

TWO SCENARIOS OF NUCLEAR POWER AND NUCLEAR WASTE PRODUCTION IN NORTHEAST ASIA OCTOBER 30, 1997



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ANNEX A:

UNDERLYING ASSUMPTIONS FOR ESTIMATES OF FUTURE ELECTRICITY DEMAND IN THE COUNTRIES OF NORTHEAST ASIA

1. Assumptions driving energy demand growth in China

HOUSEHOLD SECTOR

The **population** of China is assumed to increase to 1.45 billion by 2020. The number of **households** is assumed to increase to 430 million by 2020, representing a decrease in the average number of persons per household from 4.19 to 3.37. The fraction of the population living in cities is assumed to increase from 29 percent in 1990 to 46 percent in 2020.

Electricity use per urban household for lighting is assumed to increase at 3 percent/yr. Electricity use per urban household for appliances is assumed to roughly 6-fold to about 5,000 kWh per household (an average increase of more than 6 percent/yr) by 2020, relative to 1990 usage. The use of kerosene for rural lighting is assumed to be phased out by 2010. Electricity use for lighting per rural household increases by an average of 1.3 percent/yr, with most of the increase coming after 2000. Electricity use per rural household for appliances is assumed to roughly 14-fold to about 2,500 kWh per household (an average increase of more than 9 percent/yr) by 2020, relative to 1990 usage.

SERVICES SECTOR

Commercial and Other Services output is assumed to increase at an average rate between 9 and 10 percent/yr through 2020, with higher growth rates in the period before 2010 than after 2010. Electricity use per unit output is assumed to decrease slightly (Commercial) or remain at 1990 levels (Other Services).

AGRICULTURAL/FISHERIES SECTOR

The **land area cropped** is assumed to decrease from 95.7 million hectares to 85 million hectares by 2020. The fraction of the land area cultivated with tractors is assumed to increase from 50.5 percent in 1990 to 68 percent in 2020. Mechanical irrigation and drainage of fields is assumed to increase from 49.5% of agricultural area in 1990 to 60 percent in 2020, and the use of electric pumps is assumed to increase to 35% of all irrigated/drained area by 2010, decreasing again (as marginal lands are abandoned?) to 30 percent in 2020. Fisheries output is assumed to increase by a factor of 3.6 between 1990 and 2020 (about 4.4 percent per year). "Sideline Production", assumed to mean (primarily) agricultural product processing, is assumed to increase at between 2.5 and 2.8%/yr through 2020, with higher growth earlier in the period.

Agricultural subsector energy intensities (fuel use in tractors and pumps per hectare cultivated) are

assumed to remain at 1990 levels through 2020.

INDUSTRIAL SECTOR

Changes in output vary by subsector, with three to ten-fold increases in output. Heavier industries, including iron and steel, non-ferrous metals, and (especially) cement and other building material show reduced growth rates in the later years of the projection period, as the economy matures. Light industry, machinery and chemicals are the fastest-growing subsectors.

Energy intensities in the industrial subsectors are assumed to decline nearly across the board, with substantial reductions (up to 75 percent) for some coal-fired devices, and more modest reductions in other applications.

BUILDING SECTOR

Gross output in the Building (construction) sector is assumed to increase by an average of 7.7 percent/yr through 2020, with growth at a slightly higher rate earlier in the period.

The intensity of electricity use in this sector is assumed to decline by a third over the projection period.

TRANSPORT SECTOR

The total passenger kilometers of **public passenger transport** are assumed to grow at 4.5 percent/yr through 2020. Passenger traffic is assumed to continue to shift from railroad and water transport to road and air transport. The use of steam locomotives continues to decline, and the use

of electric locomotives increases, with the fraction of passengers carried on diesel trains increasing slightly until 2000, then decreasing.

The total tonne-kilometers of **freight transport** are assumed to grow at 5 percent/yr through 2020. Freight traffic is assumed to continue to shift from water transport to road, rail, and air transport. The use of steam locomotives continues to decline, and the use of electric and diesel locomotives increases. The kWh of electricity used per passenger-km in electric trains increases at 1 percent/yr (presumably as passengers demand more elbow room). The kWh per tonne-km in electric trains also increases at 1percent/yr.

2. Assumptions driving energy demand growth in Chinese Taipei

HOUSEHOLD SECTOR

Population is assumed to grow at 0.8 percent/yr from 1995 on. This increase is slightly lower than the 1990 to 1995 rate, but the rate of population increase in Chinese Taipei has been decreasing of late. The number of persons per household is assumed to decrease at 1.0 percent/yr, (a slightly slower decrease than in 1990 to 1995) until 2000, then set to decrease at 0.5 percent/yr.

The intensity of electricity use in households is assumed to increase at 1 percent/yr through 2000, but to stay stable thereafter as natural efficiency gains and decreasing household size balance increased use of electric appliances.

PUBLIC/COMMERCIAL SECTOR

Services GDP is assumed to increase at 7.5 percent/yr through 2000 (similar to recent trends), continuing to increase at 6 percent/yr from 2000 to 2010, and at 5 percent/yr thereafter as the economy matures. The energy intensity of electricity use in the public and commercial sector (fuel use per unit real services GDP) is assumed to decrease to 90 percent of its 1990 value by 2000, decreasing at 0.5 percent/yr thereafter.

AGRICULTURAL/FISHERIES/FORESTRY SECTOR

Agricultural GDP is assumed to increase at 3 percent/yr through 2000 (similar to recent trends), at 1.5 percent /yr to 2010, and at 1 percent/yr thereafter as the economy matures and population growth slows. Agricultural sector energy intensities are assumed to remain at 1990 levels, as increases in agricultural mechanization are (assumed to be) roughly balanced by increases in energy efficiency.

INDUSTRIAL SECTOR

In the **iron and steel, and non-metallic minerals**, steel and cement production are assumed to remain constant at 1995 levels until 2000, declining at 0.5 percent/yr thereafter. For the **chemicals, non-ferrous metals, machinery, mining and quarrying, and non-specified** subsectors, manufacturing GDP (which is used as the driving activity for these subsectors) is assumed to increase at 2.8 percent/yr through 2000 (similar to recent trends), and at 1.6 percent/yr thereafter as the economy continues to become more service-oriented. In the **transport equipment** subsector, automobile production is assumed to remain steady at 1995 levels through 2020. **Processed food and meat** production (tonnes) is assumed to follow the same trend as agricultural GDP. In the **pulp and paper** subsector, paper and paperboard production (tonnes) is assumed to remain constant at 1995 levels. **Construction** GDP is assumed to increase at 5 percent/yr through 2000 (similar to recent trends), at 3 percent/yr from 2000 to 2010, and at 2 percent/yr thereafter as the economy of Chinese Taipei continues to become more service-oriented. The tonnage output of **textiles and fiber** are assumed to increase at the rate of manufacturing GDP increase. The energy intensity of all manufacturing subsectors is assumed to decrease at 0.5 percent/yr from 1990 on.

TRANSPORT SECTOR

Rail passenger-km traveled is assumed to remain stable at 1995 levels throughout the projection period. Rail tonne-km is assumed to decline at 2 percent/yr until 2000, decreasing at 1 percent/yr thereafter. Energy intensities for all subsectors in the transport sector are assumed to remain constant in the Base Case for the projection period.

• **Assumptions Driving Changes in Electricity Demand for the DPRK**

We based our estimate of electricity demand in the DPRK on a "Recovery" scenario for the years 2000 and 2005 that we have compiled earlier. Generally, the Recovery scenario assumes that as the DPRK complies with the Agreed Framework on nuclear issues (signed in October 1994 by the governments of the United States and the DPRK), relations with the U.S. and other trading partners improve. As a result, availability of scarce fuels and parts increases, and the DPRK is able to substantially (but not fully), revive its economic output relative to 1990 levels, and to make small inroads toward renewing its economic infrastructure. This scenario does not foresee a substantial rapprochement between the DPRK and the ROK before 2000; such a rapprochement is assumed possible only once the DPRK has fulfilled the terms of the Agreed Framework, when the outstanding special inspection of nuclear waste issue is resolved, and when the first nuclear components of the PWRs are delivered-at the earliest, 2001.

INDUSTRIAL OUTPUT

In the Recovery scenario, industrial output recovers to about 70 percent of 1990 levels by 2000-and to 120 percent of 1990 levels by 2005-in most industrial subsectors, as shown in Table A-1. One exception is the fertilizer industry, which expands output to 86 percent of 1990 levels by 2000 to feed the agriculture sector, which in turn must supply food to a growing population using croplands that are (in many cases, reportedly) stressed by the effects of flooding, overuse, and lack of proper soil conservation. Another exception is the "Other Minerals" subsector-which produces magnesite-which we assume to expand production to 100 percent of 1990 levels by 2000 and to 150 percent by 2005, in keeping with its probable role (under a Recovery scenario) as a major generator of foreign exchange for the DPRK. With the exception of fertilizer production, which is assumed to grow at 1 percent per year after 2005, and production of other minerals, which grows by about 2 percent per year after 2005, industrial output is assumed to increase at 3.5 percent/yr from 2005 through 2020. With industrial output (and use of productive capacity) generally nearing 1990 levels in 2000, we assume that the energy intensity of industrial production in the various subsectors will be near 1990 levels as well, and will improve by an average of five percent (that is, use 95 percent as much energy per unit of output) between 2000 and 2005, and that the intensities of electricity use in industry will continue to decline at an average of 0.75 percent per year between 2005 and 2020.

Table A-1: Assumptions for Changes in DPRK

Industrial Production by 2000 and 2005

Subsector	Production Relative to 1990		
	1996	2000	2005
Iron and Steel	36%	69%	93%
Cement	32%	69%	101%
Fertilizers	60%	86%	120%
Other Chemicals	30%	70%	120%
Pulp and Paper	30%	70%	120%
Other Metals	30%	70%	120%
Other Minerals	30%	100%	150%
Textiles	30%	70%	120%
Building Materials	30%	70%	120%
Non-Specified Industry—non-oil fuels	20%	70%	120%

Our Recovery scenario implies growth in industrial output averaging roughly 23 percent per year between 1996 and 2000, and over 11 percent per annum between 2000 and 2005. Although these growth rates, considered in the context of developing economies, would seem unreachable, it is worth remembering that the DPRK already has most of the infrastructure that would be required to support the assumed levels of industrial production. We have been told that—at least for industrial facilities in the DPRK designed and installed with Soviet assistance—DPRK plant managers adhere to strict procedures, developed by the USSR, for maintaining and conserving plant equipment, so that bringing plants "out of mothballs" (reactivating deactivated industrial facilities) once fuels, key spare parts, and product markets become available, should be a relatively efficient process.

TRANSPORT ACTIVITIES

Total freight carried by all modes increases to 75 percent of 1990 levels by 2000, and to 120 percent by 2005. After 2005, rail freight volumes are assumed to increase at 3.5 percent/yr. Use of personal public transport per capita by electric trains increases to 100 percent of 1990 levels by 2000 as economic and entertainment opportunities increase, rising to 150 percent of 1990 levels by 2005, and continuing to grow at an annual rate 4 percent. To put these increased mobility figures in perspective, it should be remembered that the baseline use of personal transport in the DPRK is extremely low by United States or ROK standards.

RESIDENTIAL SECTOR

For our estimate of residential sector energy use, we assume that population (and household) growth continues at 0.8 percent per year after 1996. We assume that per-household consumption of electricity recovers to 85 percent of 1990 levels by 2000, and is 140 percent of its level in 1990 (as a result of greater affluence and greater availability of electrical appliances) by 2005. After 2005, we assume that this trend continues, with growth in per-household use of electricity at 5 percent annually.

AGRICULTURAL SECTOR

In the agricultural sector, the use of oil fuels per unit of land cropped is assumed to return to 90 percent of 1990 levels by 2000 in response to the increased availability of diesel fuels and the need

to provide food for a growing population. By 2005, agricultural area is assumed to return to its 1990 level, growing at 0.5 percent/yr thereafter. We assume that electricity use per hectare of land cropped will increase to 105 percent of its 1990 level by 2005, increasing at 2 percent per year from 2005 through 2020.

COMMERCIAL/PUBLIC/INSTITUTIONAL SECTOR

We assume that floor space in this sector per unit residential floor space increases to 105 percent of 1990 levels by 2000, and to 125 percent by 2005, reflecting more small "private" enterprise. After 2005, commercial/public/institutional floor space increases at about 2.75 percent/yr. Electricity use per unit area increases to 1990 levels by 2000-and by 50 percent above 1990 levels by 2005-to reflect a combination of the needs of buildings in the sector to serve more people, and the use of electricity in small "private" enterprises such as garment shops and tourist hotels. Electricity use per unit floor area is assumed to grow at roughly 5 percent per year between 2005 and 2020, as is other electricity use in the sector.

MILITARY SECTOR ACTIVITIES

We assume that electricity use in military-sector buildings climbs, by 2010, to about 60 percent above its level in 1990, remaining stable thereafter. In our Maximum Nuclear scenario, we assume that military electricity use will be 10 percent higher in the year 2020 than in the base Case. This increase in military electricity use is intended to reflect the probability of heightened military activity to help safeguard larger amounts of nuclear materials.

4. Assumptions Driving Changes in Electricity Demand for Hong Kong

We chose to model Hong Kong separately from the rest of China for several reasons. First and foremost, the composition of energy use in demand is very different from that in China, both in terms of fuel types used and in terms of the sectoral breakdown of energy use. Even long after 1997, when China formally took over governance of Hong Kong, these distinctions will undoubtedly persist. Second, data for Hong Kong are compiled separately (at present) from data for China. Third, per-capita energy use in Hong Kong is much higher than that in China, even if differences for efficiency are not accounted for.

Data on energy use in Hong Kong, and on related sectoral activity, have been compiled from IEA energy balances, UN publications, Hong Kong Government statistical office WWW sites, USDOE EIA statistics, and other sources. Our assumptions about the changes in activities that drive energy use and changes in electricity use intensities per unit of activity are described below.

HOUSEHOLD SECTOR

Population is assumed to grow at 1.65 percent/yr (as in 1990-1995) through 2005, then at 1 percent/yr, mostly through migration from the mainland to Hong Kong. The number of persons per household (HH) is assumed to decrease at 1percent/yr from 1995 to 2010, remaining stable thereafter (at 2.96 persons/HH). Electric energy intensity in the household sector is assumed to increase to 17 GJ/HH-yr (4700 kWh/yr) by 2000, remaining steady thereafter.

PUBLIC/COMMERCIAL SECTOR

For Commercial and Services GDP, it is assumed that the recent trend of about 8 percent/yr real growth in sectoral GDP continues through 2010, increasing at a slower 5 percent/yr thereafter. Electric energy intensity in the sector (fuel used per unit commercial and services GDP) is assumed to remain the same as in 1995 through the projection period.

INDUSTRIAL SECTOR

We have assumed that the output of the (small) **iron and steel** production sector will not change over the projection period. In the **chemicals and non-specified** subsector, we assume that the trend in real manufacturing GDP continues its decline (at -10 percent/yr) until 2000, then declines at a less precipitous -3 percent/yr as manufacturing continues to shift to mainland China. We have assumed no changes (on average) in energy intensity between 1995 and 2020 for the industrial subsectors, as any efficiency gains are offset by sub-optimal operating efficiency due to lower capacity factors.

TRANSPORT SECTOR

Electrically-powered transport (primarily rail) is assumed to increase at the rate of population growth. The energy intensity of electrically-powered transports is assumed not to change between 1995 and 2020.

STREET LIGHTING

Electricity use for street lighting is assumed to rise to 300,000 GJ by 2000 (increasing at approximately 1 percent/yr, as per recent trends), remaining the same thereafter as efficiency gains are balanced by additions of lamps to the street lighting network.

5. Assumptions Driving Changes in Electricity Demand for Japan

Our main source for recent Japanese energy data has been a set of very detailed (41 fuel categories by 45 rows) Japanese-language energy balances compiled by the Japanese Institute for Energy Economics (IEEJ) and the Energy Conservation Center, and published by the MITI (Ministry of International Trade and Industry) Research Institute. These data were augmented by data from the USDOE EIA (the US Department of Energy's Energy Information Administration), the IEA (International Energy Agency), United Nations documents, Japanese government statistics World-Wide Web (WWW) sites, and other sources.

HOUSEHOLD SECTOR

Our assumptions for population growth are taken from the Japan Department of the Census Projections (figures in millions): 1995 = 125.57; 2000 = 127.39, 2010 = 130.40, 2020 = 128.35.

The number of persons per household declined from 2.99 in 1990 to 2.82 in 1995, an average decline of 1.16 percent/yr. We assume a continued decline in average household size of 0.8%/yr through 2000, 0.5%/yr to 2010, and 0.3 percent/yr thereafter. We assume that the average usage of electricity per household increases at 2 percent/yr through 1995 (it actually grew faster between 1990 and 1993), then remains constant, as improvements in efficiency (which have been slowing or stopping in Japan in recent years) and decreases in the number of persons per household (which should lower per-household use) are balanced by increasing use of household energy services.

COMMERCIAL/PUBLIC SECTOR

The growth in Commercial/Services GDP is assumed to be 3.5%/yr-consistent with growth during the early 1990's-until 2000, then decreases to 2.5%/yr from 2000 to 2010, and 2%/yr thereafter. Electricity use per unit of Commercial/Services GDP is assumed to increase at 1.3 percent/yr through 2000, 0.75 percent/yr from 2000 to 2010, and 0.3 percent/yr thereafter.

INDUSTRIAL SECTOR

Our assumptions for subsectoral activity in the industrial sector include:

- In the **water treatment** subsector, the volume of water to be treated scales with population.
- **Mining and quarrying** subsectoral GDP grows at 1.5 percent/yr from 1993-2000, and 0.5 percent/yr between 2000-2010, with no growth thereafter.
- **Processed food** output is assumed to increase at 1.3 percent/yr (comparable to recent trends) from, 1993 to 2000 and 0.75 percent/yr from 2000 to 2010, with no change, on average, thereafter (as population starts to decline)
- Output of **textiles and fiber**, which contracted sharply in the early 1990's, is assumed to continue to decline at 5 percent/yr through 2000, then at 2.5 percent/yr from 2000 to 2010, remaining stable thereafter.
- Output of **Paper and Paperboard, and Chemicals** is assumed to increase at 1.0 percent/yr (comparable to recent trends) from, 1993 to 2000, and at 0.5 percent/yr from 2000 to 2010, with no change, on average, thereafter.
- **Ceramics** output is set to increase by 1.0 percent/yr (somewhat lower than cement output change from 1990 to 1995, but output in 1995 seems to have been unusually high) through 2000, then at 0.75%/yr from 2000 to 2010, and 0.5 percent/yr from 2010 to 2020.
- Output of **iron and steel** decreased during the early 1990's. We assume that the decrease continues at 1.5 percent/yr through 2000, changing to a decline of 1 percent/yr through 2010, and at 0.5 percent/yr thereafter.
- Manufacturing GDP (a benchmark for the **Non-ferrous Metals, Metal Finishing, and Other**

Manufacturing subsectors) is assumed to grow at 1.5 percent/yr from 1993 to 2000 and 0.5 percent/yr from 2000 to 2010, with no growth thereafter.

The intensities of electricity use in industrial subsectors in Japan are assumed, with the exceptions noted below, to remain constant at the 1993 level from 1995 through 2020. In food processing, we assume that electricity use intensity increases at 1 percent/yr. In the ceramics and steel industries, electric intensity is assumed to continue to increase modestly until 2000, then remain constant.

TRANSPORT SECTOR

We assume no growth in rail freight over the scenario period. The period from 1990 to 1995 showed an overall slight decline in rail freight volume, although freight increased between 1985 and 1990 and between 1994 and 1995. We assume rail passenger volumes will grow at 1 percent/yr through 2000, and 0.5 percent/yr thereafter. Electric rail is assumed to provide 75 percent of rail passenger and goods transport by 2010, and 80 percent by 2020.

The trend in Japan in the last few years, in virtually all transport sectors, has been for energy intensities to increase slightly from a 1990 minimum. For the base case scenario, we assume that the intensity of electricity use in electric trains will remain the same, on average, through 2000, then decrease slowly (0.2 percent /yr) through 2020.

• Assumptions Driving Changes in Electricity Demand for the Republic of Korea

Our assumptions as to future growth in the activities for which electricity is used in the ROK are summarized in Table A-2. Our growth rates for the years 1995 to 2000 for most activities assume a general continuation of trends in recent years, and we generally assume that growth in the ROK economy slows in the period from 2000 to 2020 as the ROK economy continues to mature. As shown in Table A-3, we used a similar approach to estimate trends in energy intensities of activities in the ROK economy, generally continuing recent trends through 2000 (most of which show increasing intensity of electricity use), with progressive reduction in the growth of electricity intensity in most sectors and subsectors through 2020.

Table A-2:

Assumptions for Growth in Activities that Drive ROK Electricity Demand

Sector Subsector	Value in 1995	Assumed Growth Rates (%/yr)			Units
		95-2000	2000-2010	2010-2020	
Residential	44,851	0.91%	0.80%	0.70%	population (thousands)
Public Services	14,831	2.52%	2.00%	1.50%	Gov. Serv. GDP, billion 1990 Won
Water	22,886	6.80%	4.00%	2.00%	kcu.m./day capacity
Commercial/Other	111,537	8.00%	6.00%	4.00%	Services GDP (5 categories), billion 1990 Won
Agriculture/Fisheries	16,832	1.54%	1.00%	0.70%	Agriculture, Fish, Forestry GDP, billion 1990 Won
Mining	887	-2.85%	-1.00%	-0.50%	Mining GDP, billion 1990 Won
Manufacturing					
Food					
Textile	459	-5.00%	-3.00%	-2.00%	million cu.m cloth
Wood	4,755	-1.35%	0.00%	0.00%	th. cu.m. (wood and plywood)
Paper and Printing	1,738	4.61%	3.00%	2.00%	kte
Chemicals	77,075	7.50%	3.50%	2.50%	Manufacturing GDP, billion 1990 Won
Ceramics	56,101	7.50%	4.00%	3.00%	th te cement
Basic Metals	22,344	7.82%	4.00%	2.00%	th. te pig iron
Machinery and Equip.	77,075	7.50%	3.50%	2.50%	Manufacturing GDP, billion 1990 Won
Other Manufact.	77,075	7.50%	3.50%	2.50%	Manufacturing GDP, billion 1990 Won

Table A-3: Assumptions as to Changes in Intensity of Electricity Use in Economic Activities in the ROK, 1995 to 2020

Sector Subsector	Value in 1995	Assumed Growth Rates (%/yr)			Units
		95-2000	2000-2010	2010-2020	
Residential	2.272	7.50%	4.00%	1.50%	population (thousands)
Public Services	1.240	5.00%	2.00%	1.50%	Gov. Serv. GDP, billion 1990 Won
Electricity	1.00E+06				[Total Electricity Use (GJ)]
Water	0.631	2.00%	1.00%	0.00%	kcu.m./day capacity
Commercial/Other	0.888	7.00%	3.50%	1.00%	Services GDP (5 categories), billion 1990 Won
Electric Railway	5.79E+06	7.00%	3.00%	1.00%	[Total Electricity Use (GJ)]
Agriculture/Fisheries	0.721	7.00%	2.50%	1.00%	Agriculture, Fish, Forestry GDP, billion 1990 Won
Mining	4.140	2.50%	1.00%	0.00%	Mining GDP, billion 1990 Won
Manufacturing					
Food	1.83E+07	6.00%	2.00%	0.50%	[Total Electricity Use (GJ)]
Textile	96.389	8.00%	2.00%	0.50%	million cu.m cloth
Wood	0.595	5.00%	2.00%	0.50%	th. cu.m. (wood and plywood)
Paper and Printing	12.920	5.00%	2.00%	0.50%	kte
Chemicals	0.883	2.50%	0.00%	0.00%	Manufacturing GDP, billion 1990 Won
Ceramics	0.598	0.01%	0.00%	0.00%	th te cement
Basic Metals	2.594	1.50%	0.50%	0.00%	th. te pig iron
Machinery and Equip.	1.042	4.00%	2.00%	0.50%	Manufacturing GDP, billion 1990 Won
Other Manufact.	0.047	5.00%	2.50%	0.50%	Manufacturing GDP, billion 1990 Won

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