

Policy Forum 98-11: Two Scenarios of Nuclear Power and Nuclear Waste Production in Northeast Asia

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NORTHEAST ASIA NUCLEAR SCENARIOS

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TWO SCENARIOS OF NUCLEAR POWER AND NUCLEAR WASTE PRODUCTION IN NORTHEAST ASIA

Essay by David von Hippel and Peter Hayes

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I. Abstract

As economic growth in the countries of Northeast Asia continues, there will be an increasing need for the services that energy, and particularly electricity, can provide. Growth in the need for energy services in the region translates, under a "business-as-usual" scenario, into a 140 percent increase--from about 500 to about 1200 gigawatts (GW)--in regional electricity generating capacity between 1995 and 2020.

This paper describes the compilation of two country-by-county scenarios of electricity supply in Northeast Asia. Estimates of annual electricity generation by plant type were used to estimate the production of several classes of nuclear wastes, including low-level wastes, spent fuel, plutonium in spent fuel, and the biologically important isotopes Strontium-90 and Cesium-137. Estimates of the production of spent fuel were used to estimate requirements for "Dry Cask Storage" of irradiated nuclear fuel assemblies. Dry Cask Storage would appear to be a workable option, at least on an interim basis, for isolating spent fuel from nuclear installations in the region.

Independent of the systems for waste isolation (or recycling) chosen, the quantities of nuclear materials implied in either of the two scenarios will require regional cooperation on nuclear fuel and nuclear waste technologies, handling protocols, and planning.

II. Introduction and Background

By virtually every estimate, the growth in the demand for energy services--and, not entirely directly, for the fuels that supply energy services--will grow enormously in Northeast Asia over the next 25 years. Growth in demand for electricity, arguably the most convenient and versatile of commercial fuels, is sure to outstrip even the substantial growth of overall energy demand in the region. The rapid increase in electric generation capacity in the region in the past two decades is projected to continue, if not accelerate, particularly as China continues on its current development path. The limited endowment of fossil fuels, large and growing populations, and limited land area of many of the countries in Northeast Asia have, along with other social, political, and environmental considerations, spurred several countries to develop vigorous programs of building nuclear power facilities as a means of supplying electricity demand. Although many of the countries of Northeast Asia have plans for continued growth in nuclear power development, a combination of economic, social, and environmental concerns about these plans have been raised by a number of different constituencies over the last decade or so. Chief among these concerns is the question of what to do with the spent nuclear fuel and other radioactive wastes from civilian nuclear programs. In this paper we explore the ramifications of two different scenarios of growth in nuclear power use in the

Northeast Asia region, including the relative production of nuclear wastes under each scenario; different options for waste disposal, storage, or treatment; and possibilities for regional cooperation on issues associated with nuclear power and nuclear waste.

1.1. Growth in Electricity Demand and Supply in Northeast Asia

In greater China and in South Korea, electricity demand and supply rose rapidly from the 1980s through 1994, with electricity generation in China alone growing at 8.9 percent per year. In Japan, electricity generation grew at 3.0 percent per year during the 1980s, slowing to a somewhat more modest 2.6 percent per year between 1990 and 1994. Overall, the six countries in the Northeast Asian region (ROK, DPRK, Japan, PRC, Taiwan, and Hong Kong) increased their generating capacity by 25 percent in just four years, from 368 GW in 1990 to 460 GW in 1994. Nuclear generating capacity region-wide increased from 20 GW in 1982 to 42 MW in 1990 and 53 GW in 1994.

Our overall approach in estimating nuclear waste generation in the countries of Northeast Asia was as follows:

1. We compiled energy statistics for 1990 and 1995 for each of the countries studied, including data for electricity demand (by sector and subsector) and for electricity supply (by plant type and, in some countries, by plant).
2. We used the compiled information as the "base year data" for development of scenarios of electricity demand for each country covering the period from 1990 to 2020. As a quantitative structure for these scenarios we used the LEAP (Long-range Energy Alternatives Planning) software package. The LEAP package allows the development of detailed end-use (demand) based energy scenarios across all fuels, as well as evaluation of the physical, economic, and environmental impacts of scenarios.
3. We developed two different scenarios of nuclear power development in each country. The first, "base case" scenario generally reflects energy sector development in a way that continues recent trends. In the nuclear energy sector, the Base Case scenario typically includes primarily plants that are already under construction as of 1996, or are well into the planning phase. The second scenario for each country, a "Maximum Nuclear" scenario, reflects more aggressive development of nuclear power, typically consistent with higher-case estimates by groups such as the IAEA (International Atomic Energy Agency). The amount of electricity used in each country in each year is essentially the same in both the Base Case and Maximum Nuclear scenarios. In the Maximum Nuclear scenarios, the additions of non-nuclear generating capacity are reduced from Base Case values in such a way that the reserve margin (a measure of how much generation capacity is available above the level of peak power demand) is roughly the same in the two scenarios.
4. We ran the models to generate estimates of electricity demand (by sector) and of electricity generation (by fuel and technology type) for each country for each year from 1990 to 2020.
5. We applied waste generation factors (for low-level waste, spent fuel, Plutonium, Strontium-90, and Cesium-137) to the estimates of nuclear electricity generation by year and by technology to estimate the amounts of radioactive wastes, by country and by year, implied in each scenario.
6. We estimated the impacts of nuclear fuel reprocessing options on generation of nuclear wastes, and the potential costs of "dry-cask" technology as a spent-fuel storage alternative.

In preparing energy-sector models and scenarios for each of the countries of Northeast Asia, we have built upon ongoing work in a Nautilus Institute Project entitled "East Asian Energy Futures", as

well as the authors' ongoing analytical work on the energy sector in the DPRK and other Nautilus projects.

III. Conclusions and Issues for Further Study

1. Conclusions

Some general conclusions from our work are as follows:

* Growth in electricity demand in Northeast Asia over the next two-plus decades will be enormous if current economic trends continue. On the order of 700 GW of generating capacity will have to be built between 1995 and 2020, although aggressive programs to increase the efficiency of electricity end-uses might be able to reduce the required capacity to some degree.

* In our Base Case scenario, the fraction of capacity provided by nuclear power in the countries of Northeast Asia decreases on a regional basis and in each country except China (which has just started its nuclear program) and the DPRK (which has no operating reactors at this time). In the Maximum Nuclear scenario, nuclear power's share of total regional capacity increases from 11 percent in 1995 to 17 percent in 2020.

* Under the Base Case scenario, the total nuclear capacity in the six countries we have modeled will be 89 GW by 2020. In the Maximum Nuclear case it is more than twice as high, at 202 GW.

* Under either scenario, significant quantities of nuclear wastes will be produced. Between 1990 and 2020, approximately 50 to 70 thousand tonnes of spent fuel containing 450 to 620 tonnes of plutonium will have been generated. These figures, of course, do not count the wastes that will be produced over the remainder of the lifetime of the reactors installed during 1990 to 2020, which will be particularly in the case of the Maximum Nuclear scenario-considerable.

* Dry cask systems for medium and long-term storage of spent nuclear fuel at reactor sites seems to be an attractive, affordable option for handling at least some of the radioactive by-products of nuclear power generation. Though dry cask storage does not render spent fuel completely inaccessible (with the right equipment, casks can be opened, and fuel removed), it keeps fuel handling and transport to a minimum, and makes storage locations relatively easy to safeguard.

* Independent of the systems for waste isolation (or recycling) chosen, the quantities of nuclear materials implied in either the Base Case or Maximum Nuclear scenario will require some sort of regional cooperation on nuclear fuel and nuclear waste technologies, handling protocols, and planning. Some of the issues associated with regional cooperation on nuclear matters are discussed below.

2. Issues for Further Study

Japan and South Korea are already major users of nuclear power, China is starting a nuclear program, and North Korea is scheduled to receive 2 GWe of nuclear capacity as a part of the Agreed Framework. As the ROK will play a major role in providing equipment for and constructing the nuclear plants in the DPRK, nuclear cooperation between those countries, at least as far as plant assembly and (probably) operation, is a given.

The issue of how to manage the various categories of nuclear waste arising from the operation of nuclear reactors, however, has not been settled in a satisfactory way in any of the countries of the region. Proposals have been made for an "Asiatom" or a "PacificAtom"-a cooperative regional organization designed to coordinate nuclear activities in the countries of the region (and possibly, in

the more distant future, found and manage a regional waste repository). Even short of such a formal regional organization, the ROK and Japan have expertise and technology in techniques for handling of nuclear materials that could be made available to assist the nuclear programs of other countries in the region.

As with nuclear power, spent fuel managers face a set of common challenges whether spent fuel is stored on a national or a regional basis. However, centralized, regional spent fuel management would have to surmount an additional series of obstacles to succeed. These latter factors--any one of which could make implementation of such a scheme impossible--are outlined briefly in the following sections.

2.1. Technical Issues Regarding Nuclear Waste Management

A number of states in East Asia--most notably Taiwan and South Korea--argue that within a few years, they must either send spent fuel offshore for reprocessing and interim storage, or find some other solution to interim storage of reactor spent fuel. This argument follows from the fact that spent fuel ponds are now crowded and nearly full, even with increased density of racking. The disposition and treatment of spent fuel is linked closely to desires to extract plutonium and recycle it as mixed oxide fuel in light water reactors or as start up fuel for the breeder reactor in Japan. This goal is also sought in order to circumvent domestic opposition to national spent fuel storage by shipping it to a regional repository, to simply to preserve the option of a plutonium-based nuclear fuel strategy in the future.

However, it is not evident why dispersed, national interim spent fuel storage--either at a national facility (such as that planned for Japan) or on existing reactor sites--would not be the best technical solution for the few decades. This "distributed" solution minimizes transport and diversion-related hazards, and may be less susceptible to wartime and seismic threats as well as cheaper than regional, centralized spent fuel storage. Above all, building such local facilities at reactor sites using dry casks would be highly visible and might force local and national communities to address the issue of wisdom of producing more spent fuel until a long term disposal technology becomes available.

2.2. Institutional Issues Associated With Waste Management Regimes

The most intractable difficulties which would arise with a regional spent fuel storage system would likely be not technical, but political and institutional in nature. It is not obvious what would be a non-controversial membership or what boundary of "regional" would best serve such a system. China and South Korea could be expected to block Taiwan and North Korean membership, respectively. An "Asia" or "Asia Pacific" region which spanned North and Southeast Asia and possibly South Asia would not correspond to any existing regional entity, and the various states with nuclear spent fuel problems to solve have widely varying technical capabilities, nuclear weapons status, and political power. They range from nuclear armed superpowers (Russia, United States), to nuclear armed great power (China) to near nuclear (India and Pakistan) to nuclear powered but nuclear free (Japan, South Korea) great or medium-sized state, to nuclear powered and isolated medium sized state (Taiwan), to nuclear weapons aspirant but nuclear free (North Korea) to non-nuclear but candidate state for spent fuel storage (Australia). It is certain that the host for a regional spent fuel facility would have to be an existing and declared nuclear weapons state--which boils down to China and Russia as candidates. The former has a major problem of mistrust with many of the potential participating states, while the latter has a legal constraint on spent fuel imports.

Even if these hosting and membership issues could be solved, many practical institutional issues would have to be addressed, including the ownership and control of special nuclear materials in or

separated from the spent fuel stored in a regional repository, the transparency of the physical flows and accounting for national shipments to and from such a facility, the potentially infinite longevity of such a facility should it prove impossible to return all the wastes to states of origin, and the specific timing of attempts to create such an arrangement given all the other regional geopolitical, geoeconomic, and even geopolitical issues which could have priority over proposals for centralized, regional spent fuel storage.

2.3. Economic Issues Associated With Nuclear Power And Nuclear Wastes In Northeast Asia

The costs of interim spent fuel storage, whether for a centralized, regional facility or for dispersed, national facilities, are relatively small, both absolutely, and as a fraction of the cost of electricity generated by nuclear reactors. However, the distribution of costs and benefits of interim spent fuel storage will play an important role in determining the political feasibility of any such scheme, regardless of whether it is a centralized regional or a dispersed national approach. In reality, the only scheme for a regional, centralized repository which is likely to be feasible given the intense political concerns surrounding nuclear fuel cycle issues in this region is a market-based commercial scheme employing primarily private funds.

China is the only state in the region that could legally and politically pursue such an approach, but lacks the public or private financing ability to create such a facility. Thus, China's capability would be dependent on an external financier coming forth, which in turn would be subject to the interplay of much larger geopolitical and geoeconomic issues relating to China's role in the region.

At the national level, the distribution of costs and benefits has also proven to be a crucial issue in South Korea and in Japan in obtaining political legitimacy for spent fuel storage and reprocessing facilities (the Rakkasho facility may become a national interim spent fuel site for Japan, pending the resolution of legal and financing issues between Tokyo and the local community).

What seems clear is that commercial interests will predominate in the long-run development of interim spent fuel sites as the electricity utility sector is deregulated in Japan and South Korea (which will accelerate under the new IMF-directed economic policies in South Korea). As Frans Berkhout notes, all the effective multinational nuclear waste management schemes in recent decades have arisen from trade in nuclear fuel services, not from government-led initiatives.

2.4. Security impacts of Different Nuclear Fuel Cycle Futures

The location and centralization/dispersion of stored spent fuel has important implications for the possibility for terrorist attacks and seizure of fissile materials; for the clandestine diversion of fissile materials by governments in the region; for wartime missile or aerial attack; and depending on the monitoring and verification aspects of interim spent fuel storage, on the confidence in the global and regional nuclear non proliferation regimes. Each of these factors bears close examination when comparing the desirability of regional, centralized repositories versus national, dispersed facilities.

Of particular importance is the relationship between regional spent fuel storage and the plutonium economy. If the regional option is adopted in order to preserve or to facilitate plutonium recycling in light water reactors, or breeder reactor programs as in Japan, then the differential risk/benefit ratios of the regional-centralized versus national-dispersed approaches may shift dramatically in relation to these security criteria.

Some have argued that even though a regional repository may be impossible to realize, a dialogue to examine its feasibility and desirability may itself generate mutual understanding and confidence. However, it is not true that dialogue always generates understanding and confidence. We argue that

unless the underlying assumptions are explored and the empirical and technical validity and soundness of concepts are examined collaboratively, such a dialogue may lead to diversionary debates with respect to the real issues involved with realizing regional and global energy security, and could even destroy rather than build confidence in the region between already suspicious past and present adversaries.

2.5. Potential Legal Obstacles To Nuclear Development In Northeast Asia

Although the market will likely militate against regional and increasingly national government-led interim spent fuel arrangements linked to reprocessing, any regional scheme faces legal obstacles, any one of which could prove impossible to surmount. These include: US and uranium supplier bilateral agreements controlling the disposition of spent fuel from light water reactors in Japan, South Korea, and Taiwan; domestic laws concerning the disposition of spent fuel at the time of reactor licensing; and Russian laws against importing foreign nuclear wastes. In addition, certain national legal and political commitments such as the Korean Denuclearization Declaration would make it difficult if not impossible for some parties such as North and South Korea to join in schemes which revolve around offshore regional reprocessing and/or mixed oxide recycling.

2.6. The Role of Transparency in Nuclear Power Development

Decision-making in relation to national and utility level commitments to nuclear power and fuel cycle operations is becoming increasingly transparent in two respects.

First, the slow but steady democratization of the polities of the region and the emergence of vibrant civil society and non-governmental organizations has increased the pressure on governments and fuel cycle agencies to open their books, both with respect to subsidies and financing arrangements linking nuclear power to the public purse; and to the safe, accountable operation of facilities. This trend has been most pronounced in Japan and South Korea, and tends to reduce the likelihood of regional arrangements. Indeed, such schemes may be confidence destroying rather than confidence building as proved to be the case with the Taiwan-North Korea low level waste deal as it unravels in the face of intense opposition emanating from South Korean anti-nuclear organizations such as Green Korea.

Second, a much higher level of transparency with respect to long-run energy and nuclear energy planning is likely a precondition to any intergovernmental agreement to create a regional spent fuel storage scheme. Most of the official projections of nuclear power are highly optimistic. Consequently, these projections overstate the likely quantities and therefore the need for spent fuel repositories. A realistic and consensual basis for analyzing the cost-benefit ratio of such schemes would be an essential preliminary activity in exploring regional spent fuel options, assuming that the political issues arising from transparency referred to in the previous section could be overcome.

2.7. Environmental issues

A regional facility will be subject to review from many quarters on environmental grounds in terms of the risks and benefits of prospective siting and related transport of spent fuel and/or plutonium to and from the site; and to the extent that such a facility could hold the key to the long-run survival of the nuclear fuel cycle by preserving the plutonium option-an argument now made in particular by some Japanese proponents-it will be reviewed also with regard to the putative positive impacts of nuclear power on a range of local, regional (acid rain), and global (greenhouse gas) emissions-both in terms of direct avoidance of these damaging emissions, and in terms of the opportunity cost of foregone emissions-avoided if the requisite nuclear-related investments had been directed toward alternative and likely cheaper ways to achieve the same ends. In addition, liability and insurance

issues arising from a centralized, regional spent fuel storage and transport system will have to be addressed, especially in relation to trans-boundary movements and possible impacts from accidental releases of nuclear materials.

2.8. Political Aspects

In any regional spent fuel repository, the symmetries and a-symmetries of capabilities and influence will be crucial to success or failure. In particular, the perceived legitimacy of the leading states and interested parties involved in such a scheme will determine whether such a scheme could even get off the ground, let alone succeed. Given the enormous variation in scale, fuel cycle capabilities, energy needs, social systems, and economies-not to mention the role of civil society-among and within the potential member states, it is dubious whether such a scheme is viable.

One thing is crystal clear after fifty years of nuclear fuel cycle development in the region. Public opinion now affects public policy and political decisions relating to the nuclear fuel cycle in every state in the region. Public opinion-and its increasingly trans-national determinants--cannot be ignored or merely managed as a public relations problem for regional spent fuel repositories. Rather, unless there is strong public support in each and every participating and affected state, such schemes are likely to generate more political heat than useful energy, and to destroy rather than to build confidence. In our view, the onus to prove otherwise rests heavily on the proponents of such schemes.

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Nautilus Institute

2342 Shattuck Ave. #300, Berkeley, CA 94704 | Phone: (510) 423-0372 | Email:

nautilus@nautilus.org