well as energy (typically gas) used to drive the gas compressors that push gas through the pipelines.

[13] For example, the DPRK electrical system is at present winter-peaking, while the ROK grid is summer-peaking. Recent conversations with colleagues from the Russian Far East suggest that the RFE grid has ample capacity to serve needs for winter peak power, at least in the short-to-medium term, so prospects of substantial sales of power TO the RFE would seem to be limited.

Figure 4: Potential Gas Production Areas and Pipeline Routes for the Eastern Gas Program

of conductors (wires carrying current) and towers used. As a rough rule of thumb, a line capable of carrying on the order of 1000 MW (megawatts) of power might cost $250,000 to $500,000 (USD) per kilometer, meaning that a line linking the RFE with the ROK, and passing through the DPRK, would cost on the order of $0.5 to $1 Billion.

- *The cost of converter stations*. If part of the line is DC (superior in cost and performance to AC if the transmission distances are long enough), at least two converter stations must be used to convert AC power to DC for transmission, then back again to AC for use. AC-DC-AC converter stations may also be needed to provide interfaces between systems of different frequencies (the ROK and part of Japan use 60 Hertz (Hz) systems, the DPRK's system is nominally 60 Hz, though in practice operates at highly variable frequencies, and the rest of the region uses 50 Hz systems), and/or to enable the partial isolation of interconnected grids from each other5. Converter station cost has been decreasing with improvements in electronics technology, but are on the order of $100 million per 1000 MW of capacity. The technical issues associated with grid interconnection, and with the operation of AC-DC-AC interconnections, are considerable[14].
- *The seasonal availability of generation and generating capacity in the interconnected countries.* (See discussion above.)
- *The capital costs of the power plants that the long-distance transmission will avoid.* The availability of the power from the transmission link will allow one or more countries to avoid building new power plants to meet peak and/or baseload power needs. The higher these "avoided capacity costs" are, the more economic the link will be.
- *The capital costs of any power plants added specifically to provide power for the link*
- *The fuel and operating costs of the power plants that will feed into the transmission link relative to the costs for the power plants not run because of the availability of power from the link*. That is, the net generation costs avoided by the interconnection.
- *Environmental or other considerations related to transmission line and/or generation siting and operation*. Depending on what power plant operation and/or capacity is avoided, the grid interconnection may be credited with avoided pollutant emissions, transmission bottlenecks, or power plant siting difficulties. For example, providing hydroelectric power from the RFE that avoids coal-fired generation in China or the DPRK will avoid the emissions of greenhouse gases and local/regional air pollutants. Similarly, displacing new peaking capacity in the ROK with the capacity of a transmission line from the RFE avoids the transmission and siting constraints faced by the ROK in expanding its fleet of nuclear reactors.
- *Institutional and pricing arrangements*. The arrangements needed to provide a multi-lateral institution for the operation of a Northeast Asia transmission link are decidedly no-trivial, as are arrangements for agreeing on power pricing (and rents for power transmission across national territories. Some international examples for such arrangements exist, but none operate in a political climate similar to that in Northeast Asia[15] .

Initial analyses of the economic potential of grid interconnections between the RFE and the ROK through the DPRK (and in some cases involving China) indicate that may be cost-effective on purely economic grounds, or may be cost-effective ways to reduce overall regional greenhouse gas and other air pollutant emissions9. Much depends on what is assumed about the parameters discussed above, and more detailed feasibility studies and modeling of the power systems to be interconnected is needed to better characterize the net benefits (or costs) of the different interconnection schemes.

Recent proposals for power sharing in Northeast Asia have included power lines built within the RFE, to augment existing Russian transmission capacity, and across Russia's borders to China and the Koreas. Some near-term exports could be handled with existing generation capacity in the RFE until RFE domestic demand grows. For larger quantities of power, past and present proposals have included construction of new hydroelectric, nuclear, gas-fired, or coal-fired power plants in the RFE or Siberia to produce power for export. Recent plans in the RFE call for phased construction of infrastructure for exports of up to 11 GW, mostly to China, have been considered by sometime after 2015, with investment costs on the order of $18 billion[16].

To put these exports in perspective, even 15 GW would displace only a few percent (for example) of Chinese coal-fired power. No significant GHG emissions benefit

[14] For example, see presentations and papers by Felix Wu, Lev Koshcheev, and J.K. Park prepared for the "First Workshop on Power Grid Interconnection in Northeast Asia", held in May, 2001, Beijing, China. Available at http://www.nautilus.org/archives/energy/grid/materials.html and http://www.nautilus.org/archives/energy/grid/papers.html.

[15] For example, see papers by Karsten Neuhoff and Ivar Wangensteen prepared for the "First Workshop on Power Grid Interconnection in Northeast Asia, held in May, 2001", Beijing, China. Available at http://www.nautilus.org/archives/energy/grid/papers.html.

would accrue if coal-fired plants in Russia are used to provide power to China or the ROK, as any efficiency benefit from using new Russian power plants to reduce generation at (or retire) older, less efficient Chinese plants (to suggest a favorable scenario) would be at least partially offset by transmission losses in sending power from the RFE to China. There would, however, be local and regional emissions benefits in the electricity consuming nations receiving the power.

3.3 Renewable Energy and Energy Efficiency Coordination

The development of renewable energy and energy efficiency technologies have been of keen interest in many countries of Northeast Asia. Climate change, local and regional environmental concerns, and the desire for economic development all contribute to the attractiveness of these options. Northeast Asia includes countries that are leaders in the technical know-how needed to mass-produce renewable energy and energy-efficiency devices, and have the funds to finance development and deployment of renewable energy and energy efficiency, as well as countries with significant markets for such devices. (In some cases, countries fall into both categories.) Cooperative strategies that allow the countries of Northeast Asia to share and co-develop technologies to utilize renewable energy sources and to improve energy efficiency could make for accelerated deployment of these technologies, relative to a situation where countries develop and/or deploy the technologies largely on their own.

Considering the attributes of the countries in the region, possible inputs to regional cooperation on energy efficiency and renewable energy could include:

- Technology, research and development infrastructure, and financing from the ROK, Japan, and possibly the United States.
- Mass manufacturing infrastructure, labor, and quite likely financing from China.
- Labor from the DPRK (once the current political impasse has been relieved).
- Renewable resources in varying availability across the region.
- Energy efficiency potential (that is, untapped energy efficiency "resources") in all nations, particularly the DPRK, China, the RFE, and Mongolia (but significant resource potential exists in the ROK and Japan as well). A key area of untapped energy efficiency in all countries in Northeast Asia is improvements building energy efficiency, and, in countries and areas with significant heating seasons, improvements in district heating systems.
- Potentially huge combined regional markets.

Implementing cooperation strategies in these areas, however, is a non-trivial exercise. Some of the many challenges to aggressive implementation of regional cooperation in energy efficiency and renewable energy include:

- Different legal standards (affecting, for example, protection of intellectual property, and offering stable platforms for investment), and taxation systems for businesses (affecting the desirability of setting up local manufacturing) in different nations.
- Different energy, environmental, and related (for example, safety) standards for appliances and equipment in the different nations.
- Managing (and promoting) the flow of information within cooperative ventures, and organizing cooperative ventures across nations, including ventures that may involve a number of both public- and private-sector actors. Here issues of both international and inter-company competition will need to be addressed.
- Finding a way to quickly develop the human expertise to implement energy efficiency and renewable energy systems on a massive regional scale.

Investments in energy efficiency and renewable energy can potentially yield very significant environmental and economic (especially with energy efficiency) savings. A recent program to improve the efficiency of refrigerators made in China efficiency, a joint venture of the Chinese State Environmental Protection Agency and the United Nations Development Programme/Global Environment Facility, resulted in a change in refrigerator technology and refrigerator marketing that nearly doubled the efficiency of refrigerators sold in China in just a few years.[17] This kind of cooperative model could be used in other nations and for other types of products and services.

Even on a national scale, the benefits of aggressive investment on energy efficiency and renewable energy are clear. Figures 5 and 6 present, respectively, potential CO_2 emissions reductions and costs results from an electricity energy efficiency/renewable energy scenario for Japan done several years ago. Note that the results shown in Figure 6 would show significantly higher resource savings, and significantly negative total net costs (that is, significant net savings) if they were recalculated using today's $100/bbl oil prices. Regional cooperation, properly implemented, may be able to offer these types of benefits region-wide, and more cheaply and at a faster pace than if each country develops its energy efficiency and renewable energy programs independently.

3.4 Other Types of Potential Regional Cooperation on Energy Issues

Other types of regional cooperation on energy issues and infrastructure that might be pursued include the following:

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[16] R. Gulidov and A. Ognev (2007), "The Power Sector in the Russian Far East: Recent Status and Plans", prepared for the 2007 Asian Energy Security Project Meeting "Energy Futures and Energy Cooperation in the Northeast Asia Region", Tsinghua University, Beijing, China, October 31 - November 2, 2007. This presentation will be available at http://www.nautilus.org/energy/2007/beijingworkshop/papers.html.

[17] See, for example, "Transformation of the refrigerator market in China", available at http://www.un.org/esa/sustdev/publications/energy_casestudies/section1.pdf, and Ray Phillips (2004) "China CFC-Free Energy-Efficient Refrigerator Project", presented at IEA-India Workshop on Energy Efficiency Standards and Labeling, Bangalore, India October 13-14, 2004, available at http://www.iea.org/Textbase/work/2004/bangalore/philips.pdf.

Figure 5: Japan Energy Efficiency and Renewable Energy Analysis: Greenhouse Gas Emissions Reduction Benefits[18]

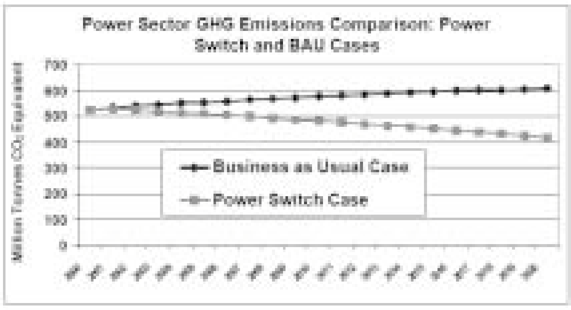
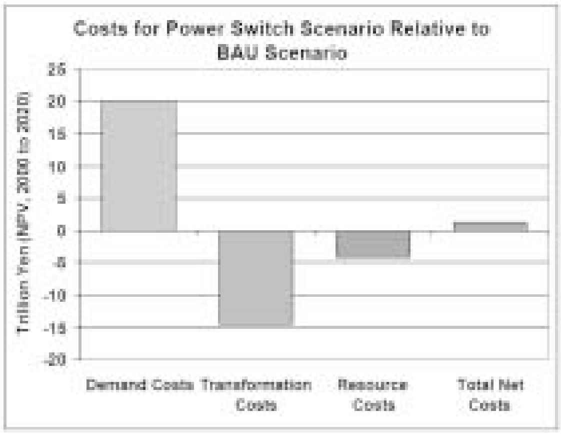


Figure 6: Japan Energy Efficiency and Renewable Energy Analysis: Cost Comparison



- Sharing of excess oil refining capacity to avoid the need to build additional capacity elsewhere in the region. For example, there may be available capacity in Japan that is "mothballed" or otherwise under-used, that could be used to provide oil refining for China, which faces a refining capacity shortfall soon. In so doing, China would defer or avoid having to increase its own refining capacity.
- Co-development of LNG import capacity by the DPRK and ROK. It is possible (given a settlement of the current political impasse) that the ROK and DPRK could share an LNG terminal located in a suitable area relatively near the border of the two countries. An LNG terminal located, for example, near Nampo on the West coast of the DPRK, would be able to serve both the Pyongyang area and, via pipeline, areas of the ROK near the border (possibly including some of Seoul). This would provide a way to finance gas import facilities in the DPRK (by selling gas to the ROK) while the DPRK's gas distribution infrastructure and gas demand is built up.
- Cooperation on regional emergency fuel storage, including, potentially, agreements on sharing fuel storage facilities, tapping shared storage resources in the event of a supply crisis, and rules for the amount of fuel to be stored (similar to those in force in OECD countries) are all possibilities[19] .
- Cooperation on nuclear technology in Northeast Asia, which could include cooperation on development and testing of new, safer and more cost-effective generation technologies, cooperation on the management of nuclear spent fuels and other wastes (including management "back-end" nuclear materials handling, transport, and disposal) and cooperation on enrichment of uranium and nuclear fuel preparation.[20]

4. The Role of the DPRK in Northeast Asian Energy Cooperation

During the decade of the 1990s, and continuing through much of this first decade of the 21st century, a number of issues have focused international attention on the DPRK. Most of these issues—including nuclear weapons proliferation, military disagreements, economic collapse, trans-boundary air pollution, floods, food shortages, droughts, and tidal waves—have their roots in a complex mixture of Korean and Northeast Asian history, global economic power shifts, environmental events, and internal structural dilemmas in the DPRK economy. Energy demand and supply in general—and, arguably, demand for and supply of electricity in particular—have played a key role in many of these high-profile issues involving the DPRK.

Solving the DPRK nuclear issue may not be a strictly necessary condition to allow significant regional cooperation on energy issues and infrastructure, but it would certainly be helpful, and would probably accelerate activities in a number of ways, and for a number of reasons—including the advantages of a regional context for engagement of the DPRK on energy issues. Even once the nuclear issue is (at least largely) addressed, however, considerable challenges to bringing the DPRK into regional cooperation activities will remain. To cite just a few examples, significant efforts will be needed to upgrade DPRK infrastructure, provide capacity building, and help to reform legal and administrative systems to allow DPRK to participate fully in regional initiatives (in many cases, similar efforts will be needed in other countries as well). "Geopolitics", that is, consideration of the impacts of regional energy cooperation activities on the relations

[18] Figures 5 and 6 from M. Nakata, J. Oda, C. Heaps and D. Von Hippel (2003), Carbon Dioxide Emissions Reduction Potential in Japan's Power Sector-Estimating Carbon Emissions Avoided by a Fuel-Switch Scenario. Prepared for WWF-Japan, October, 2003, available as http://www.wwf.or.jp/activity/climate/lib/powerswitch/ps_FinalDraft_Oct17.pdf.

[19] See, for example, Eui-soon Shin (2005), "Joint Stockpiling and Emergency Sharing of Oil: Update on the Situations in the ROK and on Arrangements for Regional Cooperation in Northeast Asia", prepared for the Asian Energy Security Workshop, May 13-16, 2005, Beijing, China, and available as http://www.nautilus.org/aesnet/2005/JUN2205/Shin_Stockpile.ppt.

[20] Exploration and analysis of alternatives for regional cooperation on nuclear fuel cycle activities has been the focus of work in Nautilus Institute's collaborative "Asian Energy Security" project during 2006-2008.

between powers great and smaller both within and outside the region, are also likely to come into play—in ways that may be difficult to predict—as resolution of the DPRK nuclear issue nears.

In addition to the challenges noted above, resolution of the DPRK nuclear issue would undoubtedly open opportunities for cooperation on energy issues. For example, as the DPRK economy becomes more integrated with the economies of the region, pipelines and transmission lines could be developed to pass through to take direct route to ROK, providing service to the DPRK as well. Additional markets for all types of technologies (and services) would open as the DPRK is redeveloped. In fact, the redevelopment of the DPRK will provide a considerable opportunity to install efficient end-use equipment and renewable energy systems, as the DPRK economy (and infrastructure) will need to essentially be rebuilt from the ground up. In the process the DPRK may in a way provide a "laboratory" for application of energy efficiency and renewable energy measures in a way that other nations, with infrastructure that has been more recently updated, cannot. Regional cooperation on energy sector initiatives also provides an opportunity to utilize DPRK labor, and to help to build a sustainable economy in the DPRK. Finally, as the final international rules for applying Clean Development Mechanisms (CDM), which allow the credit for greenhouse gas emissions reduction between nations, are worked out, redevelopment in the DPRK may provide a host of opportunities for countries within and outside the region to apply CDM in energy sector investments in the DPRK.

Below we review the recent history and current status (based on our estimates) of the DPRK energy sector, list some of the key energy sector problems facing the DPRK, and offer suggestions as to opportunities for international cooperation on DPRK energy sector problems, highlighting those opportunities with the potential to encourage the development of regional infrastructure[21] . We also provide a brief review of the implications of analysis of energy efficiency potential and future "energy paths" in the DPRK, and note the possible implications of the former (and possibly future) nuclear reactor project at Simpo/Kumho for future regional electricity interconnections.

4.1 Recent History and Current Status of the DPRK Energy Sector

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

Among the key energy-sector changes on the supply side in the DPRK in the early 1990s were a vast drop in imports of fuels from the Soviet Union and Russia. Crude oil imports from Russia in 1993, for example, were on the order of one-tenth what they were in 1990[22], and have fallen to practically zero since. Oil import restrictions have further reduced the availability of refined products in the DPRK. These restrictions arose partly (if indirectly) from external economic sanctions, and partly from North Korea's inability to pay for oil imports with hard currency. This lack of fuel, particularly for the transport sector, has contributed to the DPRK's economic malaise since 1990. Also contributing to the decline in the country's economic fortunes has been the inability to obtain key spare parts for both energy infrastructure and for factories, including factories built with foreign (often Soviet) assistance and/or technology in the 1970s.

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

Changes in the DPRK energy sector between 1996 and 2000 have, for the most part, been of a substantially more incremental nature than the changes in experienced during the first half of the 1990s. Among the key changes (or continuing processes) for the energy sector between 1996 and 2000 are:

- A decline in the supply of crude oil from China through the 1990s, though, reducing the overall output of the DPRK's remaining major (Northwest Coast) refinery, though the level of crude oil supply from China has been largely steady, at about 500,000 tonnes per year, since then.
- Continuing degradation of electricity generation infrastructure due to lack of spare parts, maintenance not performed, or use of aggressive (high sulfur) fuels in boilers designed for low-sulfur coal.
- Continuing degradation of electricity transmission and distribution infrastructure, resulting in much reduced availability and quality of electricity in most parts of the

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[21] For additional information on the topics covered in this section of this summary paper, please see D.F. Von Hippel and P. Hayes (2007), Fueling DPRK Energy Futures and Energy Security: 2005 Energy Balance, Engagement Options, and Future Paths (Nautilus Institute Report, available as http://www.nautilus.org/fora/security/07042DPRKEnergyBalance.pdf, and D. Von Hippel and P. Hayes, The DPRK Energy Sector: Current Status and Options for the Future, prepared for the International Workshop on "Upgrading and Integration of Energy Systems in the Korean Peninsula. Energy Scenarios for the DPR of Korea", Como, Italy, September 19-21, 2002, available along with other DPRK-related papers and reports at http://www.nautilus.org/papers/regional.html#dprk.

[22] 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.

Figure 7:

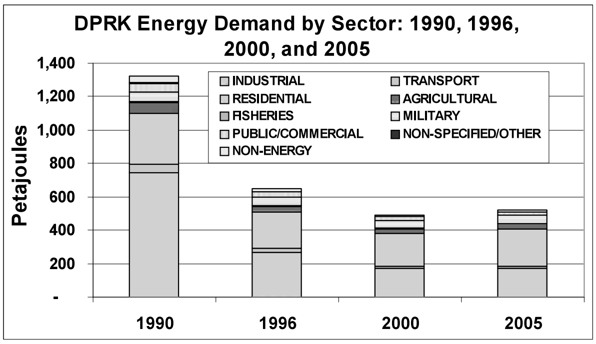
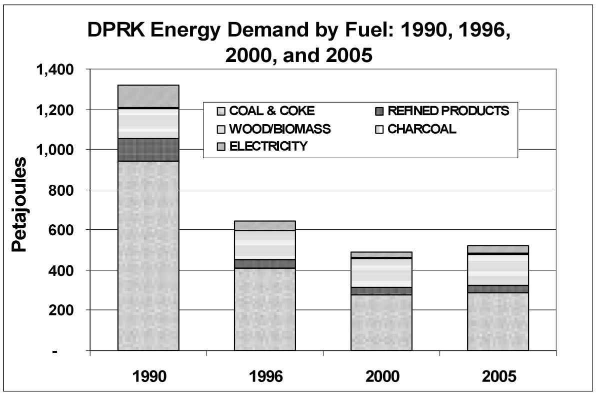


Figure 8:



country away from Pyongyang, and in the last year or so, significant problems in Pyongyang as well.

- Continuing degradation of industrial facilities in general, and the damage to industrial electric motors from poor quality electricity (electricity with highly variable voltage and frequency).
- Evidence of significant international trade in magnesite (or magnesia), and, more recently, in coal and iron ore (trade with China) and other minerals.
- Continuing difficulties with transport of all goods, especially coal, and reduced availability of passenger transport.
- Difficulties in coal production related to lack of electricity, as well as mine flooding (in the Anju and other regions) and lack of production and safety equipment.
- Some economic revival has been noted since 2000, but mostly, it seems, associated with foreign aid, small markets and restaurants, and/or with areas of the economy that are not energy intensive.

Figure 7 compares estimated final energy demand by sector for the years 1990, 1996, 2000, and 2005, and Figure 8 provides the same comparison for energy demand by fuel category. In addition to the marked decrease in overall energy consumption, there are two notable features of these comparisons. The first is the continuation of the trend of 1990 to 1996 whereby the residential sector uses an even larger share (42 percent in 2005) of the overall energy budget, while the industrial sector share shrinks to a third of the total. This change is the combined result of continued reduction in fuel demand in the industrial sector, relatively constant use of wood and other biomass fuels in the residential sector, and reductions in the use of other residential fuels (notably coal and electricity) that are not as severe as the reductions experienced in the industrial sector. Second, and for similar reasons, the importance of wood/biomass fuels to the energy budget as a whole is estimated to have increased dramatically over the course of the 1990s, and into the current decade, while the importance of commercial fuels has decreased. Increased use of wood and other stresses have resulted in significant deforestation and degradation of forest lands in the DPRK.

The DPRK electricity sector is often a focus of interest, both for the impact that the sector has on the economy of the DPRK and on the daily lives of its citizens, and also because the status of the electricity sector had (and may again have) important political implications related to the former KEDO (Korean Peninsula Energy Development Organization) Light Water Reactor (LWR) project, and to electricity grid interconnection options[23]. Analysis of the current status of the DPRK electricity sector suggests that:

The thermal power generation system in the DPRK has been eroding significantly. In virtually all of the large power stations, only selected boilers and turbines are operating, and those that are still in use operate at low efficiency and low capacity factors[24] due to maintenance problems and lack of fuel.

As a consequence of the difficulties with thermal power plants, hydroelectric plants have shouldered the burden of power generation in the DPRK, but hydroelectric output is limited by maintenance problems and, equally importantly, the seasonal nature of river flows in the DPRK.

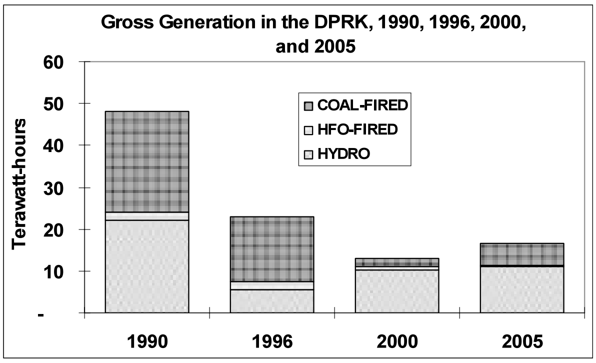
Figure 9 shows the estimated structure of electricity supply in the DPRK in 1990/1996/2000 (for comparison) and in 2005, broken down as generation in hydroelectric plants, generation fueled with heavy fuel oil (HFO, independent of whether the plant was designed to use oil), and thermal plants fueled with coal. Note that this figure displays gross generation: some of the electricity produced is used in the power plant itself, some is lost as a result of "emergencies", and more is lost during transmission and distribution. The total estimated supply of electricity decreased substantially between 1990 (46 terawatt-hours, or TWh[25]) and 1996 (23 TWh), and fell still further (by our estimate) by 2000 (to 13 TWh), before increasing somewhat to an eatimated16.6 TWh in 2005. Reflected in Figure 9 is

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

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

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

Figure 9: Estimated Sources of Electricity Supply: 1990, 1996, 2000, and 2005



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, with a slight rebound in 2005[26]. Based on anecdotal information from a number of sources, our preliminary assessment is that the power supply situation in the DPRK was likely somewhat worse in 2007 than it was in 2005.

4.2 Key DPRK Energy Sector Problems

Key energy-sector problems in the DPRK include:

- *Inefficient and/or decaying infrastructure*: Much of the energy-using infrastructure in the DPRK is reportedly antiquated and/or poorly maintained, including heating systems (including district heating systems) in residential and other buildings. Industrial, power supply (as noted above), and other facilities are likewise aging and based on outdated technology, and often (particularly in recent years) are operated at less-than-optimal capacities (from an energy-efficiency point of view).
- *Suppressed and latent demand for energy services*: Lack of fuels in many sectors of the DPRK economy has apparently caused demand for energy services to go unmet. When and if supply constraints are removed there is likely to be a surge in energy (probably particularly electricity) use, as residents, industries, and other consumers of fuels increase their use of energy services toward desired levels.
- *Lack of energy product markets*: Compounding the risk of a surge in the use of energy services is the virtual lack of energy product markets in the DPRK. Without fuel pricing reforms, there will be few incentives for households and other energy users to adopt energy efficiency measures or otherwise control their fuels consumption. Anecdotal indications are that some pricing reforms are underway in the DPRK economy, including, for example, some experiments with card-based metering systems in the Pyongyang area, but it is not yet clear (to us) to what extent pricing reforms have been broadly implemented in the energy sector.

4.3 Opportunities for International Cooperation on DPRK Energy Sector Problems

Key economic resources for the DPRK include a large, well-trained, disciplined, and eager work force, an effective system for dissemination of technologies, the ability to rapidly mount massive public works projects by mobilizing military and other labor, and extensive reserves of minerals. What the DPRK lacks are modern tools and manufacturing methods, fuel, sufficient arable land to reliably feed its populace, and above all, investment capital. As a consequence, given the energy sector problems outlined above, a coordinated program of assistance from the ROK, the United States, and/or other countries that builds upon these attributes will be needed. Providing key assistance in a timely manner will enhance security in Northeast Asia, accelerate (or, given recent events, help to re-establish) the process of North Korean rapprochement to its neighbors, and help to position countries and firms as major suppliers for the DPRK rebuilding process.

The nature of the DPRK's energy sector problems, however, mean that an approach that focuses on one or several massive projects—such as a single large power plant —will not work[27] . A multi-pronged approach on a number of fronts is required, with a large suite of coordinated, smaller, incremental projects addressing needs in a variety of areas. Below, we identify priority areas where we see DPRK energy sector assistance as both necessary and in the best interests of all parties. All of these interventions would put foreign (US, European, ROK, or other) engineers and other program staff in direct contact with their DPRK counterparts and with DPRK energy end-users. In our own experience working on the ground in the DPRK, visitors working hard to help and to teach North Koreans has great effectiveness in breaking down barriers between peoples.

- *Provide technical and institutional assistance in implementing energy efficiency measures*. Focusing in particular on energy efficiency, regional cooperation would be useful to help the DPRK to provide the DPRK with access to energy-efficient products, materials and parts, pursue sector-based implementation of energy efficiency measures, and carry out demonstration projects.
- *Promote better understanding of the North Korean situation in the ROK*. South Koreans have a deep and natural interest in what goes on in the DPRK, but generally have no better access to information on the DPRK than those in other countries. It will be important in particular to involve South Korean actors in the types

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[26] 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 was actively seeking both low-cost and longer-term (for example, contacts in approximately 2001-2002 on T&D infrastructure refurbishment with the Swiss multinational ABB) "fixes" to its problems. Some work by foreign contractors on elements of the DPRK electricity system continues, but is limited in scope and thus impact, probably by constraints on hard currency available to pay for these services.

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

of assistance activities described here.

- *Work to open opportunities for private companies to work in the DPRK*. Grants or loans from foreign governments cannot begin to fill the needs for energy infrastructure in the DPRK, but the US, ROK, European, and other governments can help to facilitate the efforts of private companies (including independent power producers) from abroad in the DPRK energy sector.
- *Cooperation on technology transfer for energy efficiency and renewable energy applications*.

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

- *Assistance for internal policy and legal reforms to stimulate and sustain energy sector rebuilding in the DPRK*. This could include reform of energy pricing practices, and the physical infrastructure to implement them, capacity building for careful energy planning to allow aid to be based on need and rational objectives, training for energy sector actors, strengthening regulatory agencies and educational/research institutions in the DPRK, and involving the private sector in investments and technology transfer.
- *Rebuilding of the T&D system*. The need for refurbishment and/or rebuilding of the DPRK T&D system has been touched upon earlier in this paper. The most cost-effective approach for international and ROK assistance in this area will be to start by working with DPRK engineers to identify and prioritize a list of T&D sector improvements and investments, and to provide limited funding for pilot installations in a limited area—perhaps in the area of a special economic zone or in a "demonstration" county.
- *Rehabilitation of power plants and other coal-using infrastructure*. An initial focus should be on improvements in small, medium, and district heating boilers for humanitarian end-uses such as residential heating.
- *Rehabilitation of coal supply and coal transport systems*. Strengthening of the coal supply and transport systems must go hand in hand with boiler rehabilitation if the amount of useful energy available in the DPRK is to increase. Coal supply system rehabilitation will require provision of basic systems for providing ventilation, light, and motive power for water pumping and extraction of coal to mines, as well as improvements in mine safety.
- *Development of alternative sources of small-scale energy and implementation of energy-efficiency measures*. The North Koreans we have worked with have expressed a keen interest in renewable energy and energy-efficiency technologies. This interest is completely consistent with both the overall DPRK philosophy of self-sufficiency and the practical necessities of providing power and energy services to local areas when national-level energy supply systems are unreliable at best. Such projects should be fast, small and cheap, and should (especially initially) emphasize agricultural and humanitarian applications.
- *Rehabilitation of rural infrastructure*. The goal of a rural energy rehabilitation program would be to provide the modern energy inputs necessary to allow North Korean agriculture to recover a sustainable production level and the basic needs of the rural population to be met.
- *Begin transition to gas use in the DPRK with Liquid Petroleum Gas (LPG) networks*. LPG is more expensive than natural gas, but the infrastructure to import LPG, relative to liquefied natural gas (LNG) is much easier, quicker, and less expensive to develop, and allows imports in smaller quantities. LNG is also clean burning, has limited military diversion potential, and setting up LPG networks can be a first step toward the use of natural gas in the DPRK—if done with a future transition to natural gas use in mind. Ultimately, natural gas pipelines and LNG terminals, shared with neighboring countries, can serve as a step toward economic development coupled with regional integration.

4.4 DPRK "Energy Futures": Different Approaches to Providing Energy Services in a Redeveloping DPRK

As touched upon in an earlier section of this article, the potential for energy efficiency improvements in the DPRK is considerable. Table 4 presents two rough estimates of potential energy savings, and the costs of those savings, for a set of measures to save coal, and a set of measures to save and generate (through use of wind power) electricity, respectively. In each case, a limited set of measures is estimated to have the potential to reduce the need for energy by over 28 percent, relative to 2005 supplies, at a cost that is far lower than the cost for producing coal and electricity.

Using these and other results, we have prepared (and are currently updating) future scenarios of energy-sector development for the DPRK, using the Long-range Energy Alternatives Planning energy/environment software tool or LEAP[28]. Earlier results, in which we compared a "Redevelopment" path without significant emphasis on energy efficiency improvement, with a "Sustainable Development" path emphasizing energy efficiency and (to a lesser extent) renewable energy, and a "Regional Alternative" path also including DPRK participation in the types of regional energy infrastructure (for example, gas pipelines and electricity trading) noted above, showed a significant reduction in, for example, electricity needs (Figure 10) and greenhouse gas emissions (Figure 11) for the latter two cases. The net costs of those reductions may be relatively small or even negative—our earlier work showed negative net costs (that is, net savings) for the Sustainable Development and Regional Alternative paths, relative to the Redevelopment path, even assuming future oil prices much lower than today's levels. We are continuing to update these analyses, but expect that revised

[28] The LEAP software tool is developed and maintained by Stockholm Environment Institute-United States. Please see http://www.energycommunity.org/ for information about the LEAP tool.

Table 4: Examples of DPRK Energy Efficiency Potential Analysis

MEASURES TO SAVE COAL:

Measure	Estimated Energy Energy Savings Potential, TJ/yr		Total Estimated Investment Cost, $US 2005
TOTALS	115,000	TJ/yr	$ 529,300,000
Avoided Losses of Coal During Transport:	1,200	TJ/yr	
TOTAL COAL SUPPLY SAVINGS	116,000	TJ/yr	
Fraction of 2005 Total Coal Supply	28.7%		
Investment required, $ per GJ/yr of Coal Supply Savings			$ 4.55
Investment required, $ per tce/yr of Coal Supply Savings			$ 133

MEASURES TO SAVE/GENERATE ELECTRICITY:

Measure	Estimated Energy Energy Savings Potential, TJ/yr		Total Estimated Investment Cost, $US 2005
TOTALS	15,240	TJ/yr	$ 844,000,000
Additional Avoided T&D Losses (based on 2005 Rates)	1,490	TJ/yr	
TOTAL ELECTRICITY SUPPLY SAVINGS/GENERATION	16,720	TJ/yr	
Fraction of 2005 Total Electricity Generation	28.1%		
Investment required, $ per GJ/yr of Electricity Supply Savings/Generation			$ 50.47
Investment required, $ per MVVh/yr of Electricity Supply Savings/Generation			$ 182

Figure 10:[29]

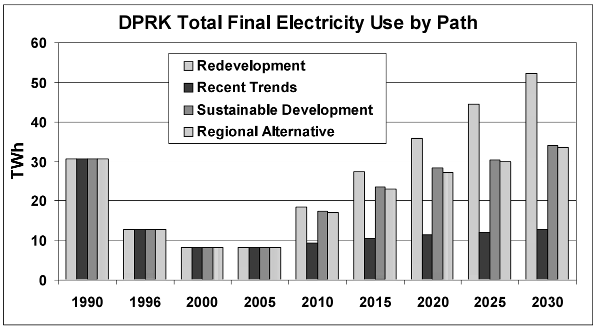
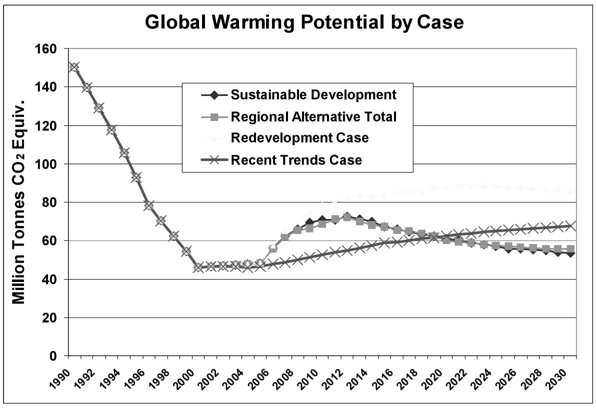


Figure 11:



results will show the same general trends, reinforcing the conclusion that the least expensive way to redevelop the DPRK will be as an energy-efficient economy, and underscoring the benefits of the energy-efficiency-related regional cooperation options noted earlier in this article.

4.5 The Potential Influence of the Simpo/Kumho Reactors on Grid Interconnection Proposals

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

The Simpo/Kumho reactors were intended to help alleviate DPRK electricity shortages, but use of these reactors in the DPRK grid was always problematic, at best[30]. First, the DPRK grid is highly fragmented, and reactors

[29] An additional path shown in Figures 10 and 11, the "Recent Trends" path, assumes that a substantial solution to the DPRK nuclear issue is not forthcoming, and recent trends in the DPRK economy continue.

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

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

5.The Potential Role of the United States in Northeast Asian Energy Cooperation

Though not located in the Northeast Asia region, the policies of the United States have traditionally had considerable influence in regional affairs. Many of the infrastructure and other cooperative activities described above, and most of the types of energy cooperation involving the DPRK, will stand a much better chance of success if joined and/or encouraged by the U.S., and, conversely, may have little chance of succeeding if the U.S. remains on the sidelines, or worse, actively discourages cooperation initiatives.

The United States could play a number of positive roles in encouraging NE Asian energy cooperation, including:

- Working with U.S. companies and others to promote the licensing of key technologies for manufacture and use in the region. Leading candidates for technology licensing would be renewable energy technologies for solar, wind, and tidal power, and energy efficiency technologies (advanced lighting products, appliances, transportation equipment, building energy efficiency technologies, combined heat and power systems, and building/motor control electronics, for example), but other opportunities may include waste-treatment and environmental control technologies, fossil-fuel-extraction-related technologies (coal mining safety equipment, coal-bed methane technologies, and technologies for oil and gas exploration and extraction under harsh conditions, for example), and electricity sector control technologies. In some cases, promoting these technologies may mean lowering or modifying U.S. barriers to export or licensing.
- Assisting with capacity building and technical training. There are a number of topic areas where the United States could assist the countries of the region with developing the human infrastructure needed to efficiently and effectively participate in the cooperative activities identified above. These will vary by country, and include, but are certainly not limited to, development and regulation of energy markets, energy and environmental law, environmental regulation, energy management in buildings, energy-efficient building design and construction, environmental management, renewable energy system design and implementation, development and implementation of energy-efficiency programs, and environmental emissions control, and environmental clean-up.
- Co-development and co-marketing of key energy-efficiency and renewable energy products. The United States has significant domestic opportunities for improving energy efficiency and expanding the use of renewable energy, and there are likely to be a number of opportunities to form research and development consortia—possibly between national laboratories in the U.S. and in Northeast Asian countries and with key industries on both sides of the Pacific—as well as to promote, through coordinated national policies (for example, energy codes for buildings and appliances, greenhouse gas emissions restrictions), markets for the resulting energy-efficiency and renewable energy products. Adding the 1.5 billion consumers of Northeast Asia to the 300 million in the U.S. would create formidable markets for these products, and should, if designed properly, accelerate the movement to mass market of technologies such as very efficient automobiles, electronics, lighting, appliances, high-efficiency/low-cost solar photovoltaic systems, combined heat and power systems, and other devices.
- Setting a positive example by making a serious effort to reduce national greenhouse gas emissions and to improve and aggressively promote energy efficiency and renewable energy, including setting stringent energy efficiency/renewable energy standards. Most observers of the international environmental scene would agree that the United States government has not, particularly in the current decade, provided strong and positive international leadership in the areas of climate change mitigation, energy efficiency, or renewable energy. Reversing this trend is highly likely to provide a boost to the efforts of the countries of Northeast Asia to make improvements in this area, both through the effect that U.S. policies would likely have on markets for related energy efficiency and renewable energy goods (increasing the speed of development, and ultimately bringing down prices through economies of scale), and by setting an example for policymakers and consumers in the region.
- Encouraging productive investment in the DPRK. U.S. policies toward the DPRK to a large extent determine the degree to which countries closely allied to the U.S. (Japan and the Republic of Korea, for example, as well as the European Union, Australia, and others) interact economically with the DPRK. U.S. policies may have a more limited effect on how China and Russia, for example, interact with the DPRK, but there is little doubt that if the United States were to reach an agreement with the DPRK and other parties whereby the U.S. could set out workable guidelines for encouraging investment in and business with the DPRK, the result would be a considerable increase in the opportunities available for all parties for energy cooperation involving the DPRK, bringing some of the opportunities outlined earlier in this article closer to fruition.

Alternatively, U.S. policies may develop in such as way as to frustrate attempts at energy-sector cooperation by the countries of the region. For example:

- The U.S. may feel threatened by cooperation between the countries of Northeast Asia. One possibility here is that United States policymakers may feel that geopolitical considerations regarding the influence of Russia and/or China with Japan, the ROK, and the DPRK make the promotion of energy cooperation—including, for example, the economic linkages and dependencies that major international energy infrastructure would imply—are not in the United States' best interests. Among a listing of considerations that show the potential complexities involved in multi-nation cooperation in Northeast Asia (specifically, on Korean reunification), P.A. Minakir, paraphrasing R. Scalapino, notes "The USA is not interesting in the easing of the tension in this region, as under these conditions the 'natural' reasons for the US military and political control will stop existing"[31] .
- The US may (continue to) provide a negative example on energy efficiency and greenhouse gas emissions reduction. For those countries whose people often look to U.S. lifestyles as models (deserving or not), it will be more difficult to make significant progress on improving energy efficiency and reducing greenhouse gas emissions—and participating in regional cooperation to do so—if the U.S. continues to resist taking significant steps to address its greenhouse gas emissions.

U.S. Policies in general, and with regard to the Northeast Asia region in particular, may change substantially when a new administration takes office early next year. Given the inertia built into the U.S. political process, however, substantial change is far from certain. Although the U.S. is much more than a marginal "player" in the energy sector of the region, it is not a central player, and if energy sector cooperation sufficiently benefits the countries of the region, regional resources—including financial, labor, technological, and natural resources—should be sufficient to make cooperation a reality, given the countries have the political will to cooperate.

[31] From P.A. Minakir, 2007, Economic Cooperation between the Russian Far East and Asia-Pacific Countries, Chapter 2, "Russia and the Russian Far East in Economies of the APR and NEA", page 52. While this quote does not directly address the U.S. position on energy cooperation in Northeast Asia, it is generally indicative of potential U.S. fears over loss of influence in a more cooperative, and thus less U.S.-dependant, Northeast Asian region.