PACIFIC NUCLEAR COUNCIL

REPORT ON INTERNATIONAL COOPERATION ON HIGH LEVEL NUCLEAR WASTE (HLW) AND SPENT NUCLEAR FUEL (SNF) MANAGEMENT

PNC - Task Group on HLW/SNF

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CONTENTS

1. Background and Introduction

According to the APEC Energy Demand and Supply Outlook (APERC, 2002), energy demand in the APEC region is likely to grow faster than in other regions. Most APEC economies, in particular Northeast Asian economies, do not have enough energy resources to meet their growing demand and must rely on imports. Dependence on regions outside APEC for energy will increase in the future.

Nuclear energy can be one of the important options from the viewpoint of "trilemma" between 3Es (Environmental protection, Energy security and Economic growth), especially considering the rapid economic growth seen in Northeast Asian countries. The use of nuclear energy however inevitably generates radioactive waste which has potential radiological impacts on humans and their environment. All categories of radioactive waste therefore must be managed in a safe and reliable manner and an extensive infrastructure has been developed or is under development in each of the countries for this purpose.

Under the circumstances, the management of spent fuel (SNF) and high-level radioactive waste (HLW) has become one of the most difficult and, sometimes, from a public view point, intractable problems associated with nuclear power generation. SNF, discharged from nuclear reactors, must be stored safely and securely at reactor sites, or at interim storage facilities away from reactors. Some countries consider SNF as a valuable resource, while others consider SNF as a waste to store at least for a while.

If the SNF is to be directly disposed of, a suitable geologic repository must be properly constructed to ensure the permanent isolation of SNF from the biosphere. If the SNF is to be reprocessed for recovery of uranium and plutonium, the resulting high-level liquid waste must be solidified and stored and then finally disposed of in a geologic repository.

The safe and secure storage of SNF/HLW and their subsequent management has become a major public, political, environmental and/or security concern for the country generating them, and for their regional neighbors. There are an increasing number of utilities in East Asia whose SNF inventory is expected to exceed their storage capacities before a geologic repository becomes available. These utilities would have to expand at-reactor (wet or dry) storage for SNF, or face premature shut-down of their reactors. The storage of SNF has some options, such as pool, casks and vaults. All of them are technically feasible.

Most countries which promote or maintain their nuclear power programs have been required to find a domestic solution for the management and disposal of SNF and radioactive wastes, regardless of their limited land area and/or population density. For as long as these problems of SNF and HLW management and disposal remain unresolved, the viability of nuclear power generation as an economic energy option remains questionable. It is quite possible that no new reactors would be ordered in the emerging Asian market if such solutions are not presented to the public with reasonable confidence.

This problem could not only impact the economic competitiveness of nuclear power, but could influence social and ethical aspects of nuclear power programs. It is clearly a responsibility of the present generation to do its best to come up with reasonable solutions and not to leave this problem without any options. It would be unethical for the current generation to leave this problem unresolved and to put burdens on future generations. On the other hand, it is also important to keep future options open so that future generations can decide what to do with this problem (e.g. OECD/NEA, 1995). Recognizing that SNF/HLW management is a common and important issue among East Asian nuclear programs, and that the issue could inhibit further development of nuclear power if not satisfactorily addressed, a Task Group on SNF/HLW Management was formed by the Pacific Nuclear Council (PNC) in its April 1997 meeting in Seoul, South Korea.

The objectives of the Task Group are to promote the understanding and collaboration of SNF/HLW management among PNC member countries, and to investigate, on an informal basis, the feasibility of the International Interim Storage Scheme (IISS) for management of SNF as well as what collaborative activities other than IISS could be realistic.

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2. Present Status of PNC Member Countries SNF/HLW Program

Each country that generates nuclear power selects direct disposal or reprocessing approach, based on comprehensive considerations of energy resource reserves, supply and demand situation in the energy sector, economics and political backgrounds. Specifically, France, UK, Japan, China and Russia are among the countries which have adopted the reprocessing approach while the United States and Canada are taking the direct disposal approach. South Korea and some other countries have yet to decide their direction and are in a "wait and see" status for the time being.

The following sections present the status of selected countries in the region.

2.1 Canada

The CANDU fuel cycle is based on the once-through use of nuclear fuel. The used fuel bundles are presently stored in water pools (wet storage) or in concrete containers (dry storage) at the nuclear reactor sites. The dry storage design is modular and capacity is increased as required. There are currently no plans in Canada to reprocess the used fuel.

In 1978, the governments of Canada and the Province of Ontario issued a joint statement regarding the research and development program for nuclear fuel waste management. The responsibilities were as follows: AECL to develop the technology for disposal, and Ontario Hydro to continue work on storage and develop the technology for transportation of used fuel.

In October 1989, the Minister of Environment announced the formation of a seven-member Environmental Assessment Review Panel to assess the concept for geologic disposal of nuclear fuel waste. In 1994, AECL completed it's Environmental Impact Statement and submitted it to the Panel. The Panel held public hearings on the concept, beginning in March 1996 and ending in March 1997. The Panel presented its recommendations on the safety and acceptability of the concept to the Government of Canada in February 1998. The Panel concluded that from a technical perspective, safety of the geologic disposal concept has been adequately demonstrated, although it did point out certain technical issues that merited further study. However, the Panel also concluded that the concept has not yet been demonstrated to have sufficiently broad public support.

Concurrently with the public review, the Government developed a Policy Framework for Radioactive Waste Disposal in Canada. This policy statement was issued in July 1996. The elements of this framework consist of a set of principles governing the institutional and financial arrangements for disposal of high, intermediate and low-level radioactive wastes by waste producers and owners.

In December 1998, the Federal Government issued its response to the Panel's recommendations. The government concluded that:

(a) responsibility for future work on the development of high level waste issues should be undertaken by a new "Waste Management Organization" to be created and funded by the three provincial electric utilities that operate nuclear power stations;

(b) the new WMO should proceed with the necessary work to address the technical issues that were identified by the Panel as a result of the public review of the concept; and

(c) this work should proceed in parallel with further consultation with the public and with a review of other waste management and disposal options.

In April 2001, the Federal Government submitted draft legislation to the House of Commons entitled "An Act Respecting The Long-Term Management of Nuclear Fuel Waste", referred to as the "Nuclear Fuel Waste Act". The legislation, which came into effect in November 2002, defines "nuclear energy corporations" as those organizations "that own nuclear fuel waste resulting from the production of electricity by means of a commercial nuclear reactor". This definition includes Ontario Power Generation (formerly Ontario Hydro), Hydro Quebec and New Brunswick Power, but excludes Bruce Power because the used fuel produced by Bruce Power will come under the ownership responsibility of Ontario Power Generation for subsequent long-term management and disposal. The use of the word "commercial" excludes AECL (which owns used fuel from three prototype reactors – NPD, Douglas Point and Gentilly-1).

The legislation states that the "nuclear energy corporations shall establish a separate Waste Management Organization (WMO) whose purpose is to:

(a) propose to the Government of Canada approaches for the management of nuclear fuel waste; and

(b) implement the approach that is selected by the Government of Canada.

The WMO shall offer its nuclear fuel waste management services (at a reasonable fee) to AECL and any other owners of nuclear fuel waste. The WMO also must provide annual reports of its activities to the Minister of Natural Resources.

The legislation states that each nuclear energy corporation and AECL shall maintain a trust fund (either individually or jointly) which can be drawn on for the long-term management and disposal of nuclear fuel waste. The initial deposits to these trust funds shall be made within ten days of the Act coming into force. Thereafter, annual deposits will be required at pre-defined levels.

The legislation requires that, within three years after the Act comes into force, the WMO shall submit to the Minister:

(a) a study setting out multiple options for the long-term management of nuclear fuel waste, including (but not limited to) storage at reactor sites, centralized storage (either above or below ground), and deep geologic disposal; and

(b) its recommendation as to which of the possible options should be adopted.

The study must include a detailed technical description of each option, a comparison of benefits, risks and costs, a timetable for implementation, a summary of preliminary comments received from the public and from aboriginal peoples regarding the various approaches, and a program for subsequent public consultation. In addition, the study must provide the necessary financial analysis, including an estimate of the total quantity of fuel to be managed, and the cost and the timing of expenditures for each option.

After receipt of the options study, the Minister may initiate further public consultations, and may ask the WMO to revise the relevant portions of the study if it has failed, in a significant way, to meet the requirements spelled out in the Act. However, this section of the legislation concludes with possibly the most important sentence in the whole document: "The Governor in Council (i.e., the Federal Cabinet), on the recommendation of the Minister of Natural Resources, shall select one of the approaches for the management of nuclear fuel waste from among those set out in the study."

After the long-term strategy has been chosen, the WMO will be responsible for implementing the strategy. Once the implementation plan has been established, and a proposed site has been defined, the proposal will be subject to the normal Canadian environmental assessment process before a construction license will be granted.

The Nuclear Fuel Waste Act was approved by parliament in June 2002, and was declared "in-force" on November 15, 2002. Consistent with the legislation, the three nuclear utilities established an independent Nuclear Waste Management Organization (NWMO) during the summer of 2002, and announced the appointment of the Board of Directors and the President in October. The three utilities and AECL made their initial deposits to their respective trust funds shortly after the legislation came into force in November.

In summary, Canada is currently developing options for a national solution for the long-term management of its nuclear fuel waste. Canada's policy is to manage its nuclear fuel wastes (no international wastes) within its borders. Thus, Canada will not be a participant in the use of an International Interim Storage Scheme (IISS). However, Canada recognizes the potential value that such a scheme could have (because of geologic and economic conditions) to countries of the Pacific Rim and therefore supports the regional development of such a concept.

2.2 Japan

Nuclear power program and interim storage of SNF

Since 1966 Japan has consistently developed and utilized nuclear energy including development of a nuclear fuel cycle to secure a stable energy supply for the future and to minimize environmental impacts. This position was reconfirmed in the "Long-term Program for Research, Development and Utilization of Nuclear Energy (referred to as Long-term Program)" revised by the Atomic Energy Commission of Japan (AEC) in November 2000 (AEC, 2000). In accordance with the Long-term Program, the Japanese Government has been promoting establishment of a nuclear fuel cycle including construction of the domestic commercial reprocessing plant at Rokkasho, utilization of MOX (Mixed Oxide) fuel in Light Water Reactors (LWR), management of radioactive waste including storage of spent fuel, R&D program of Fast Breeder Reactor (FBR), etc.

As of April 2002, 52 commercial nuclear power plants (29 Boiling Water Reactors /BWR including two Advanced Boiling Water Reactors/ABWR and 23 Pressurized Water Reactors /PWR) were being in operation and the total capacity of these plants reached approximately 46 GWe as shown in Figure 2-1. Nuclear power generation represented approximately 35.0% of total electricity generated. Electricity generated by the nuclear power plants, which constitutes the base load, are estimated 319.8 TWh. Four plants (four BWRs) are now under construction, and six plants (five BWRs including four ABWRs and one PWR) are planned at this moment.

Number of nuclear units in operation	Nuclear electricity capacity ~2000 (GWe)	Nuclear electricity generation (TWh)	Nuclear percentage of total electricity supply
52	46	319.8	~35

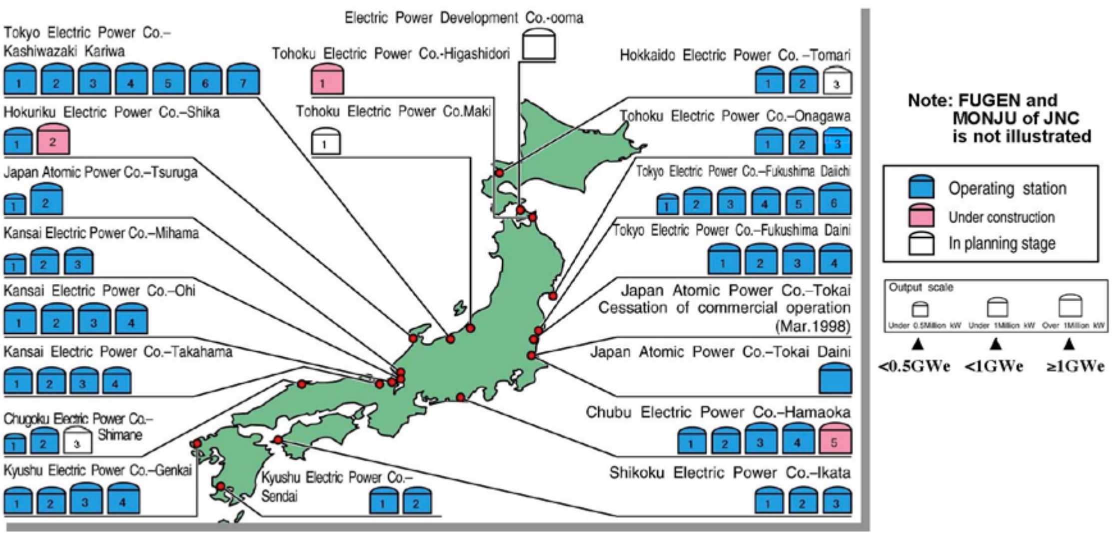

Figure 2-1 Nuclear Power Generation in Japan
(Modified figure from the FEPC's Nuclear Graphic Book (2002))

Since the first commercial nuclear reactor operated in 1966, approximately 17,320 tU of SNF have been discharged from the power reactors through the end of September 2002, of which about 5,610 tU have been shipped to overseas reprocessing plants in France and UK from 1973 to 1988. Even assuming that the

Rokkasho reprocessing plant will be in operation around the planned year 2005, the total amount of SNF to be stored would be in excess of the current storage capacity by about the year 2010. The "Nuclear Sub-committee of the Advisory Committee for Energy (NSACE)[1]" organized under the Ministry of International Trade and Industry (MITI, now METI)[2] concluded the following points in its interim report of June 1998 (NSACE, 1998).

- Recognizing SNF as reusable energy resource, the storage capacity for SNF shall be enhanced by the year 2010 by constructing some independent spent fuel storage installations (ISFSI).
- Technologies and experiences required by the ISFSI such as storage options of the water-pool and dry cask have already been established domestically as well as internationally.
- The service of ISFSI can be operated by a private company. The Government should establish the regulation framework including legislation in order to ensure the public safety and smooth operation of the ISFSI.
- The utilities have to make efforts to find appropriate sites for the ISFSI facilities.

The AEC authorized the above conclusion of the NSCACE interim report in its Long-term Program (AEC, 2000). For regulation, the "Act for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors" was also amended to appropriately regulate the commercial ISFSI service in 1999.

In 2000, the local government of Mutsu-city, Aomori Prefecture in northern Honshu Island invited the Tokyo Electric Power Company (TEPCO) to investigate the siting feasibility of the Mutsu area for the candidate site of ISFSI. Extensive surveys in the Mutsu area including meteorological, seismological, geologic, hydraulic, environmental studies and others were car ried out by TEPCO from January 2001 through March 2002. In April 2003, the TEPCO reported to Mutsu-city that no evidence was found, which would affect the performance of ISFSI. Following the report from TEPCO, the local government of Mutsu-city made a decision to accept the ISFSI site and announced it to the public on June 26, 2003. Some of other utilities are also calling for candidate sites for an ISFSI in Japan.

HLW disposal program

Since the first statement on the strategy for radioactive waste management in Japan was made by the AEC in 1976, about a quarter century has passed, in which much experience has been accumulated both in technical and social domains. Focusing on HLW disposal, this 25-year history of the radioactive waste management program in Japan is summarized by Masuda (2002).

Since 1976, the Japan Nuclear Cycle Development Institute (JNC, successor to the Power Reactor and Nuclear Fuel Development Corporation (PNC)), has been assigned to lead R&D activities for HLW disposal. The assignment is aiming at establishing not only a firm scientific and technical basis for geologic disposal in Japan but also a basis for gaining understandings of the general public and

[1] Now renamed as the "Nuclear Sub-committee of the Advisory Committee for Natural Resources and Energy"

[2] METI: The Ministry of Economy, Trade and Industry (due to reorganization of the Japanese Government on January 6, 2001)

policy-makers. It must be emphasized that the R&D had been carried out in the absence of both an implementing body responsible for HLW disposal and legislation to regulate such disposal, and with a generic manner which was assigned neither a particular rock type nor a particular geographical area.

One of the important features of the R&D program is that its progress is documented in a highly comprehensive manner at appropriate intervals. This approach allows the experts to clearly assess the level of technical achievements and hence to raise the level of public understanding. Following the release of the First Progress Report in 1992 (referred to as H3) (PNC, 1992), the JNC elaborately compiled the Second Progress Report (referred to as H12) and submitted it to the AEC in November 1999. The report gave a comprehensive and thorough assessment of the technical feasibility and reliability of the reference disposal concept in Japan's geologic environment on a generic basis.

The OECD/NEA review team carried out an independent, international peer review of the draft H12 Project Overview Report prior to the issue of the final version of the H12 report (OECD/NEA, 1999). Taking account of the review comments made by the team, JNC finalised the H12 and submitted it to the AEC on November 26, 1999 (JNC, 2000). The AEC also reviewed the H12 and concluded that the contents in the report were appropriate after receiving not only public comments but also feedback from an international review. The report should be used to provide reference for HLW disposal siting and regulatory processes.

Following the technical achievements in H12 and activities for public understanding, legislation titled the "Specified Radioactive Waste Final Disposal Act" (Final Disposal Act) was promulgated in June 2000, and thereby established the Nuclear Waste Management Organization of Japan (NUMO) in October 2000. This Act specifies the overall framework for implementation and defines the roles and responsibilities of the Government (i.e. METI: Ministry of Economy, Trade and Industry) and relevant organizations including NUMO, the funding management organization (i.e. RWMC: Radioactive Waste Management Funding and Research Center) and the owners of power reactors (Figure 2-2).

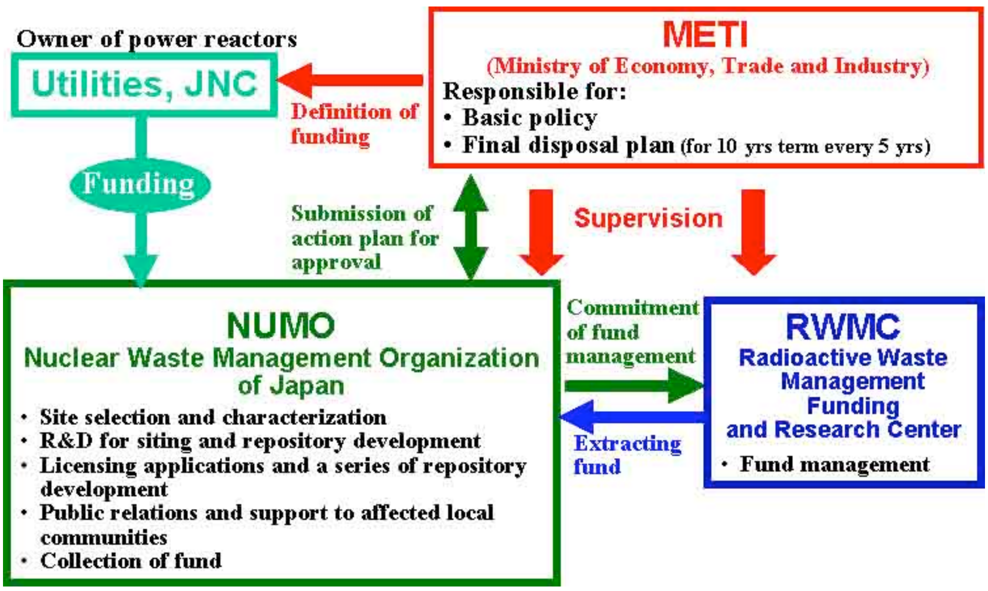

Figure 2-2 Organizational framework of implementation

NUMO is the implementing organization responsible for pursueing the overall HLW disposal program in Japan. The assigned activities of NUMO include selection of the repository site, development of licensing applications, construction, operation and closure of the repository as well as collection of fund. As producers of HLW, the owners of the nuclear power plants are responsible for bearing the costs for the repository development program. They are required to make contributions to a disposal fund in accordance with the amounts of electricity generated. NUMO commits to RWMC the management of the collected fund. The budget for NUMO's program is allocated from the fund and authorized by METI.

According to the national final disposal plan for HLW (MITI, 2000), the total inventory to be disposed of is estimated to correspond to 40,000 canisters of vitrified HLW by the year 2020, and repository operation will start as early as the 2030s. As of the end of 2001, SNF corresponding to approximately 15,500 vitrified HLW canisters had been produced, which includes fuel currently in reactors.

The Final Disposal Act provides that the NUMO's siting process shall consist of following three steps.

- In the first stage, preliminary investigation areas (PIAs) for potential candidate sites are nominated based on area-specific literature surveys focusing on long-term stability of the geologic environment.
- Detailed investigation area(s) for candidate site(s) are then selected from PIAs by surface-based investigations including boreholes carried out to evaluate the characteristics of the geologic environment.
- In the final third stage, detailed site characterization including underground experimental facilities will lead to selection of the site for repository construction.

The METI supervises the entire process carried out by NUMO. At every step, NUMO will call for opinions of local residents, and METI will call for opinions of governors and mayors to respect them.

It is also specified in the Final Disposal Act that the Nuclear Safety Commission of Japan (NSC) is responsible for providing guidelines for safety regulations. The NSC published the "First Report on the Basis for Safety Standards for HLW Disposal" (NSC, 2000) in November 2000, followed by the report entitled "Considerable Environmental Requirements for Selecting Preliminary Investigation Areas of HLW Disposal" (NSC, 2002) in September 2002, which should be reflected in PIAs selection.

As the first milestone of the siting process, NUMO announced to the public the start of open solicitation of volunteer municipalities for PIAs with four documents published together as an information package on December 19, 2002. The information package is aiming to provide basic information for supporting and promoting discussions by municipalities to decide whether the repository plan can be accepted, and is therefore sent to all (over 3,200) municipalities in Japan (e.g. Masuda, 2003). The four documents are entitled "Instructions for Application", "Repository Concepts", "Siting Factors for the Selection of Preliminary Investigation Areas" and "Outreach Scheme" (NUMO, 2002). In the siting procedure, it is especially important to promote public understanding of geologic disposal and to obtain their trust. To ensure the decision-making process is transparent, NUMO makes available a variety of information relevant to its siting activities through the publication of documents, web-sites, etc., and provides opportunities for inhabitants around the potential candidate sites to voice their opinions (e.g. Masuda, 2003).

Concerning the R&D in the implementing phase, the AEC has specified its framework in the revised Long-term Program issued in November 2000 (AEC, 2000). According to the program, NUMO is responsible for conducting R&D for safe implementation of the repository with improved technology from the economical and practical aspects. Meanwhile, the government and other relevant organizations should promote R&D activities to provide scientific and technical basis for safety regulation and implementation of the final disposal including geoscientific studies and research activities to enhance the reliability of geologic disposal technology. With its extensive experience and expertise in this field, JNC should carry on these studies as well as other R&D activities to increase the reliability of geologic disposal technologies and to improve safety assessment methods using underground research laboratories (URLs) and the Quantitative Assessment Radionuclide Migration Experimental Facility (QUALITY), etc.

Under the above-mentioned framework, JNC has been conducting its R&D efficiently and effectively to collect relevant data, develop advanced models and increase the reliability of geologic disposal technologies for extending the scientific and technical basis developed through the H12 project. Using the URLs and other facilities, it will also demonstrate the reliability of the technologies developed for the generic geologic environments observed in Japan by applying the technologies to the specific geologic environments (e.g. Shiotsuki, et al., 2003).

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2.3 Korea

In Korea, the accumulated amount of spent fuel generated from nuclear power plants (NPP) are 6,500 tHM for 12 PWRs and 2,700 tHM for 4 CANDU (Canadian Deuterium Uranium) reactors, respectively, as of the end of 2001. In June 1996, the Korean Atomic Energy Committee (AEC) decided to establish a dedicated organization, Nuclear Environment Technology Institute (NETEC) under Korea Electric Power Corporation (KEPCO) for radioactive waste management. Since the nuclear power generation business was separated from KEPCO to a subsidiary company Korea Hydro & Nuclear Power Co., Ltd (KHNP) in April 2001, NETEC was also transferred to KHNP. At present, KHNP/NETEC is responsible for all radioactive waste management including spent fuel generated from nuclear power plants in Korea.

AEC has decided that spent fuel will be stored in a centralized interim storage facility until the Korean policy for the back-end fuel cycle is established.

Since 1985, enormous efforts have been made to secure a site for the permanent disposal of low- and intermediate-level radioactive waste. This site is also to accommodate a centralized interim storage facility for the spent nuclear fuels.

The details of the AEC's decision for the spent fuel management are as follows:

(1) A centralized spent fuel interim storage facility will be built by 2016 with storage capacity of 2,000 MTU at the first stage and 20,000 MTU finally.

(2) All the spent fuel should be stored at reactor sites until 2016 with expansion of exiting on-site storage capacities.

(3) The storage type of spent fuel (dry and wet) at the central facility will be determined after a feasibility study considering technical and economic aspects.

The current storage capacities at reactors are insufficient to store the spent fuels until the year 2016 when the centralized interim spent fuel storage facility is available. Consequently, the expansion of storage capacity within reactor fuel building has been the major task to be implemented at nuclear power plants.

KHNP has started to replace the existing standard racks with High Density Storage Racks (HDSR) for pressurized water reactor power plants. After the additional storage space is obtained by installing the HDSR, transshipments of spent fuel from the pools with standard racks to the pools with HDSR within the same site is being carried out. The HDSR's have been installed at Kori-3,4, Ulchin-1,2, Yonggkwang-1,2 and the 370 spent fuels assemblies have been transshipped so far.

In Wolsong site where four CANDU reactors are in operation, concrete silos were constructed in addition to the spent fuel storage pools at the reactors. Spent fuel bundles with the minimum 6-year cooling time in the pools are transferred to the silos. Since CANDU reactors produce much more spent fuel than PWR's due to the lower U-235 enrichment, the number of silos has to be rapidly increased as the reactors produce power. Therefore, the space saving storage facility has to be developed. KHNP is currently developing such a facility with Atomic Energy of Canada Limited. The new type of the dry storage system named as MACSTOR/KN-400 will make it possible for Wolsong spent fuels to be stored at the site until 2016.

By expanding the on-site spent fuel storage capacity, the spent fuels will be stored at each reactor site before the centralized interim storage facility is open in 2016. Currently KHNP is working to secure a waste disposal site where the spent fuel interim storage facility will be located.

Much effort is being carried out under the governmental supervision with the following principles.

- Voluntary subscription of candidate sites by local governments
- Democratic and open site selection process for public acceptance
- Financial support programs for the local community

The site subscription was offered to local governments in June 2000 to June 2001. There were several requests for voluntary subscriptions by local residents in several areas, but final subscription was not filed by the local governments due to the pros and cons among the residents.

Since the open subscription was not successful, KHNP decided to nominate candidate sites first, and to negotiate with the relevant local governments and residents for the final site.

2.4 United States of America

<u>Background</u>

The United States approach to the disposal of SNF/HLW is based on several factors as follow:

1. The U.S. National Academy of Sciences, after a detailed study, stated that HLW could be safely disposed of in a geological repository. This was a very important finding since it allowed the Nuclear Regulatory Commission (NRC) and its predecessors to continue to license the operation of nuclear power plants on the basis that on a scientific basis, the fuel cycle could be closed.

2. During the Carter Administration, the U.S. adopted a policy of no commercial fuel reprocessing, and direct disposal of SNF.
3. At the time of the policy decision set forth in (2), the U.S. had some stored liquid HLW from early reprocessing at the West Valley Reprocessing Plant.
4. The U.S. Government had reprocessed and continued to reprocess fuel at its Hanford and Savannah River plants to extract plutonium from spent reactor fuel for its military weapons program. It also reprocessed spent naval ship fuel at its Idaho Engineering Laboratory (INEL) to reclaim unused high enriched uranium for recycle. The HLW at Hanford and Savannah River was stored as liquids in underground tanks, while the much of the waste at INEL was calcined into a solid form, the remainder being stored as liquid in tanks.

Against this background of findings and creation of HLW in several forms, the U.S. Government began a program to find a suitable site for permanent disposal of the existing and future SNF/HLW, capable of storing both spent fuel and vitrified HLW from the weapons program, the naval fuel reprocessing program, and the early commercial reprocessing program.

A broad U.S. program was established to search for a suitable site for a permanent repository. Sites in various locations and geological formations were identified, and screened. From this initial screening process three sites, in different media were selected for further study. The three sites selected were a bed salt formation at Deaf Creek, Texas, a tuff (compressed volcanic ash) site at Yucca Mountain, Nevada, and a basalt rock formation at the Hanford site in Washington state. Study and evaluation of the three sites proceeded through the mid-1980s. In 1987, amendment of the Nuclear Waste Policy Act (NWPA) of 1982 was passed by the U.S. Government. One of amendment provisions established that only the Yucca Mountain site could be evaluated, until its suitability as a SNF/HLW repository was determined. It stated that the selected site would store the first 70,000 tonnes of heavy metal waste.

It was originally planned that the first repository would be operational in 1992. In recognition of the program delays, the 1987 amendment of NWPA committed the U.S. Government to begin accepting and storing commercial spent fuel in early 1998. The Government was unable to meet the requirement, resulting in serious problems and potential shutdown of various nuclear power plants as their spent fuel storage ponds filled up. Some plant owners increased the size of their ponds; some obtained licenses and have started storing their oldest and coolest fuel in dry storage casks; and some with multiple plants have transferred spent fuel between sites to take advantage of storage space available at their newer plants. In some cases plant owners have met very stiff opposition by state regulators to dry cask storage. As a result, there have been several efforts, at least one still in process, to establish remote dry spent fuel storage sites to solve the problem of a lack of on-site storage capacity.

In addition to the SNF/HLW disposal program, the U.S. weapons program developed large quantities of transuranic waste. The decision was made to also dispose of this material in a deep geological repository but in a repository separate from the SNF/HLW waste storage site. A site in bedded salt about 25 miles east of Carlsbad, New Mexico was chosen. The very large salt bed is approximately 600 meters thick and begins approximately 300 meters below the surface. Facility design began in 1978, and basic construction was completed in 1986. The Waste Isolation Pilot Plant (WIPP) main repository horizon is at the vertical center of the salt bed, approximately 600 meters below the surface. A long delay ensued while the licensing process was completed. Licensing was completed and the repository went into operation in 1999.

Current Status

The WIPP repository is the world's first licensed and operating repository for permanent disposal of transuranic waste. Waste is being transported to the repository from the several U.S. Government sites where it was generated. The transport system and repository operation are satisfactory in every respect, with no significant incidents having been reported since operations began.

Much work is under way to prepare the HLW for disposal in the repository. Vitrification of the commercial waste at West Valley is nearly complete. The vitrification plant at Savannah River has been operating for approximately a decade. Construction of the vitrification plant at Hanford is well underway with production expected to begin in the later part of this decade.

At Yucca Mountain, over the last 14 years, test tunnels have been bored and a very extensive scientific characterization program has been conducted. The site was found suitable for long term disposal of SNF/HLW, and a recommendation was made to the President to proceed to develop the site as the first U.S. SNF/HLW disposal site. Following the procedures established in the 1987 Nuclear Waste Amendment Act, the objection to the site by the state of Nevada resulted in submittal of the program to the U.S. Congress, which approved the site for continued development. Work is proceeding on preparing a site licensing application for review and approval by the U.S. Nuclear Regulatory Commission. While it is expected that there will be continuing legal efforts to stop the licensing and development of the site, it is also expected that work will go forward resulting in licensing and operation of the Yucca Mountain by 2010.

3. International Cooperation on HLW/SNF Management

Background

The International Atomic Energy Agency (IAEA)'s Joint Convention on the Safety of Spent Fuel and Radioactive Waste Management[3] recognizes that the ultimate responsibility for ensuring SNF and radioactive waste rests with the country which produces them. It also recognizes, however, that the choice of a nuclear fuel cycle policy rests with the individual country. Some countries consider spent fuel as a valuable resource that will eventually be reprocessed, and others consider spent fuel as waste as the cost of recycling is larger than the current value of the contained energy and that separation of plutonium may increase unnecessary proliferation risk.

Nowadays, most spent fuel is being stored either on power plant sites, or at reprocessing plants. Final disposal programs for HLW have been taken in many countries. In recent years, there have been remarkable progresses, as described in section 2 for some PNC member countries such as the United States, Canada and Japan, and also, some European countries such as Finland and Sweden have been

[3] http://www.iaea.org/worldatom/Documents/Infcircs/1997/infcirc546.pdf

making significant steps in their SNF/HLW disposal programs.
All programs, whether large or small, should be able to contribute to find out the possible solutions of their SNF/HLW management problems.

The IAEA recognizes the importance of international cooperation in enhancing the safety of spent fuel and radioactive waste management through bilateral and multilateral mechanisms. It recognizes, under certain circumstances, safe and efficient management of spent fuel and radioactive waste can be fostered through agreements among contracting parties in such a manner that facilities in one party's country could be used for the benefit of other contractual parties. More recent statement by Dr. ElBaradei, the Director General of IAEA, at the 58th Regular Session of the United Nations General Assembly on November 3, 2003, emphasized the multinational approach to the management and disposal of spent fuel and radioactive waste, since "not all countries have the appropriate geological conditions for such disposal and , for many countries with small nuclear programs, the financial and human resources required for the construction and operation of a geological disposal facility are daunting."

Interest in international storage and disposal of SNF has been still taken during the past decade for various reasons summarized below:

(1) Need for additional capacity and difficulties in expanding storage capacity or finding new sites for storage facilities
(2) Delay in final repository programs for SNF in most countries
(3) Need for international cooperation on dealing with the legacy of the Cold War, especially need for support on the appropriate management in the former Soviet Union
(4) Need for reexamination of the effective assurance from the non-proliferation scheme

In particular, in East Asia, there have been a number of studies and proposals for international cooperation in dealing with SNF/HLW. However, so far, none of these proposals have been realized. There are various reasons for lack of progress, but the most fundamental barrier is that it is not clear whether potential benefits are greater than the potential costs and risks. Therefore, it is important to study both sides of such international proposals and carefully define the key policy issues.

The report on interim storage of spent fuel by Harvard University and the University of Tokyo analyzes the idea of international storage/disposal and discusses in detail the advantages and disadvantages of such proposals.[4]

And, it is widely recognized among nuclear utilizing countries that building confidence in the long-term safety of geologic disposal is vital to the overall SNF/HLW management strategy, even though concepts and programs differ from country to country.

Regarding the R&D on HLW disposal, international cooperation has been continuously promoted through bilateral and multilateral frameworks (e.g. OECD/NEA, IAEA, and other individual mechanisms). It can provide the perspective of achieving international scientific consensus for assessment methods

[4] "Interim Storage of Spent Nuclear Fuel: A Safe, Flexible, and Cost-effective Near-Term Approach to Spent Fuel Management," A Joint Report from the Harvard University Project on Managing the Atom and the University of Tokyo Project on Sociotechnics of Nuclear Energy, June 2001. see http://ksgnotes1.harvard.edu/BCSIA/Library.nsf/pubs/spentfuel.

and results, complementing and efficiently promoting domestic research and international contributions.

Potential Advantages

(1) Economy of Scale

The first potential advantage is the *economy of scale*. Economy of scale is clear for many parts of the nuclear power and fuel cycle facilities as they typically require large capital investment. It seems, however, the potential advantage on economy of scale is clearly greater for a permanent repository than for interim storage. Dry cast storage technologies, for example, provide few economies of scale. On the other hand, there is a strong economy of scale argument for a geologic repository or even for a large underground R&D facility for HLW. In short, the benefit of economy of scale is more apparent for a final repository or large R&D facilities than for interim storage.

(2) Saving Efforts (through joint efforts)

Second, efforts from planning to completion of the facilities for managing SNF/HLW are tremendous for any nation with nuclear power. Joint cooperative efforts, rather than duplicating such efforts by country, would provide significant advantage over national programs. These benefits can be significant for final repository programs which require large R&D programs, safety assessment, and siting efforts. On the other hand, such efforts for interim storage are relatively small and joint cooperative efforts may not provide a big advantage over national efforts.

(3) Provide more options (in particular for smaller nations)

The third possible advantage is to *provide more options* to national nuclear power programs. In particular for smaller countries, finding such sites is a difficult political challenge even in the case of additional capacity for interim storage of spent fuel. An international site could provide an option for reactor operators that have not been able to provide sufficient storage capacity within their countries.

(4) Enhance Transparency

The fourth advantage is to *enhance transparency* of SNF/HLW management programs. Currently all civilian spent fuel in NPT countries (non-nuclear weapon states) is under international safeguards (full-scope safeguards). But the IAEA typically treats that information as confidential. In addition, there are still large amounts of spent fuel in nuclear weapon states as well as in non-NPT countries that are not under international safeguards. For example, in East and South Asia, spent fuel in China, North Korea, India and Pakistan are not fully safeguarded. If a joint international management scheme is realized, it is possible to enhance transparency of information on spent fuel in those countries. Enhancing transparency of spent fuel should, of course, be pursued regardless of possibility of an international storage/disposal scheme. However, it is possible that such international storage/disposal scheme will make it easier to enhance transparency of SF/HLW management.

(5) Non-proliferation and security advantage

Finally, but not least important, international storage/disposal can bring a significant *non-proliferation and security advantage* over national programs. An example would be the removal of spent fuel from countries posing particularly high proliferation risks. In East Asia, removing spent fuel from North Korea is an important condition to minimize proliferation risk. International storage could avoid unnecessary reprocessing in some countries where additional spent fuel storage cannot be found easily. The proposals, for example by the Russian Ministry of Atomic Energy (Minatom)[5], include international storage of spent fuel from other countries in Russia to help funding of important management and disposition program of surplus fissile material from nuclear disarmament. It is believed that specific cost of spent fuel storage, e.g. per unit of fuel serviced, is currently one order of magnitude smaller than that of reprocessing or final disposal. Therefore, it seems practically feasible to start from storage of spent fuel when an international scheme is to be implemented. It is also important to note that the non-proliferation and security advantage are one of the original driving forces of international schemes since the 1970s.

(6) Sharing technical knowledge and concern

Although international storage and/or repository programs and proposal have received high attention, there have already been many international cooperation programs in this area. For those international cooperative programs, the most visible advantage is to share advanced technical knowledge as well as policy concern, such as public outreach. For example, IAEA has programs like "A Network of Centers of Excellence for Demonstration of and Training in Disposal Technologies" and "The Peer Review Services."[6] OECD/NEA also has such programs as "Integration Group for the Safety Case (IGSC)". These are typical examples of international cooperation which facilitate sharing and transferring the advanced knowledge among the member nations. OECD/NEA has a program called "Forum on Stakeholders Confidence (FSC)" which focuses on public perception and confidence.[7] The Peer Review program and FSC program would also enhance the public confidence as it will increase transparency of the program. One specific area of cooperation is risk communication and consensus building approach, where many stakeholders will have dialogue with experts to increase understanding of science and other parties' views. In Asia, such experience is relatively limited and thus can be an important area of international cooperation.

To utilize limited and valuable research resources, technical collaboration and information exchange in the field of R&D on geologic disposal have been encouraged recently between related institutes and organizations in East Asia under both bilateral and multilateral basis recently. Successful large scale experimental projects have also been undertaken on a cooperative basis, between various institutes and agencies, e.g., the Tunnel Sealing Experiment in Canada's Underground Research Laboratory, which was jointly supported by Atomic Energy of Canada Limited (AECL), Japan Nuclear Cycle Development Institute (JNC) and Agence Nationale Pour La Gestion Des Dechets Radioactifs (ANDRA).

[5] Nuclear Fuel, November 10, 2003

[6] Arnold Bonne, "Radioactive Waste and Spent Fuel Management at Crossroads," Global Spent Fuel Management Summit 2001, Washington, DC, October 15-17, 2001.

[7] Jeffrey Williams, "OCRWM International Program Briefing", Global Spent Fuel Management Summit 2001, Washington DC, October 15-17, 2001.

Two underground research laboratories in Japan (Mizunami and Horonobe) as well as two surface experimental laboratories (ENTRY and QUALITY) will be expected to play an important role for center of excellence (COE) of R&D on geologic disposal in East Asia. In the Mizunami URL for crystalline rock (Granite), the sinking of shafts started in 2003 and complete excavation of the shafts up to 1000metre depth and installation of access and ventilation systems expected to be completed by 2010. At the Horonobe URL for sedimentary rock, the sinking of shafts will start in 2005 with schedule for completing excavation of the shafts up to 500metre depth, etc by 2010. JNC has much experience for accepting more than 360 foreign researchers from Asia region to its research facilities in several R&D areas since 1985 with it's fellowship program. JNC has also constructed a facility with accommodations for promoting its international exchange program at Mizunami URL.

A concept of a Joint Underground Research Laboratory had been proposed by Prof. A. Suzuki, which could also be understood as an attempt to facilitate such international collaboration in this field.[8]

Potential Disadvantages

(1) Need for complex international negotiation

First, export and import of SNF/HLW requires *complex international negotiations* which itself can bring significant disadvantage over national programs. One concern is non-proliferation. In East Asia, most spent fuel outside China is US-origin and thus any international transaction requires prior consent from the USA. Russian proposal for international storage and reprocessing service for East Asian countries would face tough approval process in the USA. It is likely that if reprocessing service is included in the proposal, the USA will deny such transactions.

Another concern is of course negotiation with local government and residents. The "Not in my Backyard (NIMBY)" phenomena is now common to most countries. Negotiations for national programs are already very difficult; it is highly probable that negotiation for an international SNF storage program with local residents will be more complicated and difficult. Negotiation with neighboring countries as well as countries on the transportation route is also required.

Such added need for complex international negotiation is probably the largest hurdle for realization of a successful international scheme.

(2) Possible negative impacts on domestic programs

The second disadvantage is that efforts to start international programs may bring *negative impacts on domestic programs* that are already underway. Efforts to establish an international program might give an impression that there is less need for domestic programs and thus undermine current domestic SNF/HLW management programs. Important resources (time, fund, manpower etc) may also need to be shifted from domestic programs and thus it could slow the progress of domestic programs. Ironically, creating the additional option of an international

[8] Atsuyuki Suzuki, "A Proposal on International Collaboration with Nuclear Power Development in East Asia," paper presented at the Energy Workshop of Northeast Asia Cooperation Dialogue V, Institute of Foreign Affairs and National Security, Seoul, September 11-12, 1996.

program may in fact reduce the chance of success of domestic SNF/HLW management programs.

(3) Increase transportation requirement

The third potential disadvantage is the *increased need for transportation* of SNF. Transportation of SNF has had exceptional safety record when compared with the transportation of many hazardous materials. However it still requires careful management and protection and could be costly if long distance transportation is increased significantly. This also requires international negotiation, as noted above. Therefore, it is desirable to minimize the need for transportation of SNF. An international storage scheme, in particular, would have more disadvantage than an international repository program, as it requires additional transportation to the final repository site.

(4) Raising ethical and fairness issues

As the IAEA Convention on SF/HLW management says, in principle, each national government should take care of its own SF/HLW. And thus, any international scheme may raise ethical and fairness issues since it would mean that the county which generated the SF/HLW would be passing on some of its responsibility to the recipient (host) country. In the past, it is often the case that possible host countries are less wealthy and/or less democratic. Therefore, such proposals could be considered as politically and ethically incorrect. Resolving such ethical issue will be another significant burden of SF/HLW management.

Policy Issues

Given those potential advantages and disadvantages, it is not an easy task to decide whether an international storage/repository would make sense. In addition, to implement such international facilities there are important policy issues to be considered. What are the key policy issues for the international SF/HLW management to be successful? The Harvard-Tokyo University report listed the following as important policy issues.

(1) What service to be offered?

It is important to define what type of services that international scheme would provide. Does it provide interim storage, reprocessing or final disposal? Or is it just an international cooperation for joint R&D? The differences between those services are very important, as we discussed above, for assessing potential benefits and risks of such proposals.

(2) Who bears responsibility?

The second important issue is liability issue. The key question here is whether the ownership and liability of SF/HLW should be transferred to the host state or organizations. This issue is also related to the first question of what type of service will be provided. If interim storage is the only service, ownership is likely to stay with the reactor owner/operators. But for HLW repository service, this question is more difficult to answer.

(3) How would the host state be chosen?

Finding a host state is probably the most difficult policy question to be answered. The Harvard-Tokyo University Report also listed necessary conditions for a host state. They are: [1] willingness, [2] geologic and geographic suitability (in particular for repository program), [3] effective technical and regulatory infrastructure, [4] strong non-proliferation credentials, [5] political stability, [6] agreement of customer states and consent right states, and [7] democracy. It is not easy to find host nations that satisfy all the above conditions, and that is exactly why such a scheme has not yet been realized.

(4) What institutional arrangements?

There are various proposals for international arrangements. Options include: private company, national government, consortium of private firms, and international or multinational organizations. In Asia, proposal for ASIATOM or PACATOM includes such ideas.

(5) What customers?

Customers of such international scheme also can vary from one specific country or region to nations all over the world. Many proposals call for a regional approach, such as in East Asia. But currently COGEMA and BNFL already provide services to much wider area and thus such proposals could also be realized.

(6) Where does the revenue go?

As discussed above, interim storage business could be quite profitable and thus it is important to utilize such potential profits for desirable purposes. Such proposals linking the potential revenue with security as well as environmental protection may have better likelihood to gain international acceptance. There is also the need to appropriately compensate the host nation for the risks it will take and for its commitment to the program.

4. Observations and Future Steps

Much progress has been made throughout the Pacific Basin in the development of interim storage facilities and final repositories for SNF/HLW storage and disposal, as shown above in the status reports of selected PNC member's countries. While the status of each program differs from the others, each has made progress toward final resolution of its SNF/HLW program consistent with its national needs and policy. As a result, a large body of knowledge and experience has been produced. However, resolution of various technical and institutional issues remains for each of the programs.

Based on the above discussion, the following are the PNC's observations and recommendations for future steps.

(1) International cooperation in SNF/HLW management should be pursued as it could offer significant benefit to security enhancement, public understanding, and public acceptance of storage/disposal facilities.
(2) There are some countries around the Pacific Rim which have relatively small nuclear power programs, and for whom development of long term

solutions to their SNF/HLW problems would be very expensive. Countries with potential interest in participation in an international cooperation should be identified through high level discussions.

(3) It is important to continue the dialog on what form of international cooperation is desirable, not only among those countries which have an interest in the possibility of international joint solutions, but also those countries which are proceeding with their own programs. The sharing of information from all programs is important to arrive at solutions which benefit from the work of all ongoing programs. This should include a full exchange of thoughts on interim storage, reprocessing and final repositories.

(4) Most promising areas for future cooperation include:
   a. Sharing of safety analyses to develop common minimum standards;
   b. A joint program for risk assessment;
   c. Sharing of R&D to minimize duplication and expense;
   d. Development of generic site selection criteria;
   e. Developing public understanding and acceptance.

PNC should take the lead as a catalyst to develop international cooperation and technology exchange which could lead to development over time of appropriate generic siting standards, safety standards, and international solutions to the long term disposal of SNF/HLW.

In particular, the joint R&D programs for Geological Disposal utilizing existing R&D facilities such as URLs and experimental laboratories would be one of the most promising options for the cooperative activities among PNC member countries.

APPENDIX

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