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A Regional Compact Approach for the Peaceful Use of Nuclear Energy

Case Study: East Asia

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Executive Summary

Nuclear power cannot be a major energy source in the world's energy economy unless the problem of spent fuel management and radioactive waste disposal is resolved; global fears of nuclear weapons proliferation, a great impediment to nuclear-energy use in developing countries, are mitigated; the costs of nuclear energy production are lowered; and unfavorable public perception of reactor safety, intensified by the Three Mile Island mishap and the Chernobyl disaster, is overcome.

Given the global trend toward more regional economic development, group security arrangements, and collaborations on safety issues that transcend national boundaries, a possible solution to these problems in East Asia is the formation of a regional nuclear energy compact for nuclear cooperation. Such a compact could resolve East Asian nuclear proliferation and waste management concerns through effective spent fuel and special nuclear material (SNM) accounting, management, and final disposition. It could establish appropriate nuclear power plant operation safety cultures to allay public fears, and could also promote regional economic cooperation supported by a reliable, cost-effective, and environmentally sound nuclear energy supply.

The East Asian regional compact, comprised of China, Japan, North and South Korea, Taiwan, and the Russian Far East, contains declared nuclear weapons states (China and Russia) and a potential nuclear rogue country (North Korea). As a result this region is the site of an intense contest for nuclear influence, and also the focus of security concerns. It also contains fast-growing and energy-dependent economies (China, Japan, South Korea, and Taiwan) and sizable and ambitious nuclear energy programs (Japan and South Korea), making it the most dynamic nuclear energy development region in the world today. Countries and areas in the region share proximity and common needs for a stable and reliable energy supply, radioactive waste disposal, reactor safety, and regulatory standards. They also share territorial disputes, overlapping security interests, both interdependency and competition in regional economic expansion, and a historically rooted mutual mistrust of expansionist aims. The likelihood of forming a regional cooperative framework in East Asia depends not only on the goodwill of the countries and areas and their desire to join, but may also require the participation of the United States, especially in the formation phase of the framework.

Because of the unique histories, cultures, economic systems, and nuclear programs of East Asia, a model similar to Euratom may not be suitable for the region. Instead of rushing into forming a Euratom-like organization, a realistic and appropriate first step would be to set up forums (or work groups) where countries and areas can engage in dialogue on nuclear energy, environmental awareness, nuclear nonproliferation, nuclear safety, spent fuel and radioactive waste management, and economic cooperation. The outcomes of the dialogue would be used to formulate appropriate consensus for a cooperative framework for East Asia.

Forums and meetings would be held during a three-year formation phase of the compact framework. A decision to form or not to form would be made at the end of the three-year period. If the decision is positive, activities essential for the objectives and the formation of an East Asian regional compact would be carried out by a formal organization staffed with representatives from the United States and all six East Asian countries and areas. These activities are:

Radioactive Waste Management

- To select a host country (or countries) to provide spent-fuel storage and radioactive waste disposal.
- To set agreeable criteria for contracts and financial compensation to the host country(ies) for providing such services.
- To initiate and implement research and development programs on waste disposal, essential for determining the proper back-end nuclear fuel-cycle policy.

Nuclear Nonproliferation

- To establish a regional SNM monitoring and control regime.
- To promote transparency of regional nuclear programs.
- To provide coordinated management and inspection of separated SNM by technical experts from countries of the region, complementing the IAEA safeguards and security programs.
- To establish a network of fuel-cycle facilities, adhering to the region's back-end nuclear fuel-cycle policy and the SNM control regime.
- To ensure a reliable supply of fresh nuclear fuel and the delivery of spent nuclear fuel to and from the fuel-cycle facilities and the member countries, and safeguards and security for transport of these materials.

Nuclear Safety

- To cultivate and enforce a regional safety culture for nuclear facility operations, based on accepted international regulations and standards.
- To develop prudent safety practices, and provide training to regional operation personnel.
- To coordinate regional emergency response to radiation release accidents.
- To ensure safety in transporting nuclear materials in international waters and across national boundaries.

Economic Cooperation

- To establish a regional development banking network for providing loans at favorable terms to regional nuclear energy development programs.
- To promote regional economic cooperation through stable, economical, and environmentally acceptable sources of nuclear energy.

1.0 Introduction

Nuclear energy, once deemed a cheap, abundant, and environmentally benign energy source, has been plagued by:

- Problems of management and disposal of spent fuel and radioactive wastes.
- Concerns over nuclear proliferation, and theft and diversion of separated nuclear materials.
- Adverse public perception of nuclear safety due to events at Three Mile Island and Chernobyl, and of the long-term disposal of radioactive wastes.
- Steep competition from electricity generation from other fuel sources, especially in countries with deregulated (or privatized) utility industries, and increases in operating costs because of plant aging and degradation, leading to premature plant shutdown and burdens of “stranded assets.”

Radioactive waste management. The generation of nuclear energy in light-water reactors (LWRs) using low-enriched uranium (LEU) as fuel produces spent fuel which contains plutonium as a by-product. The spent nuclear fuel is stored in cooling water pools at reactor sites, and is eventually destined for final disposal in a geologic repository. There are an increasing number of utilities in many nuclear power countries, however, whose spent fuel inventory will exceed their spent fuel storage capacity before a geologic repository is available. These utilities must expand their interim storage capabilities for spent fuels or face premature shutdown of their reactors. Dry storage of the spent fuel is an option, but the storage casks are usually stored above ground at reactor sites, visible from local communities and thus often a source of anxiety and opposition from the public.

Spent nuclear fuel can be reprocessed using a conventional aqueous process, a management method adopted by many nuclear power countries, including France, the United Kingdom, Japan, and Russia. Spent-fuel reprocessing separates uranium and plutonium from other highly radioactive materials in the spent fuel. The separated uranium can be re-enriched and fabricated into UO_2 fuel for recycle. The separated plutonium can be mixed with natural uranium (or depleted uranium) and fabricated as MOX fuel and recycled into the reactor to produce nuclear energy. The remaining radioactive materials are vitrified, most likely into borosilicate glass, and eventually destined also for final disposal in a geologic repository.

In addition to spent nuclear fuel from commercial power-producing reactors, in many countries spent fuel is produced from other types of reactors, such as research, weapons-production, and naval reactors. The nature of the radioactive waste disposal may be different for different back-end fuel-cycle policies adopted by these countries. The political difficulties of siting waste repositories are the same, however, and are immense in countries with dense populations and small geographic areas, such as Japan.

*Nuclear nonproliferation***.** The separated plutonium, deemed "nuclear-weapons usable," can also become a source of nuclear proliferation. The United States is very concerned with what to do with the separated fissile materials (Pu^{239} and U^{235}) from dismantled weapons and from fuel-reprocessing facilities, and specifically about the potential for theft and diversion of these materials in countries where appropriate material control and accountability systems are not in place. The world is already awash in separated fissile materials, especially weapons-usable plutonium. There are hundreds of tons of plutonium in deployed weapons, in weapons marked for dismantling, in scrap at nuclear weapons production complexes, and in stockpiles at fuel-reprocessing plants. In addition, each year the 440 commercial power reactors that are scattered over thirty countries produce 6,000 to 7,000 tons of spent nuclear fuels containing roughly 60 to 70 tons of plutonium.

The management and disposal of spent nuclear fuel produced by nuclear reactors (civilian, research, production, and naval) and the separated fissile material (Pu^{239} and U^{235}) from dismantled nuclear weapons and reprocessed spent fuel are currently among the most pressing environmental and proliferation problems. Solutions to the problems of nuclear waste management, along with answers to concerns over nuclear proliferation, are urgently needed.

Nuclear safety. The public's confidence in nuclear power has been greatly diminished since the mishap at Three Mile Island (TMI) and the catastrophic accident in Chernobyl. Although the partial core melt in the Unit 2 reactor at TMI in 1979 caused no human casualty, the incident brought about excessive regulations and numerous safety "fixes," resulting in delay of new plant construction and significant cost increases. The accident at the Chernobyl nuclear plant in 1986 demonstrated that major nuclear accidents can have a far more widespread effect than accidents involving any other source of energy production. It also provided proof of the transnational nature of nuclear safety. The Chernobyl accident has practically bankrupted the energy economy in Ukraine, and continues to cast a long shadow of safety concerns over the nuclear industry worldwide.

Technologically advanced Japan has also felt the impact of concerns over nuclear safety. In December 1995, a sodium leak in the secondary loop of the 280 MWe Monju fast breeder reactor (FBR) prompted a shutdown of the reactor. About 700 kg of non-radioactive sodium was lost in the leak, which was caused by a broken thermowell. The Power Reactor and Nuclear Fuel Development Corporation (PNC), a government corporation that operates Monju, admitted that there was a failure in its command structure at the time of the leak, and the deputy general manager investigating the incident committed suicide. The incident shook the foundation of the public's trust in the government on the country's nuclear matters, and resulted in opposition by several local communities to the construction of new nuclear plants in Japan.

Economic competitiveness. Public skepticism over nuclear safety and the long-term disposal of radioactive wastes have undermined the credibility, if not the viability, of many nuclear power industries. The nuclear power industries of the United States and the United Kingdom, while in the midst of adjusting to deregulation and privatization, also face steep competition from electricity generated from other fuel sources.

A recent study commissioned by the Interstate Natural Gas Association of America Foundation reported that thirty-seven nuclear power plants, representing 40 percent of the United States' nuclear generating capacity, could be forced to close early, driven out of business by over-market production costs. Most of the power reactors in the United States were custom built, making the costs of operation and maintenance of these plants very high. Fortunately, this is not the norm in the nuclear power industries in other countries. France and South Korea, for example, have standardized their plants, and Japan has worked diligently to keep its nuclear operation and maintenance costs low to maintain a competitive edge in overall costs over fossil plants. Also, because not all countries have access to other cheap fuel sources for electricity generation like the United States, their reliance on nuclear for electricity generation is clear. Increasing competition and deregulation in the electric power industries in several of these countries, however, will place extreme financial pressure on the utilities and make investments for new plant construction, or continued operation of existing non-economical plants, harder to justify.

The Case Study

Given the trend toward more regional economic development, group security arrangements, and collaboration on nuclear issues that transcend national boundaries, a possible solution to these nuclear problems is the formation of a regional compact[1] for the peaceful use of nuclear energy. Such a compact, as proposed here, could resolve waste-management and nuclear proliferation concerns through regionally coordinated spent fuel and SNM accounting, management, and final disposition. It could establish appropriate regional safety cultures for operating nuclear facilities in order to allay public fears, and could also promote regional economic cooperation supported by a reliable, cost-effective, and environmentally sound nuclear energy supply.

This study explores an East Asian regional compact for the peaceful use of nuclear energy. The proposed East Asian regional compact is comprised of China, Japan, North and South Korea, Taiwan, and the Russian Far East. The compact would cover declared nuclear weapons states (China and Russia) and a potential nuclear rogue country (North Korea). It also would contain fast-growing and energy-dependent economies (China, Japan, South Korea, and Taiwan) and sizable and ambitious nuclear energy programs (Japan and South Korea).

Countries and areas in the East Asian region share proximity and common needs for a stable and reliable energy supply, radioactive waste disposal, reactor safety, and regulatory standards. They also share territorial disputes, overlapping security interests, both interdependency and competition in regional economic expansion, and a historically rooted mutual mistrust of expansionist aims.

The main thrust of the study is a consideration of the feasibility of such a regional compact for East Asia. It examines the need for an East Asian regional compact framework, identifies the mutual interests that could bring this diverse group of countries together, and suggests a modest approach for pursuing a regional framework for nuclear cooperation in East Asia.

Section 2.0 describes the regional compact approach and gives examples of possible compact formations among current and future global nuclear programs, including those in East Asia.

The present and future nuclear programs in China, Japan, South Korea, Taiwan, North Korea, and the Russian Far East are summarized in Section 3.0.

The need for an East Asian regional compact framework is examined in Section 4.0. The examination is based on criteria of energy, environment, security, safety, domestic policy and politics, and economics. Discussions include whether now is the appropriate time to establish a nuclear cooperative framework in East Asia and the type of regional framework that should be established.

The examination also explores the role the United States would play in an East Asian regional compact. It argues that the status quo in regional nuclear matters, a result of the United States' emphasis on bilateral agreements, is problematic, and suggests a multilateral compact approach as a viable option.

Section 5.0 describes the objectives of the East Asian regional compact framework, and Section 6.0 discusses how a regional framework for nuclear cooperation in East Asia might be pursued.

Section 7.0 presents the conclusions and some thoughts regarding further studies.

The appendixes consider the impact of an East Asian regional compact on regional nuclear issues. These are:

1. U.S. nuclear export controls to China
2. The peaceful use of plutonium in Japan
3. South Korea's research on DUPIC
4. Taiwan's security concerns and spent fuel management problem
5. The U.S.–DPRK Agreed Framework
6. Russia's nuclear wastes in the Far East
7. Uranium enrichment and front-end nuclear fuel-cycle policies
8. Spent fuel management programs and back-end nuclear fuel-cycle policies

2.0 A Regional Compact Approach for the Nuclear World

Nuclear energy, which currently supplies 17 percent of total worldwide electricity demand, cannot be expanded into a continuing major source for the global energy economy unless the problem of spent fuel management and radioactive waste disposal is resolved; international fears of nuclear weapons proliferation, a great impediment to nuclear-energy use in developing countries, are mitigated; the costs of nuclear energy production are lowered; and unfavorable public perception of reactor safety, intensified by the Three Mile Island mishap and the Chernobyl disaster, is overcome.

Radioactive wastes from nuclear reactors pose a long-term health risk to humans. Because of their longevity, radioactive wastes must be properly managed to ensure prolonged isolation from the biological environment. Many countries with advanced nuclear energy programs presently are exploring the possibility of permanent waste disposal in underground geologic repositories. The political difficulties of siting such waste repositories are immense, however, especially in countries with large populations and small geographic areas.

Proliferation resistance in the nuclear fuel cycle is an essential element in reducing the risks to society associated with possible theft or diversion of fissionable nuclear materials. However, since it is not technically feasible to prevent the atom used for peaceful means from being used militarily, any proliferation-resistant fuel cycle would require political agreements, possibly supplemented by regional and international safeguards and inspection.

Regarding safe operation of nuclear facilities, the events at Three Mile Island (TMI) and Chernobyl indicate that radioactivity and public concerns about radiation fallout can transcend national borders, with neighboring countries being the most affected. The significant overhaul of U.S. regulations following the TMI incident has resulted in considerable increases in the capital and operating costs of nuclear power plants. The aftermath of the Chernobyl accident continues to cast a long shadow over the safety of nuclear power operation, especially for reactors designed and operated in Eastern Europe.

In the post–Cold War era, when economic development and raising the standard of living command high priorities, countries seek regional economic cooperation and form regional trade pacts. A stable and reliable energy supply is foremost in importance for regional and global economic development. Hence, a framework for a regional compact for the peaceful use of nuclear energy is essential to reach the goal of sustainable economic development.

Regional nuclear compacts could serve as centers for regional cooperation and coordination of civilian nuclear programs consistent with the resources of the region. The selection of nuclear fuel-cycle policies by the member countries would be based on the fuel-cycle services made available by the more advanced nuclear energy countries of region, conforming to international norms. The regional compacts could offer regional fuel supply, including enrichment and fuel fabrication; assistance in nuclear facility operation; interim storage and/or long-term geologic disposal of spent fuel; spent-fuel reprocessing; recycled fuel fabrication; and long-term disposal of reprocessed high-level radioactive wastes. The regional safeguards and nonproliferation systems would supplement and complement the safeguards, objectives and obligations of the International Atomic Energy Agency (IAEA). The objectives of the regional compact are:

- *Radioactive waste management*. To provide regional spent-fuel storage facilities and a waste repository located in a host country (or countries) for the disposal of radioactive waste generated by countries of the region.
- *Nuclear nonproliferation*. To establish a material control regime where the production of special nuclear material is controlled and monitored by regional personnel and supported by IAEA safeguards and security systems.
- *Nuclear safety*. To implement a safety culture and regulate regional nuclear power stations with internationally accepted safety standards and requirements.
- *Economic cooperation*. To promote economic cooperation among countries in the region through stable, economical, and environmentally acceptable sources of nuclear energy.

The major elements of a regional compact are:

- **A region**, such as the North America Free Trade Agreement (NAFTA) group, the Euratom, and the Eastern European countries (the former Soviet Union and its satellite states).
- **Host country(ies)** to receive spent fuel and radioactive wastes from other member countries for storage and/or disposal. The host country(ies), which would receive financial compensation from participating member countries, could operate regional fuel-cycle center(s) to provide fresh fuel to and receive spent fuel from regional reactors. Fuel enrichment and reprocessing services would preferably be provided in host countries that already are declared nuclear-weapons states, and/or otherwise be inspected and monitored by personnel from member countries.
- **Member countries** to operate their nuclear facilities for peaceful purposes. They would maintain a safety culture and standard for the region's nuclear facilities, conforming to the international norm. They would also pay the host country for the fuel-cycle services and provide personnel for safeguards and inspection of regional fuel-cycle facilities to ensure transparency of nuclear intent and secure separated nuclear materials.
- **The IAEA** to assist the regional compact in safeguards and security and to promote the use of internationally accepted safety standards and requirements for safe operation of regional nuclear facilities.

Three different types of regional compacts could be formed, based on different groupings of countries in a region, their nuclear policies, the size of their nuclear energy programs, and the availability of suitable repository sites. These are:

Regional Compact	Member Countries	Host Country(ies)
A	Consist of declared nuclear weapon state(s), and countries with nuclear power programs. The region has reprocessing and/or enrichment facilities.	Preferably declared nuclear weapons state(s) with sizable nuclear power programs and suitable sites for spent-fuel storage and radioactive waste disposal.
B	Consists of no declared nuclear weapon state, but countries with nuclear programs of varying sizes. The region has no reprocessing and/or enrichment facilities.	Could be any country in the region, preferably one with a sizable nuclear program and suitable storage and repository sites.
C	Same as (B), except countries have small nuclear programs and/or small geographic areas.	No ideal host country. This compact could consider paying other compacts to store/dispose its spent fuel.

At the end of 1995, there were 447 commercial reactors in thirty-one countries, generating a total of 366 GWe of electricity.[2] An additional thirty-nine nuclear units are now in construction in fifteen countries; when all are in operation they will provide a total capacity of 33

GWe. Figure 1 shows the world's nuclear programs, listing for each country the number of nuclear units and the gross capacity (MWe) in operation and in construction, and Figure 2 groups these nuclear programs into possible regional compacts. These compacts are:

1. NAFTA (North America Free Trade Agreement) Compact: The United States, Canada, and Mexico

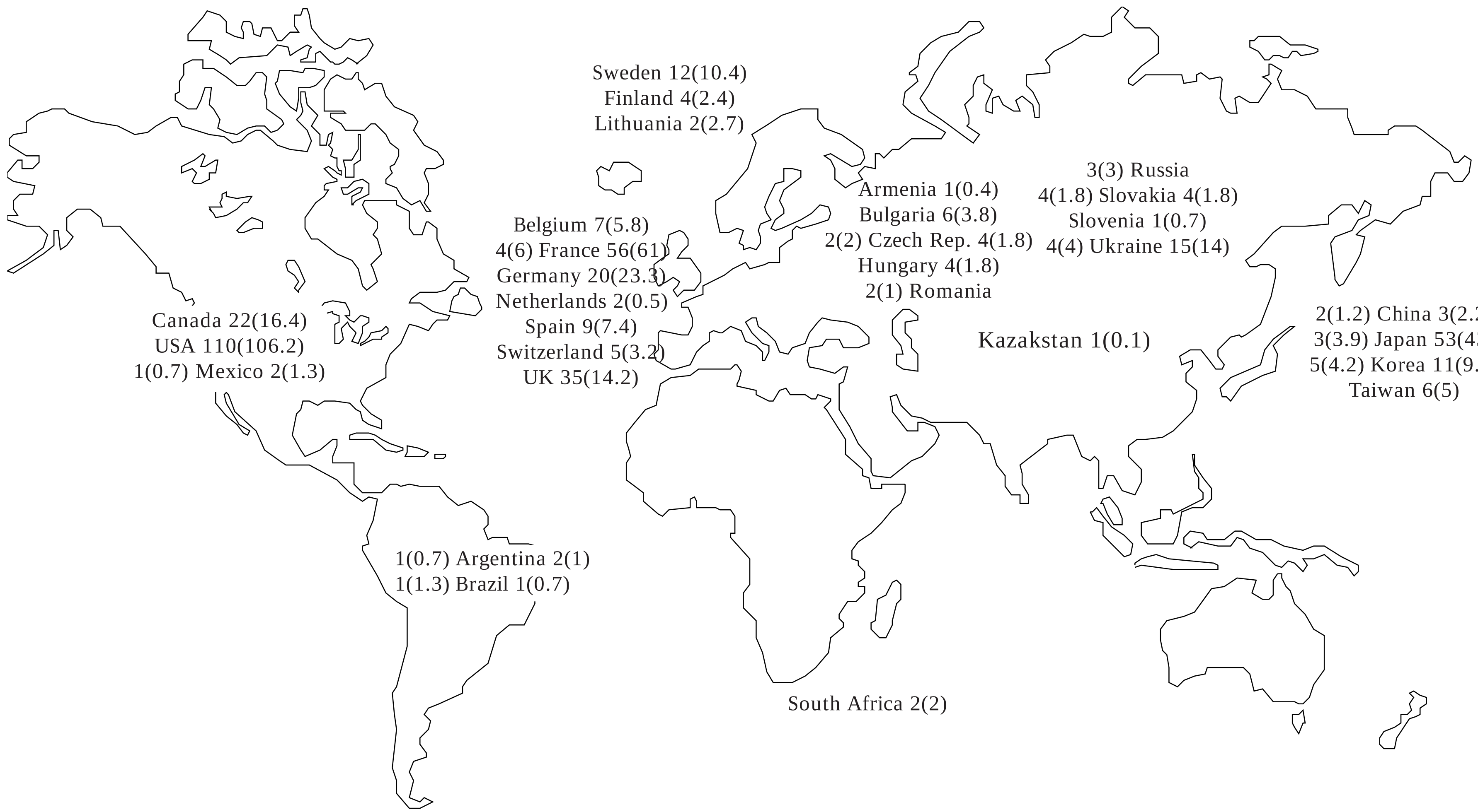
This regional compact would consist of a declared nuclear-weapons state (the United States) and two sizable civilian nuclear programs (the United States and Canada), which together account for about one-third of the world's nuclear generating capacity. The three countries signed the North America Free Trade Agreement (NAFTA) in 1994, forming a regional economic trading bloc. This is an example of a Type (A) compact in which regional countries would directly dispose of their spent fuels.

The U.S. nuclear program, which operates 110 units, accounts for more than 85 percent of the generating capacity in the region, and is by far the largest commercial nuclear power program in the world. The U.S. nuclear program is facing a downturn, however, as there have been no new orders for nuclear reactors since the TMI incident in 1979, and increasing competition and deregulation in the utility industry have created financial pressures that could result in the premature shutdown of some nuclear plants or the mergers of nuclear utilities. There is concern that safety at some plants may be compromised due to cost-cutting efforts to stay competitive. At the same time, the operating costs of existing nuclear plants are rising because of expensive retrofits and maintenance, including sleeving of steam-generator tubings and annealing of reactor pressure vessels. As a result, it is expected that U.S. nuclear capacity will decrease over the next decade as old plants retire and the lack of orders for new plants continues.

Due to a strong nonproliferation policy, the United States does not reprocess any of its spent nuclear fuel, and does not encourage others to do so. Spent fuel storage and disposal remains a political problem for the United States. There is continued uncertainty as to when the U.S. Department of Energy (DOE) will take possession from the utilities of spent fuel accumulating at nuclear power plants, even though the 1983 Nuclear Waste Policy Act required DOE to accept spent fuel by January 31, 1998. And the start-up date of a planned waste repository, possibly at Yucca Mountain in Nevada, has been extended to 2015.

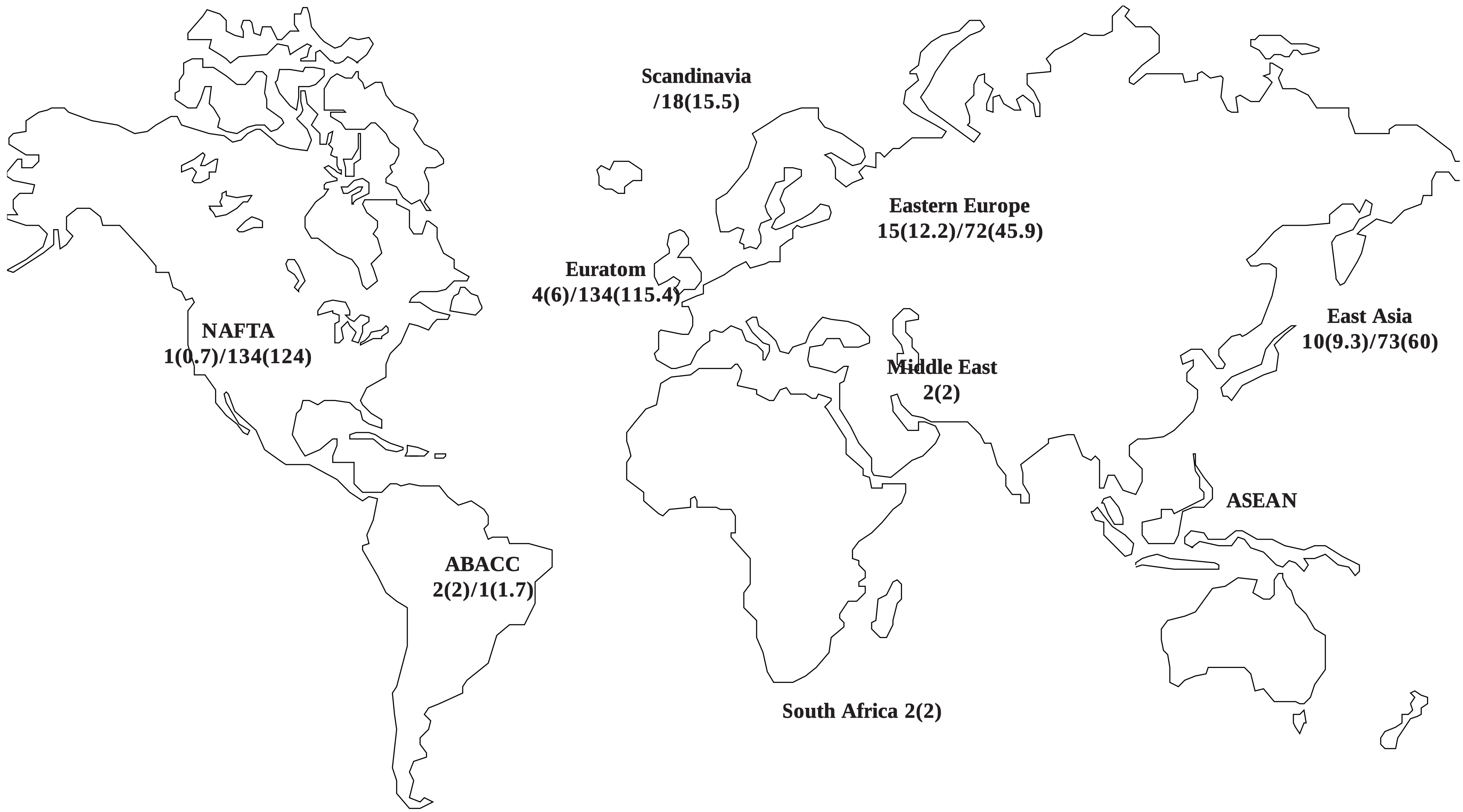
Canada builds and operates the CANDU reactor, a natural-uranium fueled, heavy-water moderated, light-water cooled reactor. The CANDU reactor technology is deemed more proliferation-prone than the light-water reactor technology because of the continuous refueling operation in the CANDU reactor. Nevertheless, Atomic Energy of Canada, Limited (AECL, the CANDU manufacturer) is aggressively pushing for export of the CANDU technology to South Korea, Romania, and Argentina, and has signed an agreement with China National Nuclear Corporation (CNNC) to supply two units of CANDU reactors. Ontario Hydro is the world's largest CANDU utility, operating twenty units and generating 15 GWe capacity for Canada's Ontario province and the northeastern United States. But Canada's nuclear capacity has reached saturation, with no new orders planned for the foreseeable future.

Figure 1: World Nuclear Programs (as of June 1996)



under construction/in operation
units (GWe) Country units (GWe)

Figure 2: Regional Compacts for the Nuclear World



World
under construction/in operation
units (GWe)/units (GWe)
39(33.4)/447(366.5)

2. ABACC Compact (Argentine-Brazilian Agency for Accounting and Control of Nuclear Material): Brazil, Argentina, and other South American countries

The Brazilian and Argentine civilian nuclear programs are too small to have any global impact. But their nuclear programs were at one time of great proliferation concern to one another and to countries outside the region. In the early 1980s both countries were pursuing unsafeguarded nuclear activities including uranium enrichment. In particular, Brazil had imported civilian nuclear fuel-cycle facilities under international safeguards and a parallel indigenous military program that was not under safeguards. There was considerable suspicion that the indigenous program was based upon imported technology, in violation of safeguards agreements.

The advent of civilian governments in the two countries gradually led to more confidence building and a reduction in the nuclear rivalry, and to the creation of a regional safeguards organization, the Argentine-Brazilian Agency for Accounting and Control of Nuclear Material (ABACC). The arrangement allows the Argentines to inspect the Brazilian nuclear facilities and vice versa. ABACC also coordinates its activities with the IAEA.

This could be an example of a Type (B) compact, although neither Brazil nor Argentina has decided on its back-end nuclear fuel-cycle policies.

3. Scandinavian Compact: Sweden, Finland, and possibly the Baltic states

Sweden faces a dilemma: it must decide whether it will shut down its twelve nuclear power plants by 2010, as decided by its parliament after the Swedish Nuclear Referendum of 1980. Political pressure may force Sweden's Social-Democratic government to show its commitment to phase out nuclear power by seeking to shut down at least one nuclear plant before the next election in October 1998. The Swedish nuclear power industry, however, has developed into a major energy provider and now meets half of Sweden's electricity demand. It also provides employment to a sizable skilled workforce. To completely abandon a clean, safe, and economical source of electricity would necessitate greater reliance on imported oil or gas-fired generation, and result in economic hardship as well as increased unemployment.

Anticipating a complete shutdown of its nuclear program, Sweden has been working on a geologic repository for storage and disposal of its spent fuel since 1980. The Swedish repository project is one of the most advanced programs in the nuclear world. Whether this can be a Type (B) compact depends on whether Sweden would accept spent fuel from neighboring countries, such as Finland and possibly the Baltic states. As of now, Finland has decided to build its own spent-fuel repository. The repository site will be chosen in 2000 and construction will begin in 2010–2020.

4. Euratom Compact: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and the United Kingdom

The Euratom Treaty, signed in Rome on March 25, 1957, allows its member states to:

- Develop research and ensure the dissemination of technical information.
- Establish uniform safety standards.
- Facilitate the capital investment needed for the development of nuclear energy.
- Ensure regular and equitable supplies of nuclear fuel.

- Ensure that nuclear materials are not diverted for unintended purposes.
- Exercise the right of ownership of fissile material.
- Create a common market in nuclear material and equipment.
- Ensure free movement of capital and labor for nuclear work.
- Establish links with other countries or international organizations for peaceful use of nuclear energy.

Euratom is the first and the most mature regional compact for cooperation in the peaceful use of nuclear energy. It consists of two declared nuclear-weapons states (France and the United Kingdom) and several sizable civilian nuclear programs. The biggest is the French nuclear program, which operates fifty-six nuclear reactors that provide more than 75 percent of France's electricity needs. France also exports its excess electric power to other European Union (EU) countries. France operates a full scope of nuclear fuel-cycle facilities, from uranium enrichment to fuel reprocessing and waste vitrification, for its own utilities and also for other countries (such as Japan). It is the country most committed to nuclear energy.

The United States has experienced difficulties over the years with Euratom in dealing with issues in the back end of the nuclear fuel cycle. The U.S. Nuclear Non-Proliferation Act requires U.S. consent for the reprocessing or retransfer of U.S.–origin nuclear materials, but Euratom has been reluctant to allow U.S. control over its nuclear activities. The United States previously has dealt with this by giving "programmatic approvals" for such activities, and now, under a new agreement with Euratom signed in 1996, will give "advance consent."

This is a Type (A) compact in which some countries would reprocess their spent fuel and dispose of the reprocessed wastes (France, Belgium), and other countries would directly dispose of their spent fuel without fuel reprocessing (Germany, Spain). Several countries (France, Belgium, Germany) have started site characterization for their own geologic repository.

5. Eastern European Compact: Russia and other states of the former Soviet Union

Nuclear programs in this region are heavily influenced by and dependent on Russian technology. Most of the Eastern European countries operate Russian-designed RBMK and VVER reactors. They also depend on Russian supplies of fresh fuel, and, as agreed before the breakup of the Soviet Union, they transport the spent fuel to Russia's RT-1 fuel reprocessing plant in Mayak.

Since the Chernobyl accident in 1986, Russia and other Eastern European countries including Ukraine have complained that financial support from Western countries to improve the safety of Russian-designed reactors has not been forthcoming. Electric utilities in this region continue to be plagued by problems of low operating staff morale, the difficulty of collecting payment from end users of electricity, aging operating facilities, and lack of funds for safety repairs.

Several countries in this region face a serious shortage of storage spaces for spent fuel. Transport of spent fuel to the Mayak facilities in Russia is no longer an easy option because the Russians demand payment for this service, and until recently storage facilities at Mayak could not accommodate spent fuel from other countries because all the spaces were reserved for Russian reactors.

Under these conditions it is possible that some nuclear plants may have to be shut down, with the full storage of spent fuel under water remaining on site exposed to the risk of corrosion. With the plutonium embedded in the spent fuel, the situation would present safety and safeguards concerns for countries in the region.

This is a Type (A) compact which faces serious problems of spent fuel storage, nuclear safety, safeguards and proliferation, and regional economics.

6. Middle East Compact: Israel, Iraq, Iran, and other Middle Eastern states

Given the historical hostilities and current confrontations among the countries of the Middle East, it is unthinkable that such a regional compact for nuclear cooperation could be formed. Israel has an indigenous nuclear-weapons program and has long been suspected to possess nuclear-weapons capability. Iraq has admitted to United Nations weapons inspectors its effort to acquire nuclear-weapons capability. Iran has restarted the construction of two Russian VVER-1000 reactors at the sites previously built for two PWRs by Siemens of Germany.

When water eventually replaces oil as the most important and contested commodity in this region, however, and when nuclear energy is economical enough for use in desalinating sea water, there may be an incentive for countries in the region to consider a compact framework for nuclear cooperation.

7. South Asia Compact: India, Pakistan, and possibly other neighboring states

Although the generating capacities of their civilian nuclear programs are small, India and Pakistan both have elaborate indigenous nuclear weapons programs. India has a nuclear fuel complex capable of making fresh fuel for its reactors and reprocessing its spent fuel. Pakistan, with assistance from China, could be well on its way to producing highly enriched uranium. Neither country has signed the Non-Proliferation Treaty (NPT) or the Comprehensive Test Ban Treaty (CTBT), making them sources of contention in global nuclear matters.

The United States has long been concerned about the indigenous nuclear programs in India and Pakistan on the grounds of nuclear proliferation and even the risk of a regional nuclear conflict. Mutual security conflicts between India and Pakistan, as well as regional security concerns involving India and China, have increased the risks of nuclear confrontation on the South Asian continent. A regional compact approach involving India, Pakistan, China, and mediation by the United States could serve to open dialogue on nuclear cooperation in this region.

8. ASEAN (Association of South East Asian Nations) Compact: Brunei, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam

No commercial nuclear power plant currently is operated in the ASEAN region. Although the Philippines has two completed PWRs (two 651 MWe Westinghouse-built PWRs), they were never operated, and the Philippines government only recently settled its long-running legal dispute with Westinghouse over the construction of these plants. The two plants are expected to be decommissioned or converted to run on fossil fuel.

Indonesia could be the first ASEAN country to acquire nuclear capacity; its National Atomic Energy Agency has confirmed that construction of the country's first nuclear power plant will probably begin in 1998. The 1800 MWe plant, consisting of three 600 MWe or two 900 MWe units, is to be built on the Muria Peninsula.

Thailand's Office of Atomic Energy for Peaceful Purposes intends to build a nuclear research center at Ongkharak, near Bangkok, to house a research reactor, an isotope production facility, and a central waste processing and storage facility.

The nuclear development programs of the ASEAN nations are in states of infancy. During this period of capacity building, their focuses are primarily on the front end of the nuclear fuel cycle; i.e., securing a stable, reliable, and economical nuclear fuel supply, and building a safe, economical, and environmentally acceptable nuclear generating capacity. Eventually, ASEAN will have to deal with the problem of managing its spent fuel. Most of the ASEAN countries are heavily populated (and some are small in geographic area), making it hard to find a suitable repository site for disposing of the spent fuel. If there is a way to cooperate with host countries in other regional compacts, spent fuel could be shipped to other compacts for storage or disposal. In that case, this could be an example of a Type (C) compact.

9. East Asia Compact: China (and Taiwan), Japan, South Korea, North Korea, and the Russian Far East

The East Asian regional compact is the focus of this study. This is the most dynamic region in the world today for nuclear energy development. It consists of declared nuclear weapons states (China and Russia) and several sizable and ambitious nuclear energy programs (Japan and South Korea). Several countries in the region (Japan, China) have already decided to close the back end of their nuclear fuel cycles with spent-fuel reprocessing, and others (e.g., South Korea, Japan) are engaged in researching advanced technologies to deal with their spent fuel. Faced with the demands of regional economic expansion and competition, the countries in the region share the need for a stable and reliable energy supply, radioactive waste disposal, and reactor safety and regulatory standards.

3.0 Present and Future Nuclear Power Programs in East Asia

With its fast-growing economies and populations, East Asia is a region with a ravenous appetite for electricity. Because nuclear power is a proven, available, and, in many cases, economically competitive source of energy, and because for many East Asian countries the alternatives are not always consistently, cheaply, or conveniently available, the region is turning to nuclear energy to help power its economic development and increase its standard of living. Coal, for example, is in short supply in Japan and North and South Korea, and virtually nonexistent in Taiwan. China's supply, while abundant, is in northwestern provinces far from the centers of population and industrial/commercial development on the south and southeastern coasts. Oil and natural gases are available primarily through import, and hence expensive. Hydropower has some potential for the East Asian countries with small geographical areas. It is being developed in China, but it cannot meet the country's appetite for electricity. That makes nuclear energy one of the most accessible, practical, and economical choices for large baseload power plants, and East Asia is currently the only region in the world that has plans to rapidly expand nuclear power as a major energy source within the next century.

China

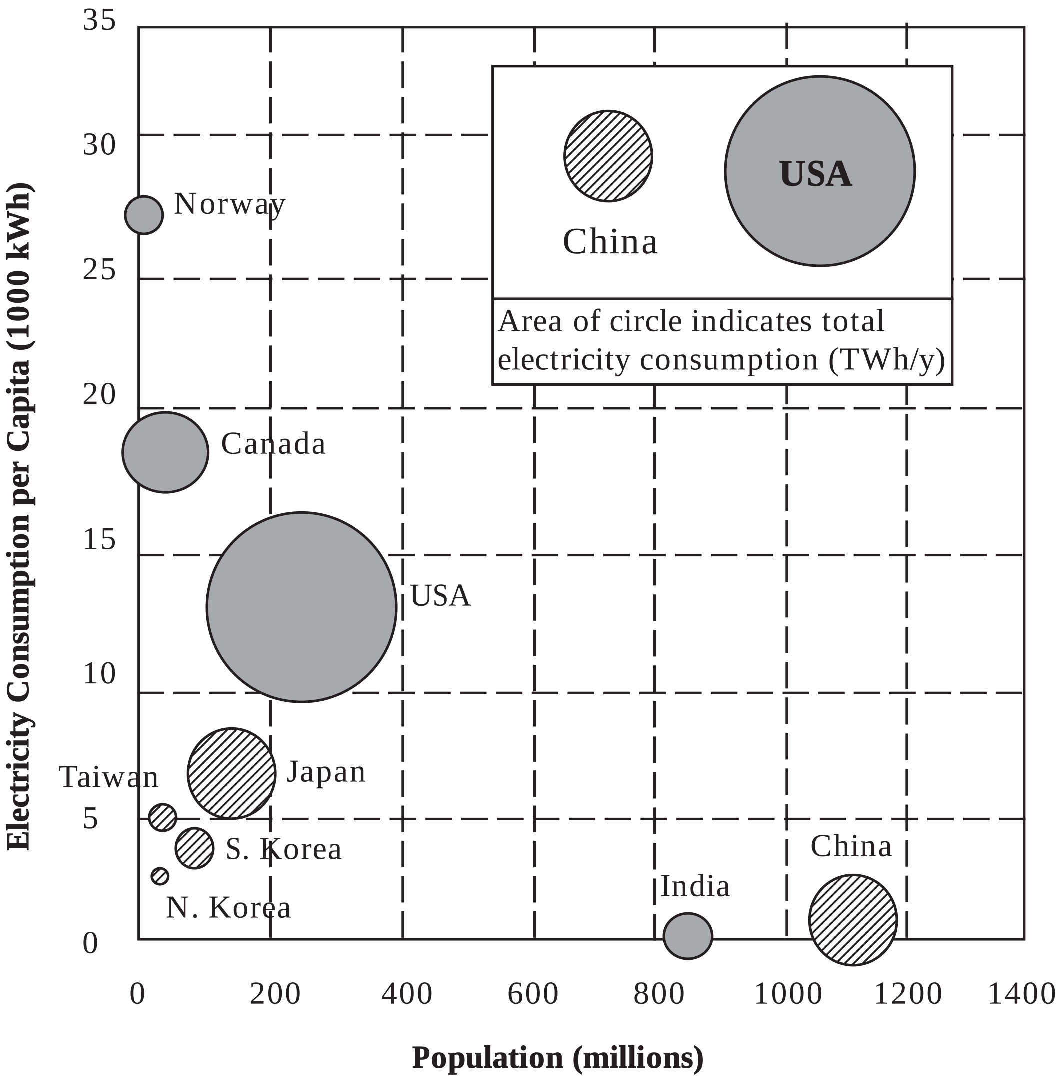
The explosive growth of the Chinese economy must be fed by a corresponding expansion of electricity generating capacity. As a result, no country in East Asia has more ambitious plans for nuclear energy than China. This ambition is driven by necessity. With one-fifth of the world's population, China must figure out how to produce enough electricity to meet the needs of its 1.2 billion people and its growing economy. Figure 3 compares electricity consumption per capita versus population for the East Asian countries and a few other countries. It shows that China produced a total of 920 terawatt hours (TWh) of electricity in 1995, about 30 percent of the United States' production. But China's population is about four times that of the United States, implying that the average American consumes fourteen times more electricity per year than the average Chinese. Since per capita electricity consumption is one of the measures of standard of living, the disparity in electricity availability explains the great Chinese energy demand.

China's nuclear capacity today consists of three operating plants producing 2,100 megawatts (MWe), about 1 percent of the total electricity generating capacity. One, a 300 MWe pressurized water reactor (PWR) of Chinese design that went on line in 1991, is near Shanghai at Qinshan in the eastern coastal region. Two others, 900 MWe PWRs known as Daya Bay Units 1 and 2, built by Electricité de France (EdF), are in the Guangdong province near Hong Kong. Under construction are two 600 MWe PWRs of Chinese design to be added to the one already in operation at Qinshan. China awarded a contract to a French consortium in early 1996 for the construction of two units of PWRs, similar in design to the Daya Bay units, at Lingao, a site not far from Daya Bay. It also signed an agreement with Atomic Energy of Canada, Limited on July 12, 1996 for financing and supply of two heavy water reactors (CANDU) to be built at Qinshan.[3] In addition, China and Russia are planning two 1,000 MWe VVERs—the Russian-designed version of the PWR—in the northeastern Liaoning province. The goal for China's nuclear infrastructure is 15 to 17 gigawatts (GWe) by 2010, and 30 to 40 GWe by 2020, according to China National Nuclear Corporation.[4]

Financing such ambitious growth in nuclear generating capacity has not been easy for China. Foreign capital is essential if China hopes to build what it needs. Between 1976 and early 1990, foreign investors pumped about US$9 billion into power plant construction in China, and the country hopes to attract US$3.5 billion annually in foreign capital through 2000 for power plant projects. Unfortunately, foreign investment has slowed somewhat in recent years because the Chinese have been reluctant to allow the high rates of return (15+ percent) required by foreign lenders to offset the risk of investing in power plant projects in China. China has also made it clear that it wants good deals; i.e., financing packages that include loans from the seller to buy state-of-the art technology and equipment.

Export of U.S. nuclear technology and equipment to China has been hampered by U.S. domestic policy and politics. Although China and the United States signed a nuclear accord on July 23, 1985 to allow American companies to sell nuclear-related technology and equipment to China, the U.S. Senate has not ratified the accord. The export restriction was further complicated by incidents such as the 1989 violence in Tiananmen Square and China's sale of nuclear-related equipment to Pakistan. Appendix 1 describes the U.S. nuclear export

Figure 3. Comparison of Per Capita Electricity Consumption



controls to China. Some movement toward relaxation of the export restrictions imposed on nuclear sales to China has recently taken place. The specific case, however, involves the sale of US$137 million of advanced U.S. technology from Westinghouse to CNNC, which is small compared with other sales by France and Canada.

Japan

The Japanese nuclear industry is now a mature one, and as such it must deal with managing aging nuclear plants as well as constructing new ones. Japan's ten utility companies also are working toward establishing a fully closed nuclear fuel cycle. This includes spent fuel reprocessing and recycling of recovered uranium and plutonium, and the commercialization of fast breeder technology by 2030. Nearly 30 percent of all electricity in Japan is now provided by forty-nine nuclear power plants generating 42 GWe of capacity. Japan's nuclear program, consisting of a mix of nuclear power reactors (twenty-two boiling water reactors [BWRs], twenty-two PWRs, one gas-cooled reactor, one advanced thermal reactor, and one fast breeder reactor) and fuel-cycle facilities for fuel enrichment, UO_2 and MOX fuel fabrication, and fuel reprocessing, is the most advanced in Asia.

Japan revised its long-term program for research and development on nuclear energy in June 1994.[5] Its goals are to rely on and continue to improve the LWR technology and to boost Japan's nuclear generating capacity from 42 GWe today to 46 GWe by 2000, and to 72 GWe by 2010. The nuclear-generated share of Japan's electricity would rise from 33 percent in 2000 to 42 percent in 2010. The increase in electricity generating capacity would include the output of the world's first two advanced boiling water reactors (ABWRs), at Kashiwazaki-Kariwa, one beginning operation in 1996 and the other in 1997.

Although Japan's commitment to a comprehensive recycling strategy has not changed, its revised program plan has scaled back the ambitious rate of fuel cycle development. Because of increased equipment prices and the need to make the plant earthquake resistant (especially after the Kobe earthquake in January 1995), Japan's first commercial-size (800 Mg/y capacity) reprocessing plant, at Rokkasho-mura, is fourteen months behind schedule and is expected to cost as much as twice the original estimate. Instead of starting operation of a second reprocessing plant around 2010, the original goal, Japan now expects only to make a policy decision on the project at that time. Furthermore, Japan's Atomic Energy Commission abandoned work on the advanced thermal reactor (ATR), including the proposed 600 MWe demonstration ATR at Ohma. The utilities proposed building a 1,350 MWe ABWR with a full MOX core as a more cost-effective alternative.

A leak of sodium coolant on December 8, 1995[6] from the secondary cooling loop in Japan's prototype fast breeder reactor, Monju, prompted the immediate shutdown of the reactor. This incident was the most serious setback to the Japanese nuclear program's plutonium-use policy. Japan's consumption of plutonium is projected to reach five metric tonnes annually by 2010, including 600 kg by Monju and 700 kg by a yet-to-be-built demonstration breeder reactor. The projection matches the corresponding amount of plutonium to be supplied by the existing Tokai reprocessing plant and the planned Rokkasho reprocessing plant. If Monju is out of service for a prolonged period, an accumulation of excess plutonium could result, not only making Japan's self-imposed goal of maintaining a supply-demand balance of plutonium difficult to achieve, but also raising concerns about the protection of the plutonium in Japan and worry in other Asian countries about the prospect of Japan developing its weapons program. Japan's plutonium-use policy and its implications are further explored in Appendix 2.

South Korea

South Korea will have twenty-seven operating nuclear power plants in 2010, including four "next generation" evolutionary PWRs, according to the revised nuclear power development program for South Korea's electric power industry.[7] Nuclear power, in the form of ten PWRs and one CANDU reactor, provided more than 30 percent of South Korea's electricity generation in 1996. The new program aims to increase that proportion. If all goes according to plan, in 2010 some 46 percent of total electricity generation will be nuclear, supplying about 190 TWh of electricity from nuclear units that make up about 40 percent of the country's installed capacity.

Under the program, South Korea will complete eighteen new nuclear units between 1996 and 2010, in addition to the nine already operating. Of the new units:

- Eleven will be Korean Standard Nuclear Power Plants, 1,000 MWe PWRs based on ABB-Combustion Engineering's System 80 design.
- Three will be 700 MWe pressurized heavy-water reactors (PHWR) supplied by Atomic Energy of Canada, Limited (AECL).
- Four will be 1,300 MWe evolutionary PWRs, destined to be South Korea's second standardized design (the Korean Next Generation Reactor, KNGR).

Because South Korea has meager fossil fuel resources, nuclear energy was selected to be the country's ultimately dominant electricity source. After the 1970s oil shock, South Korea made a deliberate decision to develop its own nuclear expertise. Since launching a national policy of energy independence in the 1980s, South Korea's energy goal has been to not only reduce its reliance on foreign fuels, but also to reduce its dependence on foreign energy generation technology and equipment. Self-reliance on nuclear energy requires expertise in nearly all areas of nuclear technology: design, procurement, equipment manufacturing, construction, installation, start-up, operation, and decommissioning. Early on, South Korea strove to obtain its own nuclear supply infrastructure, including Nuclear Steam Supply System (NSSS) engineering and manufacturing capability. After its first two turnkey Westinghouse PWRs and its first pressurized heavy water reactor (PHWR) from AECL, in whose construction few domestic industries could participate, South Korea gradually shifted its contractual practices to "component-based" and insisted on foreign technology transfer to Korean industry as the major condition of project awards. As a result, South Korea significantly increased local participation in its nuclear projects as well as acquired nuclear technology for major systems and components. South Korea adopted and modified ABB-Combustion Engineering's System 80 PWR, and renamed the enhanced version the Korean Standard Nuclear Power Plant (KSNPP). Other technology purchases were made from General Electric for turbine generators, Sargent & Lundy for architectural/engineering work, Siemens AG for PWR fuel fabrication, and a French consortium for waste management, PHWR fuel fabrication, and uranium conversion.

South Korea is now developing the design for a next-generation reactor (KNGR) planned for operation in 2007, based on ABB-Combustion Engineering's System 80+ advanced design. It has also teamed with AECL of Canada to conduct research on advanced fuel cycles, including the unique tandem fuel cycle in which PWR spent fuel is reused directly in CANDU reactors. Appendix 3 describes South Korea's research collaboration with AECL on DUPIC (Direct Use of spent PWR fuel in CANDU) technology.

In addition to its goal of achieving energy independence and self-reliance via its nuclear program, South Korea also wishes to export the nuclear technology it has acquired from the West to other countries. South Korea has already won consulting contracts in China and Turkey, and is negotiating with China to supply reactor pressure vessels to China's future nuclear power plants.

South Korea's nuclear program faces several challenges. Domestically, the biggest hurdle is finding both new plant sites and waste storage/disposal sites. Issues of public acceptance of nuclear power and public awareness of nuclear safety have intensified. Nuclear plant construction costs are expected to increase due to demand for stricter safety provisions. Operating costs will likely increase because of uncertainty over radioactive waste management and disposal.

Internationally, the politics surrounding the transfer of sensitive nuclear technologies such as fuel reprocessing and enrichment are a stumbling block to South Korea's reliance on its own nuclear fuel technology. South Korea's intent to become self-sufficient in nuclear fuel supply is apparent since it is now manufacturing PWR assemblies at a plant originally supplied by Siemens AG, and it is interested in spent-fuel reprocessing and recycling to minimize the import costs of uranium. However, having developed much of its nuclear technology in cooperation with the U.S. nuclear industry, South Korea has not provoked the United States by seeking reprocessing capability, although it has sought reprocessing-related technology—so far without success—from the United States and Canada, and has held talks with Russia over reprocessing South Korean spent nuclear fuel at an incomplete facility (RT-2) at Krasnoyarsk in Siberia.

Like Japan, South Korea has bristled at U.S. criticism of its policy of nuclear self-reliance. In 1992, for instance, the United States refused a South Korean request to expand the use of a French-supplied post-irradiation examination facility beyond the "sole purpose of alteration in form or content of irradiated fuel elements originated in the U.S." In 1985, the United States set a twelve-bundle limit on the total amount of U.S.–supplied fuel that could be handled in the facility. The restriction was to end in 1996. Given South Korea's criticism of the two-tier policy of the United States on fuel reprocessing, which allows Japan to reprocess the U.S.–supplied fuel, but not the Korean, it may ask that this restriction be removed, if not an outright request for equal treatment with Japan.

Taiwan

Taiwan's destiny depends heavily on its continued international economic progress and influence, and a reliable and inexpensive energy supply is crucial to that development. Taiwan, a small island with few energy resources, has to import more than 90 percent of its energy. Due to the vacuum in new sources of electricity generation since the early 1980s caused by strong domestic political and environmental movements, the reserve generating capacity of the state-owned Taiwan Power Company (Taipower) has dropped below 5 percent, well under the 15 to 20 percent reserve margin considered prudent in the U.S. utility industry.

Taipower currently operates four BWRs and two PWRs at three different sites, with a total installed capacity of 5144 MWe, roughly 25 percent of total capacity, and about 35 percent of the island's electricity. Though domestic political opinion has recently turned against expansion of Taiwan's nuclear power program, primarily due to concerns about nuclear safety prompted by the Chernobyl accident in April 1986, the development of safe, clean nuclear power is still necessary if Taiwan is to have a sufficient supply of energy for the future.

In June 1996 Taipower awarded General Electric[8] the contract for two units of ABWRs, each rated at 1355 MWe, for the Lungmen nuclear power plant project. The two units are scheduled for commercial operation around 2004 and 2005.

Taiwan's pro-nuclear governing Nationalist Party is losing its dominance in the island's parliament, and newly formed political parties are generally anti-nuclear. For nuclear power to maintain its share of Taiwan's energy supply, these conflicts need to be resolved.

Another concern is Taipower's spent nuclear fuel management problem. Since the establishment of the nuclear back-end fund in 1986 (the current collection basis is roughly 6 mills/kWh with the planned total amount US$5 to 6 billion), little has been achieved.

Taipower has engaged in discussions with Russia, the Marshall Islands, and China for spent-fuel storage services, but no deal has been made yet. It has been looking for several sites for its low-level waste (LLW) in Taiwan, but it faces stiff opposition from local communities. Taipower signed a deal in January 1997 with Pyongyang to ship 200,000 drums of LLW to North Korea at a reported cost of $230 million. South Korea, however, citing possible health hazards and fears of inadequate safety provisions in North Korea, strongly opposed the plan. The issue of managing Taiwan's spent fuel and radioactive wastes is further explored in Appendix 4.

North Korea

North Korea obtained most of its nuclear know-how and technical assistance from the former USSR. Under the terms of the 1959 nuclear cooperation agreement, North Korea received a 2 MWt research reactor and a critical assembly from the Soviet Union. North Korean scientists expanded the reactor capacity to 8 MWt using their own indigenous technology, and produced radioactive isotopes for scientific research and for industrial and medical purposes. In 1984, North Korea began construction of a 50 MWe power reactor based on natural uranium with gas-cooled, graphite-moderated technology. The reactor was scheduled for completion in 1996. In 1986, North Korea commissioned a 5 MWe indigenous experimental reactor at the Institute of Nuclear Physics in Yongbyon. The experimental reactor was a gas-graphite design of the 1940s, similar to the Calder Hall reactor in the United Kingdom.

In 1987, North Korea began construction of a so-called "radiochemical laboratory" designed for research on the separation of uranium and plutonium, waste management, and the training of technicians. The facility is capable of reprocessing two hundred tonnes of spent nuclear fuel a year. In addition, North Korea built more than one hundred different nuclear facilities in Yongbyon. These include a uranium mining facility, a uranium purification plant, an enrichment plant for low-enriched uranium, and a subcritical facility at Kim Il Sung University.

North Korea joined the IAEA in September 1974, and signed the Nuclear Non-Proliferation Treaty (NPT) in December 1985 under pressure from the former USSR. North Korea never allowed the IAEA to verify its initial inventory of fissile material produced in its indigenous reactors, however. In 1992, North Korea signed a bilateral declaration with South Korea on the denuclearization of the Korean Peninsula, and the countries agreed not to operate uranium enrichment or plutonium separation facilities on their territories.

IAEA inspections of North Korea's nuclear facilities at Yongbyon begun in 1992 revealed North Korea's continued expansion of the clandestine reprocessing plant, a violation of its NPT obligations. The confrontation between North Korea and IAEA in subsequent inspections, especially over the issues of whether North Korea would reprocess the spent fuel discharged from its graphite-moderated reactor and allow IAEA to conduct special inspections, resulted in a standstill that led to North Korea's decision in March 1993 to withdraw from the NPT regime.

North Korea formally requested through its UN mission a direct negotiation with the United States on the nuclear issues. After prolonged negotiation, U.S. and North Korean negotiators signed the "Agreed Framework" on the nuclear issue on October 21, 1994.[9] The Korean Peninsula Energy Development Organization (KEDO), founded on March 9, 1995, was the international organization established to implement most of the Agreed Framework, which if accomplished would ultimately lead to the complete dismantlement of North Korea's nuclear weapons program, and the construction of two 1,000 MWe Korean Standard Nuclear Power Plants on North Korea's soil. Appendix 5 describes KEDO's mission and the challenges it faces.

Russian Far East

The Russians operate four units of EPG-6 reactors at Bilibino on the Chukchi Peninsula, which is about 100 miles north of the Arctic Circle in the Russian Far East. The EPG-6 is a reactor type similar to the RBMK (*reaktor bol'shoy moshchnosti kipyashchiy*). It is graphite moderated and boiling water cooled. Each of the Bilibino units has a capacity of 11 MWe. The first two units began operation in 1974. The next two began operation in 1975 and 1976, respectively. These reactors were designed to operate for about thirty years, and the first is scheduled for decommissioning in 2003.

Russia has plans to expand power generation capacity at Bilibino to 120 MWe. One plan is to replace the four 11 MWe reactors with three 40 MWe reactors. The other plan under study by the Russian Ministry of Atomic Energy (Minatom) would involve construction of floating nuclear power plants similar in basic design to those used in Russia's nuclear-powered icebreakers. The floating power plants would be built in a shipyard and towed to locations in northern Siberia such as Bilibino. It is not clear whether or when funds would be available for these projects.

Russia's civilian nuclear program in its Far East region is relatively small. However, the Russian Far East is home to Russia's Pacific nuclear fleet, which consists of about one-third of Russia's active fleet of nuclear-powered submarines, icebreakers, and surface supply ships. Russia's nuclear fleet is the largest in the world, with a total of 140 active vessels at the end of 1994. A somewhat larger number of nuclear-powered vessels makes up the inactive fleet. Much of the inactive fleet consists of submarines awaiting dismantlement and disposal of their nuclear fuel, reactor compartments, and radioactive wastes. The dismantling of the inactive fleet poses the threat of nuclear contamination to the regional environment if accidents or release of radioactivity was to occur.

To maintain an active fleet of nuclear-powered submarines, the reactor cores must be refueled on a regular basis. Because of various problems in addition to financial strain, the Russian navy is facing significant delays in defueling and refueling submarines. These problems include:

- Lack of fuel transfer and storage equipment. The breakup of the Soviet Union disrupted the supply of equipment needed for the defueling and refueling of submarines.
- Saturation of the spent fuel storage capacity. Because the central onshore storage facilities in many of the navy ports and the temporary storage compartments on board the service ships are full, they cannot take any newly removed spent fuel. In some cases, spent fuel was stored in reactor compartments of the inactive submarines docked alongside the pier. This creates the risk of accidents and the potential for radioactive releases into the environment.
- Difficulties of removing spent fuel from submarines with damaged reactor cores. There are three submarines in the Pacific fleet that cannot be defueled because of damaged reactor cores. Major portions of these submarines may have to be disposed of as wastes.

However, the Russian Far East region lacks the financial and technical resources to deal with this disposal problem.

The nuclear legacy of the Soviet Union does not end with spent fuel disposal. Russia faces serious problems in disposing of liquid and solid wastes as well.[10,11] More than 12,000 Ci of liquid radwastes and 7,000 Ci of solid intermediate and low-level radwastes were dumped in the Sea of Japan (East Sea) and near the Kamchatka Peninsula. No reactor cores with spent fuel in place were dumped in the far eastern seas. However, radioactive releases from the accident aboard a nuclear-powered submarine in Chazhma Bay during refueling and the loss of a 350,000 Ci radioactive thermal generator during transport near Sakhalin Island increased the level of radioactive contamination in the far eastern seawater. The difficulty of disposing of the three nuclear-powered submarines and their damaged fuel on board remains a concern because of potential environmental contamination. The degree of contamination already existing in the Sea of Japan (East Sea) and its effects on the marine resources contested by the countries surrounding this semi-enclosed body of water are discussed in Appendix 6.

Table 1 summarizes the nuclear programs (including the front end and back end of the nuclear fuel cycle, as well as the number and types of reactors in operation) in the East Asian region.

4.0 The Need for an East Asian Regional Compact Framework

Background

Since 1995, considerable discussions have taken place on the possibility of creating an Asian regional nuclear cooperative framework.[12] Atsuyuki Suzuki of Tokyo University first proposed an "Asian equivalent of Euratom," in that all regional nuclear programs, including Japan's plutonium use, would be made more transparent to the international community. Suzuki, as a member of the Joint U.S.–Japan Study Group on Arms Control and Non-Proliferation after the Cold War, recommended that the East Asian countries explore cooperative arrangements leading to the creation of an Asian Atomic Energy Community (ASIATOM) that would promote transparency, the safe operation of nuclear facilities, and the safe disposal of nuclear waste. He also proposed, in September 1996,[13] two mechanisms for East Asian collaboration: (1) construction and operation of an international facility for immediate storage of spent fuel produced in East Asia, the East Asian Collaboration for Intermediate Storage; and (2) construction of an international facility for research on geologic disposal, the East Asian Collaboration for Underground Research.

Brad Roberts and Zachary Davis[14] of the U.S. Council for Security and Cooperation in Asia and the Pacific (US-CSCAP) proposed a nuclear cooperation in the Asia-Pacific to establish regional arrangements for energy and safety cooperation, regional safeguards, nuclear research cooperation, and frameworks for the management of the front end and back end of the nuclear fuel cycles.

Robert Manning,[15] also a member of the US-CSCAP, proposed the creation of a "PACATOM" organization to deal with Japan's existing stock of excess plutonium and the proliferation concerns associated with it.

Table 1: Nuclear Fuel Cycle Activities and Power Generation in East Asia

Fuel Cycle Activities		China	Japan	S. Korea	N. Korea	Taiwan	Russian Far East
Natural U acquisition		Domestic	Foreign (US, Australia, etc.)	Foreign (US, Australia, Canada, etc.)	Foreign (China, Russia)	Foreign (US, Canada, etc.)	Domestic
Conversion to UF6		Domestic	Foreign (US) and Domestic	Foreign (US)	–	Foreign (US)	Domestic
Enrichment		Domestic	Foreign (US) and Domestic	Foreign (US)	–	Foreign (US)	Domestic
Conversion & Fabrication		Domestic	Foreign (US) and Domestic	Foreign (US) and Domestic	Domestic	Foreign (US)	Domestic
Reactor operation	1996 capacity, GWe, %, & types of reactor	2.1, 1% 3 PWRs	39.4, 21% 22 BWRs, 22 PWRs, 1 GCR, 1 HWLW, 1 ABWR, 1 FBR	8.2, 36% 10 PWRs, 1 PHWR	5 MWe graphite moderated reactor operated to produce weapons material	5.3, 25% 4 BWRs, 2 PWRs	Naval submarine reactors
	Forecast: GWe@2010, %	17.0 3 %	70.5+ 42%	20.4 (yr 2006) 38%	2.0 –%	7.9 21%	Deploy lead-cooled fast reactors from submarine technology for district heating & overseas business
Spent fuel storage 1995 quantities & plan		100 MgHM on-site.Central wet storage w/capacity 2100 Mg being constructed.	12,800 MgHM on-site. Central wet storage at reprocess-ing plant site w/ capacity 3000 Mg.	2,600 MgHM on-site. An ISFSF w/ capacity 3000 Mg to be built by 2001.	8,000 rods on-site.	1,700 MgHM on-site.	In limited on-shore storage, or in service ship, or in subma-rine.
Fuel reprocessing		A reprocessing plantwas built in 1970. A new 25 tUiy plant to be operated by 2000.	Foreign (UK, France). Domestic (a 50tU/y at Tokai-mura, an 800 tU/y @ Rokkasho by 2000).	No decision yet. Working with Canada on DUPIC.	Suspected tohave reprocessed some of the fuel rods.	No decision yet.	Hindered by limited capacity @ Maya reprocessing plants & shipping problem.
Waste disposal		Prospective site for HLW reposi-tory at Lop Nur is planned for 2040.	Vitrified HLW glass is currently stored; a reposi-tory is planned by 2030.	Planning.	On-site.	Discussions w/ China, Russia, & US for disposal.	Planning.

Hiroyoshi Kurihara[16] of the Tokyo Nuclear Material Control Center, concerned that the name ASIATOM might imply the inclusion of only the Asian countries, suggested a PACIATOM to include the United States, Canada, and Australia.

Ryukichi Imai,[17] a former ambassador in Japan's foreign ministry, proposed a cooperative regional approach to the front end of the fuel cycle, including construction of joint facilities for uranium enrichment and plutonium use as well as agreements on safeguards control and safety.

Kumao Kaneko,[18] president of the Council on Nuclear Disarmament and Non-Proliferation, with the endorsement of the Japan Atomic Industrial Forum, proposed the creation of an Asia-Pacific Organization for the Peaceful Use of Nuclear Energy (APOPUNE), or more conveniently called ASIATOM, to promote technical cooperation and public acceptance of nuclear power generation, and to solve problems of both the front end and back end of the nuclear fuel cycle. A list of countries and areas have been identified for initial membership: Australia, Canada, China, Indonesia, Japan, Malaysia, Philippines, South Korea, Taiwan, Thailand, the United States, and Vietnam. Other countries may join later.

William Dircks,[19] head of the Atlantic Council of the U.S. Non-Proliferation Office, and a member of the Joint U.S.–Japan Study Group on Arms Control and Non-Proliferation after the Cold War, endorsed a broader ASIATOM concept to bring in Australia, Canada, and perhaps the United States. He proposed a separate "PACATOM" which would focus initially on nonproliferation and nuclear safety issues, then gradually include other issues.

With so many competing strategic and economic interests operating among the East Asian countries and areas, the key to forming a cooperative framework is finding enough common interests to get all the parties involved. These common interests are:

- Spent fuel storage and radioactive waste disposal (Russian Far East, Taiwan, North and South Korea, Japan, and eventually China).
- Nuclear proliferation and regional security (caused by the separated plutonium in Japan, and the clandestine nuclear weapons program in the DPRK).
- Safe operation of nuclear facilities (this is the issue that binds all the parties, because the region cannot afford a Chernobyl-type accident).
- Support for economic development, including
  - –supply of nuclear energy and fuel to East Asian countries and areas, and
  - –export of nuclear generating technologies (Japan, South Korea, and possibly later China).

How Could a Regional Compact Help?

How could a regional compact help in gathering the East Asian countries and areas together to pursue similar interests and resolve common problems for the regional good? The following table offers a few insights:

Common interests	**How could a regional compact help?**
Spent Fuel Storage and Radioactive Waste Disposal	To provide spent fuel storage and/or permanent radioactive waste disposal in a geologic repository, a country with nuclear power needs, at a minimum, (1) a piece of remotely located land, (2) financing, and (3) research and development. However, not all countries possess all of these essen-

	tial elements. For instance, China and Russia have sparsely populated lands, but they lack financing to build a storage facility and geologic repository. Japan, South Korea, and Taiwan could provide financing and R&D, but they lack suitable lands for storage and disposal facilities. A regional compact could provide the forum for these countries and areas to engage in cooperative dialogue and reach agreement on regional spent fuel and waste management.
Nuclear Proliferation and Regional Safety	To minimize concerns about theft and diversion of separated fissile material, and to help clarify the peaceful intent of a country possessing separated fissile material stocks, a regional compact framework for nuclear cooperation could provide coordinated management and reciprocal inspection of those separated fissile material stocks held by the member countries. Personnel from regional countries would inspect the fuel-cycle and storage facilities to ensure that a regional material control regime is maintained. Such a regime could supplement IAEA safeguards and security provisions.
Safe Operation of Nuclear Facilities	A regional compact organization could impose uniform safety regulations and standards and provide safety inspection to operating nuclear facilities in the region. It could also provide emergency response and coordination, and require the member countries to notify one another in cases of accidents and other abnormal events.
Export of Nuclear Generating Technologies and Supply of Nuclear Fuel	Like Euratom, a regional compact in East Asia could create a common market in nuclear technologies and equipment, facilitate the capital investment needed for the development of nuclear energy, ensure regular and equitable supplies of nuclear fuel and free movement of capital and labor for nuclear work, and establish links with other countries and international organizations for the peaceful use of nuclear energy.

Six Criteria for Formation

The need for an East Asian regional compact is examined based on six criteria:

1. Energy/electricity demand.
2. Environmental concerns.
3. Regional security implications.
4. Nuclear safety.
5. Domestic policy and politics.
6. Nuclear energy costs and regional economic cooperation.

Each of these criteria presents an unique challenge to nuclear energy development, as shown in Table 2.

Table 3 explicates each of these criteria for China, Japan, South Korea, Taiwan, North Korea, and the Russian Far East. The examination illustrates the complexity and diversity of nuclear issues among these East Asian states and areas. It also indicates that the nuclear status quo is problematic in some places. Given the global trend toward more regional economic development, group security arrangements, and collaborations among neighboring states on safety issues that transcend national boundaries, a possible solution to the current East Asian nuclear problems is the formation of a regional framework for nuclear cooperation among East Asian states and areas. Table 4 summarizes the present conditions of each of the East Asian nuclear programs and presents for each the merits of membership in a regional compact.

Table 2: The Challenges to Nuclear Energy

Energy	Nuclear energy is a proven energy source, but can it overcome issues of waste disposal, nonproliferation, and safety in order to compete with other alternatives?
Environment	Use of nuclear energy could lessen the environmental degradation caused by fossil energy use, but could problems with radioactive waste disposal become nuclear technology's Achilles' heel?
Security	Given the fact that the nuclear technology that produces useful energy can also produce weapons-usable material, what would be the most effective means to render the technology proliferation-resistant?
Safety	Nuclear power has an excellent safety record, but can it afford another Chernobyl-type accident?
Domestic Policy	For East Asian economies, could nuclear energy be justifiable: (1) based on a policy of "energy self-reliance"? (2) as a future exportable commodity? (3) as a bargaining chip in security matters? (4) as an employment avenue for displaced weapons scientists/engineers?
Economics	Nuclear technology is capital-intensive. Could operating costs and con struction times be kept low enough to make it an economically justifiable option?

Now is the right time to establish a cooperative nuclear framework in East Asia if one wishes to resolve the problems that hinder the development of nuclear energy in East Asia. However, understanding that there are distinct differences in the level of nuclear development in different East Asian countries and areas (some have reached an advanced stage, others are either in the initial stage of development or have just a foot in the door), one may not want to rush into forming a massive organization in which the mere attempt to manage the different interests from these countries could become an impossible task.

Among the proposals for a nuclear cooperative framework in East Asia, the most often mentioned are an "Asian equivalent of Euratom," "ASIATOM," and "PACATOM." These names reflect the main differences between the proposals; i.e., whether the regional framework includes only Asian countries, only Asia-Pacific countries, or Asian countries plus prominent nuclear countries such as the United States, Canada, and France.

Table 3: Examination of East Asian Regional Compact based on Six Criteria

Criteria	China	Japan	South Korea
Energy	–20% shortfall in electrical supply –became a net importer in 1993 –relies heavily on coal for power generation	–most extensive nuclear program in Asia –energy self-sufficiency based on nuclear energy	–an expanding nuclear power program in Asia –energy self-sufficiency based on nuclear energy –developed Korean Standard Nuclear Power Plant
Environment	–problems with pollution, health impact, acid rain, CO_2 emissions, and coal ash disposal –could provide regional repository for spent fuel and HLW	–committed to the Rio Declaration on CO_2 emissions –difficult to site power plants & waste facilities	–difficult to site power plants & waste facilities
Security	–a nuclear weapons state –a regional power beginning to build a regional navy –will consider participation in 4-party talks with the U.S., S. and N. Korea on security on Korean Peninsula	–relies on bilateral security agreement . with U.S. –will consider a larger share of regional security burden –should be included in the 4-party talks on security on Korean Peninsula	–relies on bilateral security agreement with the U.S. –agreed to engage in 4-party talks with the U.S., China, and N. Korea on security on Korean Peninsula –has concerns about Japan's plutonium use and nuclear ambition
Safety	–no safety record revealed on its nuclear weapons program –control rod problem at Daya Bay unit	–sodium leak at Monju fast reactor plant –otherwise, good operating safety record	–good operating safety record
Domestic Policy and Politics	–large number of nuclear personnel from weapons program –capable of influencing regional & global nuclear policy –upset over U.S. trade sanctions on nuclear equipment	–capable of becoming a nuclear weapons state –disputes with the U.S. on plutonium use policy –large R&D investment in nuclear technology, intended for future export of nuclear business	–large R&D investment in nuclear technology, intended for future export of nuclear business –puzzles over the U.S. two-tier policy on fuel reprocessing –committed to the joint development of DUPIC with AECL
Economics	–financing for power generation depends on domestic saving –nuclear is competitive in certain coastal regions only	–nuclear is competitive with other fuel sources	–nuclear is competitive with other fuel sources

Table 3: Examination of East Asian Regional Compact based on Six Criteria

Criteria	Taiwan	North Korea	Russian Far East
Energy	–reserve capacity has dipped below 5% –needs to build new plants –awarded GE contract to build two units of ABWRs	–KEDO provides 500,000 barrels fuel oil per year –S. Korea to build 2 KSNPPs in 10 years	–vast natural & energy resources –may develop a floating reactor concept based on its nuclear submarine technology
Environment	–LLW dump site at Orchid Island near capacity –needs to find spent fuel storage sites	–potential environmental damage by clandestine nuclear program	–dumping of radioactive effluents in Sea of Japan is problematic –storage problem with spent fuel from nuclear-powered submarines and icebreakers –could provide regional repository for spent fuel & HLW
Security	–gave up a clandestine reprocessing program in the 1970s due to U.S. pressure –the U.S.'s Taiwan Relations Act is ambiguous as to U.S. commitment on Taiwan's security. –security threat exerted by China	–politically & economically isolated –may consider participating in 4-party talks with the U.S., China, and S. Korea on security on the Korean Peninsula –concerned about Japan's nuclear ambition	–maintains a nuclear navy in the Far East region
Safety	–a fire in 1984 destroyed the turbine generator at Maanshan nuclear plant –otherwise, good operating safety record	–concerns about the safety of its graphite-moderated reactors –concerns over the 8,000 rods of spent fuel stored in wet pool	–safety concerns over the submarine waste storage and disposal problems –safety concerns over the floating reactor design
Domestic Policy and Politics	–wants global political recognition on par with its economic status –may restart its clandestine nuclear program (if it feels the U.S. is not committed to its security needs –public opposition to building more nuclear power plants	–difficult economic/political situation –concerns over KEDO's long-term commitment on fuel oil supply –could use its clandestine nuclear program as bargaining chip again	–its Far East region is scarcely populated, and is perceived to be ignored by Moscow politics –the Far East region is vulnerable to being assimilated by neighboring states
Economics	–nuclear is competitive with other fuel sources –Taipower wants to build U.S. reactors to offset trade surplus with the U.S.	–needs external financial assistance	–needs external financial assistance for energy development

Table 4: East Asian Nuclear Programs: Status Quo and Reasons for Membership

Status quo	Reasons for membership
China	
The U.S. exerts most of its influence on nuclear matters in East Asia through bilateral agreements with regional countries. Nuclear trade with China is prohibited because of conflicts with other policy issues.	Active and constructive participation in the regional cooperative framework would assure China's leadership role in decision-making on regional nuclear matters.
Lack of financial support to develop China's nuclear program could make China depend more on its coal for energy, resulting in great environmental impact.	Financial assistance from regional countries based on the regional framework agreement could offer China the most needed financial resources for a balanced energy-use policy.
China's influence on the nuclear programs, safeguards and security matters, and military intentions of other countries in the region is limited.	Through the regional framework, China could exert its influence on regional safeguards and security issues and the military intentions of other regional countries.
Without safety certification, the market for China's indigenous nuclear plants could be limited to Third World (or even rogue) countries.	Safety certification of China's indigenous nuclear plant design by the regional framework agreement could enhance its marketability.
Several East Asian countries have problems of indefinite storage and disposal of their spent nuclear fuel. Shipping this fuel back to the original fuel-supplying countries (mainly the U.S.) is either not acceptable or would require transport over long distances, with resultant safety and security concerns.	China could earn financial compensation if it offers the regional countries fuel-cycle services such as spent-fuel management and disposal, fresh fuel fabrication, and enrichment services. Such services would ensure short distances for transportation of nuclear materials (as compared with shipping to and from the U.S.) and hence lessen concerns for transportation safety and safeguards and security.
Most of the existing bilateral agreements with the U.S. are ambiguous and often inconsistent. For example, the U.S. approves of Japan's fuel-reprocessing program, but disallows S. Korea and Taiwan from pursuing their fuel reprocessing options.	A regional multilateral framework agreement could be more effective than the current bilateral agreements in resolving regional conflicts in nuclear matters.
Japan	
The bilateral nuclear and security agreement between the U.S. and Japan dictates much of Japan's nuclear policy. It also hinders Japan's goal of being the primary nuclear technology supplier for the East Asian region.	A regional framework could enhance Japan's leadership role in providing advanced nuclear technology, financial support, safety training, and research and development to other regional countries.
Many Asian countries are still suspicious of Japan's nuclear program, especially in regards to the separated plutonium currently stocked in Japan. This could have a destabilizing impact on regional security, notably on nuclear programs in the Korean peninsula.	A regional framework would promote transparency of regional nuclear programs and allow coordinated inspection of regional fuel-cycle facilities, and hence would lessen other regional countries' concerns over Japan's nuclear program.
Japan's pursuit of nuclear fuel self-sufficiency through domestic enrichment of uranium would be scrutinized by the U.S. and other regional countries because of safe-guards and security, and "real" nuclear intent.	Through the regional framework, Japan could not only secure its own nuclear fuel supply, but also ensure others' stable and reliable fuel supply by means of its advanced fuel enrichment and fabrication facilities.
Opposition to the siting of a waste repository in Japan's densely populated islands could prolong the debate over a waste disposal program, and adversely impact the growth of its nuclear program.	If a regional spent-fuel storage facility and ultimately a regional repository are available through the regional framework agreement, Japan's problem of spent-fuel storage and waste disposal could be resolved.
Currently there is not much coordination among regional nuclear programs in East Asia, especially in the area of safety implementation. The region is in need of a safety culture to ensure that nuclear accidents will not occur.	With a regional framework agreement in place, Japan could be more assertive in implementing a safety culture for the region, and demanding compliance with international regulations and standards from other regional countries' nuclear operations.

Table 4: East Asian Nuclear Programs: Status Quo and Reasons for Membership

Status quo	Reasons for membership
South Korea	
The bilateral nuclear and security agreement between the U.S. and South Korea dictates much of South Korea's nuclear policy. It also hinders much of South Korea's own developmental nuclear program. The U.S. has steadfastly opposed South Korea's intent of reprocessing its spent nuclear fuel, and may again oppose South Korea's program for a DUPIC fuel cycle on the grounds of nuclear proliferation. This policy would continue to offend South Korea because of its discriminatory nature: it allows Japan, but not South Korea, to reprocess spent fuel. South Korea would continue to rely on the U.S. (or the West) for nuclear fuel supply. Opposition to the siting of a waste repository in South Korea's small and densely populated country could adversely impact the growth of its nuclear program. Currently there is not much coordination among regional nuclear programs in East Asia, especially in the area of safety implementation. The region is in need of a safety culture to ensure that nuclear accidents will not occur.	A regional framework could enhance South Korea's role in providing advanced nuclear technology, financial support, safety training, and research and development to other regional countries. A regional framework would promote transparency of regional nuclear programs and allow coordinated inspection of regional fuel-cycle facilities, and hence would lessen the concerns of the U.S. and other regional countries regarding South Korea's research on a DUPIC fuel cycle. Through the regional framework, South Korea would have more alternatives in securing its nuclear fuel supply. If a regional spent-fuel storage facility and ultimately a regional repository are available through the regional framework agreement, South Korea's problem of spent-fuel storage and waste disposal could be resolved. With a regional framework agreement in place, South Korea could be more assertive in promoting its Korean Standard Nuclear Power Plant design to regional countries. Hence, South Korea's influence in implementing a safety culture for the region could be enhanced.
Taiwan	
Taiwan's current nuclear program is for peaceful energy application. It does not have much influence on other regional countries' nuclear programs. Taiwan would continue relying on the U.S. (or the West) for nuclear fuel supply. Opposition to the siting of a waste repository in Taiwan's small and densely populated island could adversely impact the growth of its nuclear program. Currently there is not much coordination among regional nuclear programs in East Asia, especially in the area of safety implementation. The region is in need of a safety culture to ensure that nuclear accidents will not occur.	A regional framework could provide Taiwan a forum in which to promote the peaceful application of nuclear energy and to voice its support or opposition to nuclear programs in other regional countries. Through the regional framework, Taiwan would have more alternatives in obtaining its supply of nuclear fuel. If a regional spent-fuel storage facility and ultimately a regional repository are available through the regional framework agreement, Taiwan's problem of spent-fuel storage and waste disposal could be resolved. With a regional framework agreement in place, Taiwan might be more indebted to sharing its safe operating practices with other regional countries.

Table 4: East Asian Nuclear Programs: Status Quo and Reasons for Membership

Status quo	Reasons for membership
Russian Far East	
Russia has an acute problem of managing the spent submarine fuel and wastes generated by its Pacific fleet, located in the Far East region. The dumping of radioactive effluents into the Sea of Japan has met with fierce objection from regional countries.	A regional framework could provide the Russian Far East a forum in which to obtain financial assistance to manage its nuclear legacy of spent submarine fuel and associated process wastes.
Russia lacks the financial resources to manage its spent fuel and wastes in the Far East region. Its rail transport system is too old and unreliable to ship the spent fuel and wastes out of the region. The persistence of the problem increases the likelihood of a major event of nuclear contamination.	Russia could earn financial compensation if it offers the regional countries a spent-fuel storage facility and ultimately a regional waste depository in its Far East region. Such services would provide a solution to its own spent-fuel disposal problem and ensure shorter distances of transportation of spent fuel and wastes from other regional countries (as compared with shipping to the U.S. or Europe). Hence it would lessen the concerns over transportation safety and safeguards and security.
Russia maintains its military presence in its Far East region with its Pacific fleet, although Russia's internal economic problems may have limited its power projection.	The regional framework would provide an additional forum in which Russia could exert its military influence over regional security in the Far East region.
Lack of financial support to develop the natural and energy resources in the Russian Far East could continue, hindering the region's economic development, decreasing the region's population, and making it the region more vulnerable to assimilation by neighboring countries.	Financial assistance from other regional countries based on the regional framework agreement could offer Russia the most needed financial resources to develop the vast amount of natural and energy resources in its Far East region.
North Korea	
North Korea has an acute economic problem. The Korean Peninsula Energy Development Organization (KEDO), set up under the bilateral 1994 Agreed Framework to assist North Korea in meeting its energy needs, is facing continuous and serious financial challenges that threaten its viability.	A regional framework could provide North Korea a forum in which to obtain the financial assistance to manage problems associated with its indigenous nuclear program.
Spent fuel from the graphite reactor is currently stored in water pools in North Korea, making it continually subject to corrosion and degradation, threatening the health and safety of workers, and increasing the potential for environmental contamination.	If a regional spent-fuel storage facility is available through the regional framework agreement, spent fuel from North Korea's graphite reactor could be sent there, lessening the concern that these fuels would be reprocessed for military use.
North Korea has insisted that it will not seek help from South Korea on a bilateral basis. KEDO may provide a workable forum; however, KEDO's own financial viability is in doubt.	The regional framework could provide an additional forum for North Korea to work with South Korea in building Korean Standard Nuclear Power Plants on North Korean soil.
North Korea intended to seek diplomatic recognition through its clandestine nuclear weapons program. If KEDO fails to meet its obligations under the 1994 Agreed Framework, North Korea could claim default on the part of KEDO and restart operation and construction of its nuclear weapons program.	A regional framework agreement may encourage North Korea to further abandon its clandestine nuclear weapons program, and to adhere more strictly to regional and international nonproliferation efforts.

For reasons of economics and safety, much of the routine handling and shipment of nuclear materials will be carried out on a regional basis. For this purpose, a region should be large enough to include countries with the needed facilities, but compact enough to minimize the costs and risks associated with shipments among them. Both ASIATOM and PACATOM may include too large an area and too many countries.

For reasons of flexibility, especially in this early stage of pursuing dialogue on the formation of such a framework, the East Asian regional compact proposed by this study has not been assigned a specific nameplate such as ASIATOM or PACATOM. The regional compact includes China, Japan, North and South Korea, Taiwan, and the Russian Far East, the six countries and areas in East Asia that currently possess nuclear programs. They were chosen because of their relatively close proximity, mutual security interests, interdependent economic objectives, and common energy needs. Between these countries and areas, however, exist hostility and distrust stemming from historical rivalries, competition for natural and energy resources, and territorial disputes. The likelihood of forming a regional cooperative framework in East Asia depends not only on the goodwill of these countries and their desire to join, but would also require the participation of the United States, a country of enormous nuclear influence in the region. The participation of the United States in the East Asian regional compact is most important in the formative stage of the framework. Its presence could provide an opportunity to engage the six countries and areas in unbiased discussion and dialogue regarding their common interests in nuclear cooperation. U.S. mediation efforts could also be effective in helping to resolve differences among them. An East Asian cooperative framework would be to the benefit of the United States because a stable nuclear East Asia is in the U.S. national security interest.

Because the United States was and still is, albeit to a lesser extent, the major provider of nuclear fuel and equipment to the region, it should play an active role in the East Asian regional compact. Discussions of important factors that may affect its role are presented below.

Bilateral versus multilateral agreements. Historically, the United States has signed bilateral agreements with countries and areas in East Asia. These include the security agreements with Japan and with South Korea and the Taiwan Relations Act with Taiwan. Each of these agreements and acts serves a unique purpose, and together they are an important element of the U.S. foreign policy to ensure security in the region.

With regard to nuclear trade and cooperation, the United States supplies fuel and equipment to Japan, South Korea, and Taiwan. U.S. nuclear power plant designers and manufacturers signed joint R&D contracts and agreements with their Japanese and South Korean counterparts, transferring nuclear technologies and know-how to these Asian countries. The United States also signed a nuclear accord with China in 1985,[20] but the accord was not ratified by the U.S. Senate because of concerns about China's export of nuclear technology to Third World countries. In October 1995, the United States signed the Agreed Framework with the DPRK (North Korea), resulting in the DPRK abandoning its indigenous nuclear-weapons program in exchange for the U.S. export of fuel oil and South Korea building two KSNPPs in North Korea.

On environmental decontamination, in 1994 the United States and Russia signed the Gore-Chernomyrdin Agreement on Cooperation in Environmental Restoration in the North Pacific to clean up the Russian radioactive legacy in the Sea of Okhotsk and the Sea of Japan (East Sea).

This spectrum of bilateral agreements illustrates the dimensions of U.S. involvement in East Asia's security, nuclear energy, and environmental matters. It also indicates that in the conduct of its foreign policy the United States prefers a bilateral approach. However, these bilateral agreements, though they seem to have accomplished their intended purposes in the past, fail to address several issues introduced by the expansion of nuclear power programs in the region, such as nuclear waste management and nuclear proliferation. Because these issues are multifaceted and their implications could affect many parties, a multilateral approach may be warranted in seeking resolutions to them. An example of how an extant bilateral agreement could evolve into a multilateral setting is shown below.

The United States signed the Agreed Framework with the DPRK to defuse the potential for proliferation from the DPRK's clandestine nuclear weapons program. However, it will be years, if at all, before the North Koreans dismantle their capacity to make nuclear weapons. Meanwhile, North Korea's food shortage could trigger internal political turmoil and lead to a regional crisis.

In an attempt to avert a potential crisis, in April 1996 the United States and South Korea proposed two-plus-two talks involving the two Koreas, the United States, and China (as signatories to the Armistice Agreement that ended the Korean War) to create a multilateral framework for inter-Korean dialogue. Such a proposal should include Japan and Russia.[21,22]

Front-end nuclear fuel cycle. The front end of the nuclear fuel cycle refers to the acquisition of fresh nuclear fuels, including yellowcake purchase, UF_6 conversion, uranium enrichment, UO_2 conversion, and fuel fabrication. In many East Asian countries and areas, nuclear fuel generally is acquired from and prepared by commercial industries operating in the international market. The United States is the world's largest uranium enrichment and LEU fuel supplier, and hence it can dictate the back-end nuclear fuel cycle policies of many of the East Asian reactor operators by demanding the right of consent over the transfer of U.S.–origin fuel (and, for that matter, any non-U.S.-origin fuel that resides in the reactor cores with the U.S.–origin fuel).

The global uranium enrichment market is undergoing a number of significant changes, however, that are making uranium enrichment a global commodity tied more to the law of supply and demand and less to nonproliferation constraints. Appendix 7 describes the changes in more detail. As a result, the United States may lose its market share in providing future enrichment services and have less control over the policies of foreign nuclear programs. Therefore, it would be prudent for the United States to consider a multilateral compact framework to ensure that its nuclear nonproliferation objectives are realized.

Back-end nuclear fuel cycle. The back end of the nuclear fuel cycle refers to the management of spent nuclear fuel discharged from reactors. This includes interim and on-site spent fuel storage, spent fuel transportation and long-term storage and disposal, spent-fuel reprocessing and recycling, and long-term disposal of reprocessed high-level waste (HLW).

The United States neither reprocesses spent fuel, according to its nonproliferation policy, nor encourages others to do so. Exceptions to this policy have been granted to Euratom and Japan, allowing them to reprocess spent U.S.–origin fuel. In other East Asian countries and areas (mainly South Korea and Taiwan), the United States continues to exercise control over the back end of the nuclear fuel cycle. On the grounds of nonproliferation, the United States does not allow these countries to reprocess spent U.S.–origin fuel, and it will not take back spent U.S.–origin fuel because of the objection of the U.S. public. As the spent fuel storage pools at these foreign reactors fill up, the pressure to find interim storage spaces and long-term solutions for the spent fuel will grow. Dry cask storage could be an interim storage option, provided that the communities where the casks are stored do not object. Appendix 8 summarizes the spent fuel management programs in the East Asian countries and areas.

Finding suitable sites for spent fuel storage facilities and final geologic repositories is very important to East Asian nuclear programs. Due to democratic movements and the greater influence of local governments, there has been strong local opposition in Japan, South Korea, and Taiwan to the investigation and acquisition of sites for spent fuel storage and waste disposal. Because of these countries' dense populations and small geographic areas, overcoming the political difficulties in siting is an immense task. With the United States' interest in imposing its nonproliferation goals and its seeming inability to take back the spent U.S.–origin fuel, it would be prudent for it to involve itself in the multilateral compact to seek solutions to the problems of spent fuel storage and radioactive waste disposal in East Asia.

The discussion above argues that the United States has a vested interest in East Asia's security, energy, and environmental matters. While the United States is losing its position as the dominant global supplier of nuclear fuel, will not take back spent U.S.–origin fuel, and is holding onto its apparently discriminatory two-tier approach regarding U.S.–origin equipment and materials, it would like to maintain its nonproliferation policy on East Asian nuclear matters. The discussion further argues that the usual bilateral approach adopted by the United States may not be effective in dealing with this complex and multifaceted nuclear problem, and that the United States should play an active role in the multilateral compact to resolve regional problems and to assure that the interests of the United States are served.

5.0 Objectives of an East Asian Regional Compact

Radioactive Waste Management

The regional compact framework would provide countries in the region with regional spent-fuel storage facilities and waste repositories for radioactive waste in host countries. The host country(ies) should be selected in conformity with the agreed nuclear policy of the regional compact and based on the availability of suitable sites. Member countries/areas should compensate the host country(ies) for providing the waste storage and disposal services.

The safe and secure storage of spent nuclear fuel and the eventual disposal of radioactive wastes (including spent fuel) is a major political, environmental, and security concern for the country generating them and for its regional neighbors. A country's inability to site storage and disposal facilities within its national borders, due to limited land area and/or dense population, would eventually result in a large accumulation of spent fuel and radioactive wastes and an end to its nuclear generation program.

Finding a host country (or countries) to accept others' spent fuel and radioactive wastes for storage and disposal is not easy, however. In 1984 China offered to take over the custodianship of the European utilities' spent fuels for a fee of US$1500 per kgHM.[23] China would dispose of the spent fuels, or the reprocessed HLW from these spent fuels, in the Gobi Desert. The deal did not go through because the nature of the custodianship of the spent fuel was not clearly defined. Both public opinion in China and the country's economic situation have since changed. Whether China would again be willing to offer a similar type of service to its East Asian neighbors (including its province of Taiwan) is not known.

Russia could site spent fuel storage facilities and a radioactive waste disposal repository in its less populated Far East region. After all, it has to manage the spent naval fuel and wastes generated by its Pacific nuclear fleet. Financial assistance could be generated if Russia were to offer storage and disposal services to its neighbors. Russian law currently bans imported wastes, however, and the amount of political effort it would take to lift this ban is uncertain.

To avoid the political difficulties of siting within its main islands a geologic repository for final disposal of its reprocessed HLW, Japan has planned to use one of the northern islands in the disputed territory with Russia as a potential repository site.[24] Much diplomatic effort is needed for such a plan to be realized, however, along with substantial Japanese financial commitment. It most likely would involve storing Russian naval spent fuel also.

Recently, an international consortium of private investors proposed to build a spent-fuel storage facility on Wake Island or another U.S.–controlled Pacific island for international spent fuel and waste storage.[25] The consortium intended to gain U.S. government backing and to offer a cradle-to-grave leasing service that would provide fresh nuclear fuel to utilities and transport spent nuclear fuel to the Pacific island for permanent storage. The consortium would charge utilities about US$1000 per kgHM to store the spent fuel. So far, Taiwan and South Korea have expressed interest in the proposal. However, previous proposals to use other Pacific islands (Palmyra Atoll, the Marshall Islands) for storage of nuclear wastes were strongly opposed by the sixteen-country South Pacific Forum.[26]

The difficulty in finding storage and disposal sites for spent fuel and/or wastes is further illustrated by the ordeal Taiwan is going through. Taiwan needs to store/dispose of its low-level radioactive wastes now and dispose of the spent nuclear fuel within the next decade. Taipower, Taiwan's utility company, has engaged in discussions with Russia, the Marshall Islands, and China for spent-fuel storage services, but no deal has been made yet. It has been looking for several sites for its LLW in Taiwan, but it faces stiff opposition from local communities. Taiwan's recent attempt[27] to ship 200,000 55-gallon drums of LLW to North Korea resulted in a furious protest by South Korea. South Korea may contemplate a naval blockade if wastes are shipped to North Korea.

This event highlighted East Asia's need for spent fuel storage and radioactive waste disposal. South Korea may oppose Taiwan's shipping LLW to North Korea, but it also has its own waste disposal problem, which could trigger similar diplomatic protests if the problem is mishandled. Even Japan, a country fully committed to reprocessing its spent fuel, sees the need for East Asian collaboration on intermediate storage of spent nuclear fuel.

Nuclear Nonproliferation

The regional compact framework would establish a regional nuclear material control regime in which the production and separation of special nuclear material is controlled first by the individual country and then monitored by personnel from regional member countries. This regional nuclear material control regime would be supplemented and supported by IAEA's safeguards and security systems.

In late January 1997 Japan's Atomic Energy Commission formally reaffirmed its commitment to plutonium recycling for electricity production and set a year-2000 target date for its utilities to begin using mixed uranium-plutonium oxide (MOX) fuel. The reaffirmation is the outgrowth of the government's wide-ranging review of Japan's nuclear power program following the December 1995 accident at Monju. The commission also called for the completion of the Rokkasho reprocessing plant and the continuing development of MOX fuel fabrication technology at Tokai.

Japan's long-standing policy of basing its nuclear power program on reprocessed plutonium will create a stockpile of separated plutonium in its fuel-cycle facilities (Tokai and eventually Rokkasho). Although the program is to proceed on a "no surplus plutonium principle," such a goal will have to be delayed because of the Monju accident. The prospect of surplus plutonium stocks is worrisome to North and South Korea, and has a destabilizing impact on security in East Asia.

The DPRK, before it signed the Agreed Framework with the United States, engaged in a clandestine nuclear-weapons program. Even with the Agreed Framework, it will be a long time (more than ten years) before North Korea finishes physically dismantling its capacity to make nuclear weapons. In the meantime, the DPRK's indigenous reprocessing facility at Yongbyon is intact and it still holds onto its 8,000 spent fuel rods.

South Korea has no current intention to reprocess spent fuel. However, it has been participating in a project with the United States and Canada to consider the feasibility of using spent PWR fuels in CANDUs (the DUPIC fuel cycle) with the aim of reducing overall fuel cost and spent fuel volume. One option in the DUPIC cycle may involve the handling of separated MOX fuel. In addition, KEPCO, the South Korean utility company, intends to load some MOX fuel into its PWRs in a joint effort with developing countries.

The operation of back-end fuel-cycle facilities (at Tokai and Yongbyon) and the research and development effort on advanced processing technologies (such as DUPIC) increase concerns about nuclear proliferation. Although Japan and South Korea both pledge to comply with international safeguards, their regional neighbors' uneasiness as to their intentions remains. To lessen the concern that they will seek nuclear weapons, a regional nuclear material control regime would be most effective. In the regime, the separated SNM stocks are first secured by individual countries or areas, and then reciprocally monitored by personnel from other regional member countries/areas. The regime would also be supplemented and supported by IAEA's safeguards and security systems.

Nuclear Safety

The regional compact framework could promote and implement a regional safety culture for operating nuclear facilities. This could include the development of prudent safety practices, the regulation of regional nuclear facilities with internationally accepted safety standards and requirements, training of operational personnel, and the coordination of regional nuclear emergency response.

Catastrophic accidents like Chernobyl spread devastating radiation contamination across national boundaries. Most of the nuclear reactors in East Asia are located in coastal regions, taking advantage of the once-through cooling by ocean water. These facilities are also located close to population centers to save transmission costs. A nuclear accident could result not only in heavy human casualties in the neighboring population centers, but also could cause widespread radiation contamination to nearby water sources and farmland, rendering them not suitable to produce food for human consumption for decades to come.

East Asia cannot afford a Chernobyl-like accident. Such an accident would spell an end to East Asian nuclear programs, and perhaps even to nuclear programs around the globe.

Therefore, it is prudent to promote and implement a regional safety culture for operating nuclear facilities.

Economic Cooperation

The regional compact framework would promote economic cooperation among countries in the region. Energy is an essential ingredient of economic development.

Nuclear power is one of the two non-fossil sources of electricity that can compete economically with fossil-fired generation (the other is hydropower generation). The circumstances surrounding nuclear energy in most Western industrialized countries (mainly, the privatization and deregulation of electric utilities in the United States and United Kingdom), however, do not allow for easy optimism about the future of nuclear power. Figure 4 compares the electricity generation costs, in U.S. mill per kWh, in OECD countries and China. It shows that nuclear generation costs in the United States and United Kingdom are higher than those of coal and natural gas. Moreover, the operating and maintenance costs of U.S. custom-built nuclear plants will increase as they experience aging and degradation. Some of those nuclear plants may be shut down prematurely and become "stranded assets," a financial burden to the utilities. In France and Germany, nuclear can be more economical than other fossil fuels, but the French nuclear capacity may have already reached saturation, and the Green movement in Germany has prevented the expansion of nuclear capacity because of the problem of disposing of nuclear wastes.

Nuclear power is competitive with other energy sources in East Asia, due mainly to the region's fast-growing economies, great demand for electricity, and the lack of fossil-fuel resources in several strong economies such as Japan, South Korea, and Taiwan. China's vast coal resources have been used to provide more than 75 percent of the country's electricity needs. But the coal mines are located in the country's northwestern area, far from the southeastern coastal area of dense population and high electricity demand. The shortage of water in coal mining areas could impose serious limitations on coal processing and coal-fired electric generation. And the higher cost of coal transportation to the south makes nuclear more competitive than coal as a source of electricity in that area.

China has an ambitious nuclear development program, especially in the country's southern and southeastern coastal areas. Nuclear technologies are capital intensive, however. It would take an enormous financial investment (from domestic and foreign sources) to make a reality of China's nuclear development goals. China could obtain loans from the World Bank, the Asian Development Bank, the ex-im banks, or the suppliers' countries. But there is competition for the limited funding available from these sources. To promote regional trade in nuclear technologies for peaceful uses, East Asia should establish a regional development banking network to provide favorable loans for regional nuclear energy development programs.

Japan and South Korea have been working hard to lower the generating costs of nuclear power plants. Nuclear power generation in Japan is highly reliable, with the frequency of unplanned outage (plant trip) as low as 0.1 per reactor per year. The new advanced LWRs currently planned for construction are designed at a 90 percent capacity factor. South Korea has achieved consistently good performance from its nuclear plants. In 1994, KEPCO achieved an average capacity factor of 87 percent, as compared with 75 percent for U.S. nuclear plants and 70 percent worldwide. In 1995, the average capacity factor was again more than 80 percent for the fifth successive year. To enhance the economics of its operating units, KEPCO has reduced unplanned plant trips due to operator error and equipment failure from five per reactor per year in 1985 to one in 1995.

In addition, in South Korea nuclear plant construction times and thus costs have been reduced by plant standardization, maximum use of modular construction, strict project control, and an improved licensing process. A 54-month construction schedule (first concrete to commercial operation) was achieved for the latest Korean Standard Nuclear Power Plant unit at Yonggwang. In the United States, in comparison, the average construction period for a nuclear unit is estimated at 100–120 months. For the Korean Next Generation Reactor (KNGR), a 48-month construction period is planned.

Despite all that has been accomplished in Japan and South Korea to make nuclear generation competitive, nuclear utilities and technology companies in both countries are concerned that:

1. Their limited land areas, and the growing antinuclear sentiments of local communities, will make siting of new nuclear plants and waste repositories difficult.

2. The U.S. insistence on nuclear nonproliferation could impact the fuel-cycle policy of both countries, and affect their decisions on acquiring fresh fuels and managing spent fuels.

3. The declining U.S. civilian nuclear program could also negatively affect both countries' ambitious nuclear technology export business. The United States' lukewarm support of nuclear development may cast doubt on the long-term viability of nuclear power as an energy source. Emerging nuclear programs in the ASEAN region, the potential clients for Japan and South Korea's nuclear export business, are hesitant to commit to investment in their nuclear programs.

Hence an East Asian regional compact, working toward resolving the spent fuel storage and radioactive waste disposal problem, assuring nuclear nonproliferation, and maintaining safe operation of nuclear facilities, could make nuclear power a stable, economical, and environmentally acceptable source of energy to sustain regional economic growth.

6.0 Pursuing a Regional Framework for Nuclear Cooperation in East Asia

Because of the unique histories, cultures, economic systems, and nuclear programs of East Asia, a model similar to Euratom may not be suitable for the region. Instead of rushing into forming a Euratom-like organization, a realistic and appropriate first step would be to set up forums (or work groups) where countries and areas can engage in dialogue on nuclear energy, environmental awareness, nuclear nonproliferation, nuclear safety, spent fuel and radioactive waste management, and economic cooperation. The outcomes of the dialogue would be used to formulate appropriate consensus for a cooperative framework for East Asia.

Therefore, the key to pursuing a regional compact framework for nuclear cooperation in East Asia is not to specify a particular nameplate (such as Euratom-like, or ASIATOM, or PACATOM, where members are represented by countries and states), but to preserve flexibility and informality in order that mutual interests and common problems can be discussed and resolved. In other words, China and Taiwan could be members of the compact working to solve the radioactive waste problem without concern for their status of representation, and North and South Korea could also be members to discuss the nuclear proliferation issue for their mutual benefit.

Given the sensitivities of cultural differences, historical backgrounds, political hostilities, and economic interdependence among the East Asian countries and areas, it would not be easy to gather their representatives together in a forum to discuss mutual interests and resolve common problems. This is where the United States could play an important role in the formation of an East Asian regional compact framework.

The United States

The United States could be an effective mediator in the formation phase of the East Asian regional compact framework. The enormous nuclear influence of the United States, together with its strong military presence, helped build peace and stability and create the subsequent economic advances in East Asia over the past two decades. The United States could help draw these East Asian countries together in forums to engage in cooperative dialogue.

As discussed in previous sections, an East Asian nuclear cooperative framework would be to the benefit of the United States because a stable nuclear East Asia is in the interests of U.S. national security. Resolving the problems of regional spent fuel storage and radioactive waste disposal is important to U.S. nonproliferation policy. As the U.S. nuclear nonproliferation goals are met, existing export controls and restrictions on nuclear generating technologies and equipment will be relieved, allowing the U.S. nuclear industry to participate fully in the nuclear market in East Asia, as well as the emerging market in the ASEAN countries.

China and Taiwan

China would be an essential member of the East Asian regional compact framework. Its status as a declared nuclear weapons state, its ambitious goal of increasing its nuclear generating capacity tenfold by 2010, and the availability of a vast amount of low-population land suitable for siting of spent fuel storage and radioactive waste disposal make China an important member of the compact framework, and qualify it as a potential host country.

The political dispute between China and Taiwan has spilled over to Taiwan’s nuclear waste problem. China would like to handle Taiwan’s nuclear waste as part of a strategy to pressure Taiwan into close cooperation. But Taiwan is not willing to depend on China as the only solution to its waste problem. As discussed in Appendix 4, an East Asian regional compact framework could offer a forum for China and Taiwan to engage in bilateral and multilateral dialogues to resolve Taiwan’s waste problem.

Japan and South Korea

Japan and South Korea would be the technological leaders of the East Asian regional compact. Because of their advanced nuclear technology capabilities, they should take the lead in cultivating a safety culture for the region, initiating and promoting nuclear research and development, training operating personnel, and coordinating regional emergency response to nuclear incidents.

Japan, because of its strong economy, should guide the effort to create an East Asian regional development banking network to provide favorable loans to regional nuclear energy development programs. South Korea, as the only country in the world operating PWRs and CANDU reactors, should lead in the effort to further advance the combined technologies, especially in the R&D on DUPIC.

North Korea and the Russian Far East

Because their civilian nuclear programs are small and limited, North Korea and the Russian Far East would be minor members of the compact framework's forums and dialogue on the resolution of common nuclear problems brought about by the region's civilian nuclear programs. Their involvement in the compact framework would add issues such as regional security and environmental contamination to the framework's agenda.

The safety of the nuclear facility operation in North Korea, what to do with the DPRK's spent fuel rods at Yongbyon, and the spent naval fuels accumulated in naval shipyards and decommissioned submarines in the Russian Far East are of great concern to the region. Solutions to these problems could be negotiated in the multilateral compact framework.

Suitable sites for spent nuclear fuel storage and radioactive waste disposal may be available in Russia's sparsely populated Far East region. If and when Russia decides to lift the ban on importing wastes for storage or disposal, Russia could compete with other countries (possibly China) to provide such services.

Meetings and forums involving representatives from the United States and the East Asian countries could be held regularly during the formation phase of the East Asian regional compact framework. In the beginning, meetings could bring together energy and policy planners, academics, and nuclear industry representatives from these countries to explore the feasibility of forming a compact framework. Later meetings could be held in a Track II format, i.e., with additional representatives from each country's foreign ministry and defense department attending the meeting in a personal capacity and voicing personal opinions and viewpoints.

Meetings and forums also could be formatted for discussion of specific topics such as energy security, nuclear safety, waste management, and proliferation. Realistic and achievable goals should be set for the meetings and forums such that a sense of accomplishment could be realized and consensus and recommendations be made.

The formation phase for the compact framework might be three years, at the end of which a decision on whether to form an East Asian regional compact could be made. If the decision is positive, a formal organization staffed with representatives from the United States and the East Asian members could be established to perform activities essential to the East Asian regional compact.

7.0 Conclusion

This study concludes that:

- The fast-growing populations and economies of East Asia have given rise to a ravenous regional appetite for energy, especially electricity. The region is turning to nuclear energy to help power economic development and increase the regional standard of living. Nuclear power is a proven, currently available, and in many cases economically competitive source of energy, and for many East Asian countries the alternatives are not always consistently, cheaply, or conveniently available.

• Nuclear energy, once deemed a cheap, abundant, and environmentally benign energy source, has been plagued by waste disposal problems, safeguards and proliferation concerns, safety issues, and expensive capital costs. To overcome these barriers, a regional compact framework is proposed with the following objectives:

Radioactive Waste Management

To provide regional spent-fuel storage facilities and waste repositories located in a host country (or countries) for the disposal of radioactive waste generated by member countries.

Nuclear Nonproliferation

To establish a nuclear material control regime where the production of special nuclear material (SNM) is controlled and monitored by regional personnel and supported by IAEA's safeguards and security systems.

Nuclear Safety

To implement a safety culture and regulate regional nuclear power stations with internationally accepted safety standards and requirements.

Economic Cooperation

To promote economic cooperation among countries in the region through stable, economical, and environmentally acceptable sources of nuclear energy.

To promote more regional economic development and group security arrangements, and to resolve common regional problems such as nuclear facility safety and radioactive waste disposal, it is suggested that a regional framework for nuclear cooperation in East Asia be formed.

• The East Asian regional compact proposed here, which in the interests of early-stage flexibility does not carry a specific nameplate, is made up of China, Japan, North and South Korea, Taiwan, and the Russian Far East. They are the current nuclear establishments in East Asia, and are selected because of their relatively close proximity, mutual security interests, interdependent economic objectives, common energy needs, and common environmental and waste-disposal concerns.

• A bilateral approach to conducting foreign policy seems to be preferred by many countries, and many existing bilateral agreements may successfully achieve their intended purposes. A bilateral approach and bilateral agreements may not be adequate to address some of the nuclear issues under consideration, however, such as nuclear waste management and nuclear proliferation introduced by the expansion of nuclear power programs in the region. Because these issues are multifaceted and their implications could affect many parties, a multilateral approach may be warranted in seeking resolutions to them.

• The likelihood of forming a regional cooperative framework in East Asia depends not only on the goodwill of the countries/areas and their desire to join, but may also require the participation of the United States, a country of enormous nuclear influence and military presence in the region. The inclusion of the United States in the East Asian regional compact is most important in the formation phase of the compact framework. U.S. leadership could draw these East Asian countries and areas together to engage in cooperative dialogue on regional interests of mutual concern and for the resolution of common nuclear problems, leading to the formation of an East Asian regional compact framework.

An East Asian cooperative framework would be to the benefit of the United States, because a stable nuclear East Asia is a U.S. national security interest. Resolving the problems of regional spent fuel storage and radioactive waste disposal would also be of interest to U.S. nonproliferation policy. A successful compact framework would eventually be beneficial to the U.S. nuclear industry, allowing companies to participate fully in the nuclear market in East Asia as well as the emerging market in the ASEAN countries.

- The study outlines the activities essential to the formation and the objectives of an East Asian regional compact, to be carried out by a formal organization staffed with representatives from the United States and the East Asian countries and areas. How to conduct these activities and the possible complexity involved are topics for future studies.

Appendix 1
U.S. Nuclear Export Controls to China*

Background

The United States and China signed an agreement of cooperation on July 23, 1985 pursuant to the Atomic Energy Act. However, the implementation of the agreement was blocked, at least temporarily, by a congressional resolution prohibiting export of any nuclear material, facilities, or components to China until the U.S. president can certify that

1. Such material, facilities, or components would be used solely for peaceful purposes, and
2. China's nuclear nonproliferation policy does not violate the Atomic Energy Act.

Implementation of the agreement was blocked indefinitely by the 1989 statute condemning the "unprovoked, brutal, and indiscriminate assault" on peaceful demonstrators in and around Tiananmen Square on June 4, 1989.

Many other sanctions were also imposed on China by the 1989 statute and by President Bush after Tiananmen, including:

1. No defense sales.
2. No satellites for China to launch for U.S. companies.
3. No export licenses for dual-use technologies granted to U.S. companies.
4. No export of Missile Technology Control Regime (MTCR) annex items.
5. No export of crime control and detection equipment.
6. No international loans, except for projects that meet basic human needs.

Some sanctions have been eased by changes in export rules, such as the Clinton administration's change in the policy on high-performance computers. However, sanctions on nuclear material, facilities, or components to China remain.

Secretary of State Warren Christopher said on October 3, 1995 that it was not yet time to lift the remaining sanctions imposed after Tiananmen.

To remove the post-Tiananmen sanctions relating to the export of nuclear technologies, the president must certify to Congress that:

1. China has made progress on political reform (including in Tibet) and on improving human rights.
2. China has provided "clear and unequivocal assurances" that it is not assisting and will not assist any non-nuclear weapons states in acquiring nuclear explosives, materials, or components.

Currently, there are disputes over exports thought to contribute to proliferation of weapons of mass destruction. These are:

1. China's alleged sale of ring magnets for uranium enrichment by centrifuge to Pakistan.
2. China's alleged sale of MTCR-banned missiles or missile parts to Pakistan and Iran.

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* This information is taken from class material prepared by George Bunn of the Center for International Security and Arms Control at Stanford University.

How Would a Regional Compact Help?

The effectiveness of the U.S. imposing unilateral nuclear export sanctions on China while other countries such as France continue to sell the U.S. restricted products to China has been the subject of fierce debate. At a time when the U.S. domestic market is shrinking, the loss of nuclear sales to China by Westinghouse, General Electric, ABB-Combustion Engineering, and many smaller companies that supply material, facilities, or components is significant. Any gain from such sanctions in inhibiting Chinese proliferation, if indeed it can be measured, is quite small. The sanctions imposed are more a matter of principle than an effective means of influencing Chinese behavior.

China is an upcoming great power, regionally as well as globally. It should be responsible for its actions within its own sphere of influence. The best means of encouraging Chinese behavior to conform to international norms is to include China in multilateral organizations. An East Asian regional compact framework could offer China the opportunity to lead, to regulate itself, and to influence other member states in nuclear cooperation for mutual benefit.

Appendix 2
Peaceful Use of Plutonium in Japan

Introduction

Japan is an island nation poor in natural energy resources. It has to import almost all the energy needed to support its advanced economy. The pursuit of energy self-sufficiency has led not only to Japan's commitment to the development and use of nuclear energy, but also to its plan for the recycling of nuclear fuel and, ultimately, the use of the plutonium in breeder reactors. Many other East Asian countries (China/Taiwan, South Korea, Indonesia, and Thailand) are also making vigorous efforts to promote the use of nuclear energy to meet rapidly increasing demands for electricity. These demands are fanned by the phenomenal economic growth in the region in the past decades and the continuing push to improve the region's standard of living.

The end of the Cold War and the indefinite extension of the Non-Proliferation Treaty generated both high hopes for nuclear arms reduction and concern over what should be done with the separated plutonium from dismantled weapons. At this crossroads, plutonium is viewed on one hand as the energy bridge to economic prosperity, and on the other as a target of proliferators and hence a chief cause of global instability.

It is not surprising, therefore, that Japan's long-standing policy of basing its nuclear energy program on reprocessed plutonium became the focus of debates between the United States and Japan.[28,29] The polarized viewpoints expressed in these debates centered on the dual aspects of nuclear energy and nuclear proliferation, with Japan steadfastly arguing the beneficial energy use of plutonium and the United States continually discouraging fuel reprocessing and the stockpiling of separated plutonium. With each side holding fast to its argument, it is unlikely that the debate will come to any fruitful conclusion soon.

Background

The debate between the United States and Japan over the dual aspects of nuclear technology is long-lived. The United States, alarmed by India's 1974 detonation of a nuclear device using technology and materials obtained in the name of peaceful purposes, in 1978 changed its policy toward the use of plutonium in the nuclear fuel cycle. For Japan, whose concern is energy security, the salient event in 1974 was not the Indian explosion but the aftermath of the first Arab oil embargo.

When President Carter announced in April 1977 that the United States was going to defer civilian reprocessing and the use of plutonium in existing reactors, right at the time when Japan was completing the final stage of its first pilot scale reprocessing plant at Tokai Mura, considerable consternation was felt in Japan. Because of the existing U.S.–Japan agreement on nuclear cooperation, the United States was asked to make a special exception for Japan, and Japan would ask for U.S. permission each time U.S.–origin fuel under Japanese custodianship was reprocessed. The exception created a disparity because Japan was allowed to do what the U.S. domestic industry was not able to do. And the permission was considered preferential and discriminatory because no such permission was granted to South Korea, Japan's neighbor, even after many requests.

The Tokai reprocessing issue served to intensify the dispute between the United States and Japan on nuclear energy and nuclear proliferation. Although President Carter's policy on civilian reprocessing was later rescinded, the U.S. stance against reprocessing was anchored on the prevention of nuclear proliferation. Under the current U.S. reprocessing policy, as announced in President Clinton's nonproliferation policy statement put forward in September 1993, the United States will neither engage in reprocessing nor encourage or discourage it in other nations, and will seek to eliminate where possible the accumulation of stockpiles of plutonium.

Japan, in light of a long-term energy program emphasizing the importance of the peaceful use of nuclear energy, enacted a plan for the recycling of nuclear fuel, including the use of plutonium in existing and advanced light-water reactors (LWRs) and in fast breeder reactors. In an attempt to dispel suspicions over its controversial plutonium-use programs, Japan has signed the NPT, accepted full-scope IAEA inspections, and promoted openness and transparency of the program, as well as imposed upon itself the rule of maintaining a supply-and-demand balance of plutonium.

The December 8, 1995 coolant leak incident in Japan's prototype fast-breeder reactor, Monju, amounted to the most serious setback to Japan's plutonium-use program. By 2010 Japan's consumption of plutonium is projected to reach five metric tonnes annually, including 600 kg by Monju and 700 kg by a yet-to-be-built demonstration breeder reactor. The projection is designed to match the corresponding amount of plutonium to be supplied by the existing Tokai reprocessing plant and the Rokkasho reprocessing plant, now under construction. If Monju is out of service for a prolonged period, an accumulation of excess plutonium could result, raising concerns for the protection of the plutonium in Japan and worry in other Asian countries about the prospect of Japan developing a nuclear weapons program.

To maintain a supply-and-demand balance of plutonium, Japan would have to increase the use of plutonium in existing LWRs. Since U.S.–origin fuel is involved and Japan's domestic capacity for mixed-oxide (MOX) fuel fabrication is not yet adequate, Japan requested U.S. consent to add the European MOX facilities to the list of fuel-cycle facilities designated under the 1988 U.S.–Japan agreement on nuclear cooperation. Again, the request highlighted a disagreement between the U.S. Department of Energy and the State Department over Japan's plutonium-use policy, creating an issue somewhat reminiscent of the 1997 Tokai reprocessing situation.

How Would a Regional Compact Help?

A regional compact framework for nuclear cooperation in East Asia could promote economic cooperation, nuclear material safeguards and transparency, the safe operation of nuclear facilities, and the safe disposal of nuclear waste material. The coordinated management and reciprocal inspection of plutonium stocks held by all member states, including Japan, would be an important aspect of such a regional framework. If Chinese and Korean personnel could monitor Japan's plutonium stock, and vice versa, the concern that plutonium could be misused in Japan for weapons activities would be minimized.

Appendix 3
South Korea's Research Program in DUPIC

Spent pressurized water reactor (PWR) fuel can be used directly in CANDU reactors without the need for conventional wet chemical reprocessing (such as the PUREX process) or re-enrichment. Atomic Energy of Canada, Limited (AECL), the Korean Atomic Energy Research Institute, and the United States Department of Energy are involved in a joint program to develop a process for the Direct Use of spent PWR fuel in CANDU reactors (DUPIC). This involves reconfiguring the spent PWR fuel into a form that can be used in a CANDU reactor without using wet reprocessing technology. The spent PWR fuel is decladded and refabricated by an oxidation-reduction dry process, OREOX.[30] In OREOX, the volatile and semi-volatile fission products are removed and all the fuel materials and solid fission products are directly reused as DUPIC fuel. The inclusion of the highly radioactive fission product in the DUPIC fuel requires that OREOX operation be remote or automated. It also provides a radiation barrier to enhance the proliferation resistance of the DUPIC fuel. The fissile content of the reference DUPIC fuel is 1.5 wt%, which is more than twice that of natural uranium fuel.

AECL has already demonstrated many of the critical features of the advanced fuel cycle. DUPIC fuel bundles are simple and therefore relatively easy to construct using remote/ automatic handling technology. This means that the advanced fuel cycle and in particular the DUPIC fuel cycle are considered feasible by the South Koreans.

The proliferation resistance of the DUPIC technology should not be focused on the OREOX process alone. The examination should involve the entire DUPIC fuel cycle, including the operation of the CANDU reactor. A regular CANDU reactor employs a continuous refueling of natural uranium in pressurized fuel channels. It is easier to conceal dedicated fuel channels for the production of desired weapons nuclear material in a CANDU than in a standard LWR. Dedicated fuel bundles could then be recycled as "deflected fuel" and processed through the remotely operated OREOX for the recovery of clandestine weapons-usable material. Stringent monitoring requirements are necessary for a DUPIC fuel cycle.

How Would a Regional Compact Help?

The two-tier fuel-reprocessing policy imposed by the United States on the U.S.–origin fuel discharged by reactors operated in South Korea is problematic. The United States has so far denied any attempt by the South Koreans to reprocess the U.S.–origin fuel, but has allowed Japan to do so. If fuel reprocessing means the conventional, aqueous PUREX process, South Korea could request an exemption to the restriction on the grounds that OREOX is not fuel reprocessing since it is a dry process and it does not completely separate the fission products from the fuel material.

An East Asian regional compact framework for nuclear cooperation could provide coordinated management and reciprocal inspection of the nuclear material held by all member states. If South Korea opened its advanced fuel-cycle facilities to Chinese and Japanese inspectors, in addition to IAEA inspectors, the concern over proliferation from its DUPIC fuel cycle could be minimized.

Appendix 4
Taiwan's Security Concerns and Spent Fuel Management Problem

Taiwan currently has a spent nuclear fuel inventory of 1,850 MgHM discharged from its nuclear reactors and stored in wet storage pools at reactor plant sites. Taipower has re-racked the on-site wet storage pools for the four older nuclear units. With increased capacity plus spent-fuel shuffling among the six operating units, the average capacity for discharged fuel could be adequate beyond 2000. Taiwan is a densely populated island, however, and it most likely would not be able to locate a suitable site for permanent spent fuel disposal. Thus, Taiwan has discussed with China, Russia, and the United States (for storage in the Marshall Islands) a possible spent fuel storage/disposal agreement.

Taiwan has left its back-end nuclear policy open and has not decided whether to reprocess or directly dispose of the spent fuel. Taiwan attempted in the late 1970s to develop fuel-cycle technology, including reprocessing, but had to give up the effort because of immense pressure from the United States.

Chinese war games in the Taiwan Strait triggered by the "private" visit of Taiwan's president to Cornell University in the United States in June 1995 heightened Taiwan's security problem. China's missile tests and naval maneuvers off Taiwan in March 1996 were confronted by U.S. carrier fleets conducting surveillance in international waters off the test area. The end of the Chinese military exercises, which occurred without incident, marked the end of the crisis. But Taiwan's desire to expand its international profile continues. In August 1996, the vice president of Taiwan "privately" visited Ukraine, a former Soviet republic that still holds a significant portion of the Soviet nuclear weapons stockpile and possesses nuclear weapons know-how. Japan's *Daily Yomiuri* newspaper reported on August 24, 1996[31] that four Taiwan Air Force pilots tested Sukhoi Su-27 fighter jets in Ukraine to learn the capabilities of the fighters used by China.

How Would a Regional Compact Help?

Taiwan's security dilemma and the presence of a large inventory of fissile-containing spent fuel are sources of concern for the stability of the region. An East Asian regional compact framework could provide members with regional spent fuel storage facilities and waste repositories. Suitable host countries for the East Asian region could be China or the Russian Far East. Spent fuel generated in Taiwan could be transported to the host country(ies) for interim storage or permanent disposal, eliminating the concern that such spent fuel could be overtly or covertly reprocessed for the acquisition of fissile material.

Appendix 5
The U.S.–DPRK Agreed Framework

The Korean Peninsula Energy Development Organization (KEDO), founded on March 9, 1995, is the international organization established to implement most of the Agreed Framework signed by the United States and North Korea on October 21, 1994. The Agreed Framework addressed international concerns about clandestine nuclear activities in the DPRK, and if implemented will ultimately lead to the complete dismantlement of those aspects of the DPRK's nuclear program, including reprocessing-related facilities and the graphite-moderated reactors.

The U.S.–DPRK Agreed Framework called for the DPRK to:

- Freeze and eventually dismantle its graphite-moderated reactors (dismantlement will be completed upon the completion of the LWR project).
- Cease activities at, seal, and eventually dismantle all reprocessing-related facilities (dismantlement will be completed upon the completion of the LWR project).
- Cooperate in finding a safe method to store existing spent fuel from the DPRK's 5 MWe experimental reactor and to dispose of such fuel in a safe manner that does not involve reprocessing in the DPRK.
- Allow the IAEA to monitor the aforementioned freeze and to resume ad hoc and routine inspections of facilities not subject to the freeze upon conclusion of a Supply Agreement for the LWR project (such a Supply Agreement between KEDO and the DPRK was signed on December 15, 1995).
- Come into full compliance with the DPRK–IAEA safeguards agreement upon completion of a significant portion of the LWR project.
- Remain a party to the Nuclear Non-Proliferation Treaty (NPT).
- Engage in North-South dialogue, and take consistent steps to implement the North-South Joint Declaration on the Denuclearization of the Korean Peninsula.

In exchange for implementing its commitments under the Agreed Framework, the DPRK will receive:

- Two light-water reactors, on a turnkey basis, with a total generating capacity of approximately 2,000 MWe. KEDO will develop a delivery schedule for the LWR project aimed at a completion date of 2003.
- 150,000 tons of heavy fuel oil for heating and electricity production by October 1995 and 500,000 tons annually thereafter until the start of full power operation of the first LWR.
- Formal assurances from the United States against the threat or use of nuclear weapons.

In addition to the above, the Agreed Framework called for the United States and the DPRK to:

- Reduce barriers to trade and investment, including restrictions on telecommunications services and financial transactions.
- Open a liaison office in each other's capital.

- Upgrade bilateral relations to the ambassadorial level following progress on issues of concern to each side.

KEDO is currently supported financially by twelve countries, though much of KEDO's costs are covered by South Korea, the United States, and Japan, including all administrative costs. South Korea and Japan will finance a major portion of the LWR project, while the United States will contribute to the cost of heavy fuel oil and the safe storage of the DPRK's spent fuel. Since its inception, KEDO has been in need of funding for the provision of heavy fuel oil. The DPRK was caught diverting the first few shipments of heavy fuel oil to uses other than providing heating to its people. The DPRK threatened to restart its indigenous reactors and reprocessing facilities if the disputes over the U.S. funding and oil diversion were not resolved in its favor. In addition, the IAEA was still seeking to verify the accuracy and completeness of the DPRK's inventory of nuclear materials, to install monitoring equipment in the Yongbyon reprocessing facility, and to examine the fuel rods from the 5 MWe experimental reactor.

How Would a Regional Compact Help?

The four main parties of KEDO, the United States, the DPRK, South Korea, and Japan, are also members of the proposed East Asian regional compact. KEDO essentially is a multilateral organization set up to deal with a specific regional problem. KEDO should extend its membership to include China and Russia, because both countries are the DPRK's neighbors and allies (former or present), both have a significant interest in the region's security and stability, and both could be suitable host countries to receive the DPRK's eight thousand spent fuel rods.

Appendix 6
Russia's Nuclear Wastes in the Far East

In early 1993, Russia admitted that the former Soviet Union had for decades dumped civilian and military radioactive wastes in the Sea of Japan (the East Sea). The total quantity of radioactive materials involved is listed below:

Location	**Activity at time of dumping (Ci)**	
	Liquid Effluent	Solid Waste
Sea of Japan (East Sea)—at six sites	11,985.00	7,000.00
Sea of Okhotsk—at one site	0.10	
East coast of Kamchatka—at two sites	350.00	

The dumping of radioactive wastes in the Sea of Japan (East Sea) is one of the most significant sources of marine pollution. The revelation of past Soviet dumping highlighted the possibility of additional uncontrolled radioactive pollution of the sea from Russia's military and civilian reactors operating in the Far East.

Russia lacks the financial resources and onshore facilities required to manage the radioactive legacy of the Cold War. Among the most urgent tasks is the removal of nuclear reactors and spent fuel from decommissioned nuclear-powered submarines and icebreakers for safe onshore storage and disposal. To curtail Russia's dumping of radioactive waste at sea and to prevent the accident of a decommissioned nuclear submarine sinking with a reactor core aboard, interim storage facilities and an eventual permanent repository must be constructed on Russia's Far East territory. The facilities are needed in the Far East because of the vast amount of radioactive material (wastes and spent fuel) already accumulated in the region, because the Russian rail system is not reliable for transport of radioactive material across Siberia, and because the Mayak facility is limited in its capacity to reprocess the naval fuel.

Russia is in need of funding and technical know-how for decommissioning and decontamination of nuclear vessels. Other countries in the region have complementary capabilities. Japan, for example, has significant experience in decommissioning its former nuclear-powered ships, and has provided Russia with support in constructing onshore LLW storage facilities.

How Would a Regional Compact Help?

The Russian Far East is a scarcely populated region. There should be ample land area for suitable sites in the region for the construction of a permanent spent fuel or HLW repository. Russia would have to construct onshore storage facilities in the Far East region for its radioactive wastes and the spent nuclear fuel generated by its Pacific nuclear fleet. If it would consider accepting radioactive wastes and spent fuel generated by its neighbors, such as Taiwan, South Korea, and Japan, financial assistance could be provided by these states. An East Asian regional compact framework could facilitate such a needed storage/disposal arrangement.

Appendix 7
Uranium Enrichment and Front-End Nuclear Fuel-Cycle Policies

Background

The global uranium enrichment market is undergoing a number of significant changes. These changes, including the privatization of the United States Enrichment Corporation (USEC), the blending and sale of U.S. and Russian high-enriched uranium (HEU), and the expanded use of new enrichment technologies (i.e., centrifuge and laser isotope separation) not only could profoundly affect the supply of future enrichment services, but also could have significant implications for the nonproliferation aspect of the nuclear fuel-cycle policies.

The privatization of the world's largest uranium-enrichment supplier, USEC, will significantly alter the primary supply picture, although the process is moving more slowly than originally projected. When privatization occurs, USEC's future business strategy will depend on its new owners' business interests and objectives, which are to maintain and increase profitability. This strategy is very different from that of a government-owned U.S. enrichment enterprise, whose supply decisions were made primarily to conform to U.S. nonproliferation objectives. Before the formation of USEC, the U.S. Department of Energy (DOE) owned and operated the three gaseous diffusion plants (the Portsmouth in Ohio, Paducah in Kentucky, and K-25, already shut down, in Oak Ridge, Tennessee) and provided enriched-uranium fuel to domestic utilities and most of the foreign-reactor operators who conformed to the U.S. nonproliferation policy. The United States could dictate the back-end nuclear fuel-cycle policies of these foreign reactor operators by demanding consent rights over the U.S.–origin fuel (and, for that matter, any non-U.S.-origin fuel that resides in the reactor cores at the same time as the U.S.–origin fuel). For example, the USDOE could grant permission to Japan's utilities to reprocess the spent fuel produced from U.S.–origin fuel, but continuously discourage South Korea and Taiwan from pursuing fuel reprocessing. As a privately owned company, however, USEC would primarily be focused on business and may not have the same nonproliferation obligation as the USDOE.

Over the next decade, the blending and sale of U.S. and Russian HEU could profoundly change the uranium enrichment market. Between the two countries' blending operations, it is likely that a quarter of the world demand for enrichment services could be met. The LEU from HEU blending would most likely be used domestically, which in turn would increase the pressure on the already competitive market serving the foreign reactor operators. It is expected that most of the demand for enrichment services would come from Asia, a region which is already competitive among non–U.S. enrichment suppliers, mainly Tenex of Russia, Cogema of France, and Urenco, a European consortium.

New enrichment technologies that reduce power consumption and production costs, like Atomic Vapor Laser Isotope Separation (AVLIS) and advanced centrifuges, will greatly influence the future uranium enrichment market. No supplier can afford to rely on gaseous diffusion or older centrifuge technology for the long term. Whether USEC is privatized or remains a government corporation, it simply could not continuously operate two gaseous diffusion plants (at Portsmouth and Paducah) and expect to make a profit. It is expected that USEC will retire one or both of the U.S. gaseous diffusion plants and deploy AVLIS over the next two decades. Japan and France also have ongoing AVLIS development programs. In addition, Russia, Urenco, and Japan all have proven operating centrifuge plants and have been successful at gradually increasing the separation efficiency and reducing the costs of their technology. The expanded use of these new technologies and the competitive market will make uranium enrichment a global commodity tied more to market forces and less to political constraints.

How Would a Regional Compact Help?

A regional compact framework could help current nuclear programs in East Asia secure the supply of uranium enrichment. It could ensure a stable, reliable, and economical supply of nuclear fuel from global suppliers to all member states and provide coordinated management and reciprocal inspection of nuclear material in the region. An assured fuel supply could reduce a country's temptation to pursue an independent policy of nuclear fuel self-sufficiency. In addition, a regional compact framework could provide a forum for constructive dialogue and promote confidence-building measures to ensure that nuclear activities in the region would be consistent with the NPT and the statutes of the IAEA.

With the United States seemingly losing its market share of providing enrichment services and having less control over the policies of emerging nuclear programs, it is prudent for it to consider a regional compact alternative to ensure that its nuclear objectives be realized.

Appendix 8
Summary of Spent Fuel Management Programs and Back-End Nuclear Fuel-Cycle Policies in East Asia

The spent nuclear fuel management programs in East Asia (China, Japan, North and South Korea, Taiwan, and the Russian Far East) are described below.

China

The amount of spent nuclear fuel accumulated in China's reactors was approximately 165 MgHM as of 1996. Its civilian nuclear power plants (the 300 MWe Qinshan, and the two units of 900 MWe each at Daya Bay) would generate 65 MgHM of spent fuel per year. Based on a nuclear generating capacity of 2.1 GWe by 2000, there will be a total of 425 MgHM of spent fuel accumulated in China's nuclear program.

In order to reduce its radioactivity, the civilian nuclear spent fuel is stored in wet storage pools at the reactor plant site for five years.[32] This interim storage period will most likely be extended to ten years or more because the reactors' owners would like to put off delivery of spent fuel to postpone payment to the fuel reprocessor. The current plan[33] is to transfer spent fuel after five to ten years at the reactor to a central wet storage facility at Lanzhou, Gansu province. Work on the wet storage facilities at the Lanzhou site has begun. They are to be constructed and completed in three phases, with storage capacities of 550, 500, and 1,050 MgHM, respectively, for each phase.

China's nuclear back-end policy is to pursue spent-fuel reprocessing and recycling of the recovered uranium and plutonium. A pilot fuel reprocessing facility with throughput of 25 MgHM per year is now under construction at Lanzhou and is expected to be operable by 2000. A commercial-size reprocessing plant with a capacity of 400 MgHM per year is to be built, most likely at Lanzhou, with completion planned for around 2020.

China's current nuclear generating capacity is too small to support a commercial-size reprocessing facility. It is anticipated that the total capacity of China's nuclear power plants, almost all pressurized light-water reactors except for a few CANDU reactors, will come to 20 GWe by 2010. Assuming that China's nuclear capacity increases at a rate of 2 GWe (equivalent to two 1,000 MWe nuclear power plants) a year beginning in 2001, the annual discharge of spent fuel could reach 600 MgHM or more depending on the CANDU reactor share, and the total amount of spent fuel accumulated by 2010 would be more than 3,000 MgHM.

China's nuclear power plants (existing and planned) are mostly located in the southern and southeastern coastal areas, while the central spent fuel storage facilities and the future fuel-reprocessing plant are located in the northwestern province of Gansu. Spent fuel thus must be transported long distances by sea and by rail. Under the terms of a contract negotiated between it and the owner of the Daya Bay nuclear power plants (a Sino-Hong Kong joint venture), China National Nuclear Corporation (CNNC) will take over the 800 to 1,000 MgMH of spent fuel discharged from the plants (which equals twenty years of discharge from the reactors covered by the joint-venture ownership period). Since there is no direct rail access to the Daya Bay plant site, a combined transport option by both sea and rail was adopted, using large loading casks for a planned schedule of two round trips a year.

A sea route of about 3,000 nautical miles from the Daya Bay site along the South China Sea coast is planned.[34,35] Two ports, Shanhaiquan or Lanshan in the middle of China's eastern coast, could be equipped with a custom-built marine terminal and equipped with a rail-mounted cantilever crane for unloading the spent fuel casks off the ships and transferring them onto the connecting rail line. The rail transport distance between the marine terminal at the port and the central storage facilities at Lanzhou is about 3,000 km.

China's emphasis during this early stage of developing its civilian nuclear program will most likely be on nuclear safety and capacity expansion. Back-end spent fuel management and disposal will not become a major issue until around 2010, when nuclear capacity has expanded significantly and the spent fuel has accumulated to a significant quantity. However, China can play an important role in helping to resolve some of the most critical nuclear issues currently facing its regional neighbors, mainly the provision of interim storage facilities (similar to those being constructed at Lanzhou) for spent nuclear fuel generated by its regional neighbors. In the mid-1980s China offered the European utilities (in Belgium and Germany) the service of managing their spent fuel for a fee of US$1500 per kgU. It would be interesting to see whether China would again be willing to offer a similar type of service (for a fixed fee and a defined duration) to utilities in the East Asia region.

In addition, China is a declared nuclear-weapons state with an established nuclear material production program. China's nuclear weapons program is relatively small compared with those in the United States and Russia. Nevertheless, its program has produced significant amounts of nuclear materials, including spent fuel and radioactive wastes, which require interim storage and ultimate disposition. How China decides to deal with the nuclear weapons material, and how this decision will impact the management of its civilian nuclear material, will be closely watched.

Japan

The amount of spent nuclear fuel accumulated in Japan's nuclear power reactors was approximately 13,000 MgHM as of 1996. Based on the current nuclear capacity of 41 GWe, its civilian nuclear power plants (fifty units) would generate approximately 1,000 MgHM of spent fuel per year. By 2010, Japan's nuclear power projection is expected to reach 72 GWe, though it is doubtful that this target can be met because of the difficulty in obtaining adequate siting for new capacity.

Spent fuel discharged from reactors is stored in wet storage pools at reactor plant sites. A total of 7,100 MgHM of that inventory is under contract to the UK and French reprocessors. The rest is stored and destined for the Rokkasho-mura reprocessing plant, an 800 MgHM/year plant expected to be in operation by 2000. High-density racks employing neutron-poison design have been incorporated in most of the wet storage pools at reactor plant sites. The total spent fuel storage capacity in Japan's nuclear program is 14,300 MgHM at current reactor plant sites plus 4,800 MgHM now in expansion.

Japanese utilities are concerned with the extremely high capital cost of constructing and completing the Rokkasho-mura reprocessing facility. Should there be further delay in Rakkasho-mura's start-up schedule, the total amount of spent fuel accumulated in the nuclear program could reach a point at which existing reactor plants would have to shut down because of lack of on-site storage space. The cooling pond that is co-located at the Rokkasho-mura facility could be used for central storage. However, the pond's storage capacity is limited to 3,000 MgHM, equal to approximately three years of annual discharge from Japan's nuclear power plants.

Assuming that the Rokkasho-mura plant could be started up by 2000 and Japan's total nuclear capacity could reach 72 GWe by 2010, additional storage capacities would be required after 2010. In addition, there is a legal issue associated with the spent fuel management problem in Japan. The relevant Japanese law requires the reactor owner to specify where and how the spent fuel will be managed before the reactor is granted a license to operate. This is the major reason that Japanese utilities contracted with UK and French reprocessors long before they were faced with actual needs. Similarly, it will very soon be necessary for those utilities filing applications for new nuclear plants to specify where spent fuel from the plants will be stored or processed in ten or fifteen years' time.

Recognizing such potential difficulty in managing Japan's vast amount of spent fuel, Atsuyuki Suzuki of Tokyo University, in his presentation to the Energy Workshop of the Northeast Asia Cooperation Dialogue V meeting in Seoul, proposed an international collaboration on nuclear spent fuel management in East Asia. His proposal was to build and operate international facilities in East Asia for intermediate storage of spent fuel from nuclear power plants and for underground research on geologic disposal.

South Korea

The amount of spent nuclear fuel accumulated in South Korea's nuclear power reactors was approximately 3,000 MgHM as of 1996. Based on the current nuclear capacity of 8.2 GWe, its civilian nuclear power plants (nine PWRs and one CANDU reactor) would generate approximately 250 MgHM of spent fuel per year. South Korea's nuclear capacity is expanding rapidly and its nuclear power projection is expected to reach 26 GWe by 2010. The total amount of spent fuel accumulated by then would be about 12,000 MgHM.

Spent fuel discharged from reactors is stored in wet storage pools at reactor plant sites. Some of the pools have been renovated with high-density racks to increase storage capacity. After the wet storage pool at the Kori site (which houses four reactor units) is re-racked with high-density racks, the average storage capacity for discharged spent fuel from all four units will reach its limits by 1997. An interim storage facility for spent fuel will be built by 2001; an away-from-reactor wet storage pool with a storage capacity of 3,000 MgHM is being considered. However, none of these plans will meet Kori's immediate need for additional storage space, and shuffling of spent fuel to other sites will be required to prevent the shutdown of any Kori units.

The South Koreans understand that spent-fuel shuffling among at-reactor sites will alleviate the management problem only temporarily. They therefore must find alternative means to store, or otherwise dispose of, the spent fuel accumulated in their nuclear power program. It is also becoming increasingly difficult to acquire extra sites for storage of spent fuel and radioactive wastes, however, let alone disposal, because of widespread resistance among local populations. The 1995 plan to build a special storage facility on Kulop Island off Inchon met with violent popular opposition and the plan had to be canceled.

Fuel reprocessing is a possible alternative, although several hurdles would have to be overcome. First is consent from the United States on reprocessing U.S.–origin spent fuel. South Korea has not provoked the United States by seeking reprocessing capability, although it has sought reprocessing-related technology—so far without success—from Canada and the United States. Second is its commitment to North Korea under the 1992 Joint Declaration on the Denuclearization of the Korean Peninsula not to build an indigenous reprocessing plant on the Korean Peninsula. (However, IAEA inspections of North Korea's nuclear facilities at Yongbyon later in 1992 revealed North Korea's continued expansion of a clandestine reprocessing plant, a clear violation of its NPT and Joint Declaration obligations. This led to South Korea's shelving of the bilateral declaration on the denuclearization of the Korean Peninsula.) South Korea could send its spent fuel abroad (for example, to the United Kingdom, France, and even Japan after 2005) for reprocessing, and it has held talks with Russia on reprocessing its spent nuclear fuel at an incomplete facility (RT-2) at Krasnoyarsk in Siberia. Third is the success of South Korea's research project with AECL and the United States on DUPIC, a process of direct-use of PWR spent fuel in CANDU reactors.

Taiwan

The amount of spent nuclear fuel accumulated in Taiwan's nuclear power reactors was approximately 1,800 MgHM as of 1996. Based on the current nuclear capacity of 4.9 GWe, its civilian nuclear power plants (four BWRs and two PWRs) would generate approximately 150 MgHM of spent fuel per year. Due to increasing domestic opposition to nuclear power, Taiwan's nuclear program is expected to experience only a modest gain over the next decade, with its nuclear power projection by 2010 at about 8 GWe. The total amount of spent fuel accumulated by then will be about 4,000 MgHM.

Taipower has re-racked the on-site wet storage pools for the four older nuclear units, and the two newer units are equipped with high-density storage racks. (The wet storage pools of the two newer PWR units were designed to store the lifetime discharge of spent fuel.) With increased capacity plus spent-fuel shuffling among the six operating units, the average storage capacity for discharged fuel should be adequate from now to the early years of the next century. Taiwan is a densely populated island, however, and it would most likely not be able to locate suitable sites for an interim spent fuel storage facility as well as for permanent disposal. Thus, Taiwan has discussed with China, Russia, and the United States (for storage on the Marshall Islands) possible spent fuel storage/disposal agreements. Without such agreements, it fears that some of the operating nuclear power plants would have to be shut down due to the lack of storage spaces at reactor sites and the massive opposition from the public to building interim storage facilities in or near local communities.

Taiwan has left its back-end nuclear policy open and has not decided whether to reprocess or directly dispose of the spent fuel. Taiwan attempted in the late 1970s to develop fuel-cycle technology, including reprocessing, but had to give up the effort because of immense pressure from the United States.

North Korea

North Korea has about eight thousand spent fuel rods discharged from and currently stored in water pools at the 5 MWe Yongbyon nuclear reactor plant. Since 1995, the USDOE has been assisting the North Koreans in recanning these spent fuel rods in stainless canisters. After recanning, the spent fuel canisters will be placed back into the wet storage pools pending future disposition. During the early phase of negotiation of the now-signed Agreed Framework, these spent fuel rods were planned to be shipped to a third country. However, North Korea is currently using them as a guarantee that the two LWRs are constructed, after which it will allow them to leave North Korea. And since then the list of possible third-country recipients of the fuel rods has shrunk significantly. (North Korea was not willing to send the rods to Russia, South Korea, or Japan. China appears unwilling to accept them, and transport to France or the United Kingdom would be too costly because of the distance involved.) The North Korean spent fuel rods may have to be brought back to the United States for storage or further processing.

Under the DOE's Reduced Enrichment to Test and Research (RETR) program, the United States is currently accepting the return of spent fuel from research reactors in foreign countries. These foreign research reactors were originally fueled with high-enriched fuel provided by the USDOE. Some of the returned fuel received at the Savannah River Site in South Carolina may require reprocessing because the fuel rods are cladded with material that would not be adequately corrosion-resistant or suitable for long-term storage. Should the United States take custodianship of the North Korean spent fuel rods, questions regarding the ownership of these rods and the recovered material, in case of reprocessing, as well as safeguards and security during transport and safety during interim storage and processing, will need to be resolved.

There is great interest in locating a host country in the East Asia region that is capable of and willing to accept the spent fuel rods from North Korea. For reasons of economics and safety, much of the routine handling and shipment of these rods should be carried out on a regional basis to minimize costs and risks (safety and security) associated with the shipments.

Russian Far East

The Russian Far East is home to Russia's Pacific nuclear fleet, which makes up about one-third of Russia's active fleet of nuclear-powered submarines, icebreakers, and surface supply ships. A somewhat larger number of nuclear-powered vessels makes up the inactive fleet. Much of the inactive fleet consists of submarines awaiting dismantlement and disposal of their nuclear fuel, reactor compartments, and radioactive wastes. The dismantling of the inactive fleet poses serious risks of nuclear contamination to the regional environment if accidents or releases of radioactivity were to occur.

Russia lacks the financial resources and onshore facilities required to manage the radioactive legacy of the Cold War. Among the most urgent tasks is the removal of nuclear reactors and spent fuel from decommissioned nuclear-powered submarines and icebreakers for safe onshore storage and disposal. To curtail Russia's dumping of radioactive waste at sea and to prevent the accident of a decommissioned nuclear submarine sinking with a reactor core aboard, interim storage facilities and an eventual permanent repository must be constructed on Russia's Far East territory. The facilities are needed in the Far East because of the vast amount of radioactive material (wastes and spent fuel) already accumulated in the region, because the Russian rail system is not reliable for transport of radioactive material across Siberia, and because the Mayak facility is limited in its capacity to reprocess the naval fuel.

Russia is in need of funding and technical know-how for decommissioning and decontamination of nuclear vessels. Other countries in the region have complementary capabilities. Japan, for example, has significant experience in decommissioning its former nuclear-powered ships, and has provided Russia with support in constructing onshore LLW storage facilities.

Summary

The spent fuel management programs and the back-end nuclear fuel-cycle policies in East Asian countries and areas are summarized below.

China

Spent fuel quantity:

- Accumulated in 1995 100 MgHM[36]
- Annual discharge ~65 MgHM (based on the current nuclear capacity of 2100 MWe)
- Accumulated by 2000 ~425 MgHM

Spent fuel storage: Wet storage at reactor plant sites for 10 years, then transfer to central wet storage.
Central wet storage is co-located with the planned fuel reprocessing facility in the northwest region.
Work has started on the wet storage facilities, which are constructed in 3 phases. Storage capacities are 550 MgHM, 500 MgHM, and 1050 MgHM.

Back-end policy: Fuel reprocessing.
A reprocessing facility was built on the Lanzhou site (northwest region) in 1970.
A new 25 tU/y pilot plant now under construction there is expected to be in operation by 2000.
A commercial reprocessing plant with a capacity of 400 tU/y is to be built in Gansu province, with completion planned for around 2015.

HLW will be vitrified, presumbly using the PAMELA technology, the vitrified wastes will be stored for 50 years,then disposed in a deep geologic repository.

The program for a repository for HLW contains 4 phases:
1985 to 1995 - technical preparation
1995 to 2010 - geologic studies
2010 to 2025 - construction of underground laboratory and site experi ments
2025 to 2040 - repository construction

Prospective repository sites for HLW will be at Chinese nuclear test sites (Lop Nur, Gobi desert) or Taiyuan in Shanxi province.

Remark: In the 80s China offered the European utilities the service of managing their spent nuclear fuel, for a fee of US$1500 per kgHM. It would be interesting to see whether China would again be willing to offer a similar type of service to utilities in countries of the East Asia region.

Japan

Spent fuel quantity:

- Accumulated in 1995 — 12,800 MgHM[36]
- Annual discharge — ~800–1000 MgHM (based on the current nuclear capacity of 39,000 MWe)
- Accumulated by 2000 — ~16,800–17,800 MgHM

Spent fuel storage: Spent fuels discharged from reactors are stored in wet storage pools at reactor plant sites.
Spent fuels transported from nuclear power plants to reprocessing are cooled for one year.
Upon receipt at the reprocessing facility, spent fuels are kept for four years in the wet storage pool.
The pool's storage capacity is 3000 MgHM, approximately three years of annual discharge.

Back-end policy: Fuel reprocessing.
A reprocessing facility is now operating at Tokai-mura.
A commercial reprocessing plant with a capacity of 800 tU/y is being constructed at the Rokkasho site, expected to start operating after 2000.

Japan will rely on BNFL of the UK and Cogema of France for repro cessing for some time to come.
Plutonium, reprocessed from spent fuel from Japanese nuclear plants by BNFL and Cogema, is to be fabricated into MOX fuel and recycled in Japanese reactors.
4 Mg of fissile plutonium to be used by the fast reactor Monju and the ATR Fugen by 2000.
From 2000 to 2010, the estimated fissile plutonium need is 35–45 Mg. About 30 Mg will be supplied by the overseas reprocessing plants and the balance from the Tokai and Rokkasho plants.

The storage facility for high-level vitrified waste returning from abroad was completed in Jan. 1995.
On April 26, 1995 the first cask, containing 28 canisters of vitrified HLW, arrived from France.
A geologic repository program is planned for 2030.

Remark: Japan AEC has recently revised the country's plan for future nuclear development. The revised program allows some slowing down of nuclear development, notably in fuel reprocessing and plutonium use. This may result in a surplus of separated plutonium. Japan would face a problem of whether to store the separated plutonium at overseas reprocessing plants and pay the high cost of storage, or to ship the plutonium back to Japan and risk diversion and theft. (Japan's constitutional ban on using heavy-armed guards is problematic in terms of safeguarding and securing the separated plutonium.)

South Korea

Spent fuel quantity:

• Accumulated in 1995	2,600 MgHM[36]
• Annual discharge	~250 MgHM (based on the current nuclear capacity of 8200 MWe)
• Accumulated by 2000	~3,850 MgHM

Spent fuel storage: Spent fuels discharged from reactors are stored in wet storage pools at reactor plant sites.
For the Kori site (which has four reactor units), after re-racking the wet storage pool with high-density racks, the average storage capacity for discharged spent fuel of all four units will reach its limit by 1997.
Shuffling of spent fuel from the Kori units to others may be required.
An interim storage facility for spent fuel (ISFSF) will be built by 2001, and an away-from-reactor wet storage pool with a storage capacity of 3000 MgHM is being considered.

Back-end policy: South Korea has not decided whether to reprocess or directly dispose of the spent fuel.
However, S. Korea is currently conducting research with AECL of Canada on a DUPIC fuel cycle (Direct Use of spent PWR fuel In CANDU): to process the spent fuel from PWRs, convert and fabricate the product into CANDU fuel bundles (with or without the fission products), and recycle into the CANDU reactor.
The goal of the DUPIC fuel cycle is to generate less HLW on the basis of per unit energy produced.
The nonproliferation aspect of the DUPIC fuel cycle warrants further evaluation.

South Korea currently has no plan for a radioactive waste repository after its plan to use the island of Kurop-do to be the country's first repository was opposed by the local government.

Remark: The DUPIC fuel cycle pursued by South Korea would be a challenging issue for U.S. nonproliferation policy. The South Koreans would re quest permission from the USDOE to (re)process U.S.-origin fuel using the DUPIC technology.

Taiwan

Spent fuel quantity:

• Accumulated in 1995	1,700 MgHM[36]
• Annual discharge	~150 MgHM (based on the current nuclear capacity of 4900 MWe)
• Accumulated by 2000	~2,450 MgHM

Spent fuel storage: Spent fuels discharged from reactors are stored in wet storage pools at reactor plant sites.

Taipower re-racked the on-site wet spent-fuel storage pools for the four older units. With increased capacity plus spent-fuel shuffling among storage pools of the six operating units, the average storage capacity for discharged spent fuel will be adequate beyond 2000.

Taipower initiated in 1993 the preparatory work for a regional reposi tory to store its spent fuel.

Discussions with China, Russia, and the U.S. Marshall Islands for a possible ISFSF site are ongoing, but so far no deal has been made.

Back-end policy: Taiwan has not decided whether to reprocess or directly disposal of its spent fuel.

Taiwan's present nuclear policy is to use nuclear energy for electricity generation. Taiwan presently has not pursued fuel-cycle technology (discounting the failed attempt in the late 1970s).

Taiwan faces a dilemma with its spent fuels (and radioactive wastes) if it is unable to find a satisfactory repository location within its territory, cannot send the spent fuel to its regional neighbors, and cannot send the spent U.S.-origin fuel to a U.S. repository for disposal.

Remark: Taiwan is a densely populated island, and most likely will not be able to locate a suitable site for spent fuel disposal. If shipping the spent U.S.-origin fuel back to the United States or anywhere else is not likely, Taiwan may request U.S. permission for fuel-reprocessing in Europe (France and the U.K.).

North Korea

Spent fuel quantity:

- Accumulated in 1995 — 8,000 spent fuel rods at the 5 MWe Yongbyon nuclear reactor plant site[37]
  The plant is currently shut down.

Spent fuel storage: The 8,000 spent fuel rods have been stored in cooling ponds since mid-1994.

In 1995, the fuel rods were placed in stainless steel canisters. The original plan was to ship them out of North Korea; however, North Korea has demanded a guarantee that the LWRs will be built before they will ship the fuel rods out.

Russia, Japan, and South Korea are not now able to receive the fuel rods, China appears unwilling to accept them, and transport to France or the U.K. would be too costly.

North Korea's spent fuel rods may need to be brought to the United States for reprocessing.

Back-end policy: North Korea is using its clandestine nuclear program to get political concessions from the United States and to obtain financial assistance from its neighbors, primarily South Korea.

The signed Agreed Framework between the United States and the DPRK should stop the reprocessing activities at Yongbyon. However, completion of the two LWRs is at least a decade away, and there are problems that could potentially undermine the framework, such as disputes on fuel oil shipment and distribution irregularities, the DPRK's internal political turmoil, and South Korea's domestic and financial uncertainties

Remark: Under the nuclear framework agreement between the United States and North Korea, North Korea's nuclear program would under even more severe IAEA scrutiny. How well this arrangement (i.e., international safeguards and security administrated by the IAEA) will work is still unknown. An alternative safeguard and security arrangement involving its regional neigbors (i.e., the regional comapct framework) is war ranted.

Russian Far East

Spent fuel quantity:

- Accumulated in 1995

Russia's commercial nuclear program in its Far East region is small (120 MWe).

However, Russia's Pacific fleet of nuclear submarines is operated and maintained in the region.

The nuclear submarines are required to be defueled peri odically. The discharged spent fuel discharged is trans ferred into service ships and brought to shore for interim storage.

Spent fuel storage: With the end of the Cold War and the breakup of the Soviet Union, spent submarine fuel discharged from the Pacific fleet currently is accumulating in the Far East region.

The Pacific fleet faces difficulties similar to those of the Northern and Arctic fleets, i.e.:

- onshore storage capacity is already filled to the limit,
- it is not financially possible to build additional storage facilities,
- the railroad system is old and frequently broken down, so shipping the spent fuel to Mayak is difficult,
- the reprocessing capacity at Mayak is too limited to accommodate spent fuel from the Far East,
- the spent fuels are either stored in storage compartments on board the service ships or left in the submarine cores.
- these vessels (service ships and submarines) are old, and it is doubtful

that they are structurally capable of maintaining the spent fuel for indefinite storage.

Back-end policy: Russia needs financial assistance from the international community to deal with the nuclear legacy of its navy.
Several of its actions, such as directly discharging low-level liquid wastes into the Sea of Japan (East Sea), and the direct dumping of entire nuclear submarine cores in the Kara Sea, received strong international condemnation.

Remark: Under the proposed regional compact framework in East Asia, Russia could offer the services of storing/disposing others' spent fuel and nuclear wastes for a fee. Russia is a declared nuclear weapons state, so its acceptance of others' spent fuel or HLW would attract less concern over the internal diversion of these materials. In addition, Russia may have to consider a repository in the Far East to dispose of spent submarine fuel from its Pacific fleet.

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