RADIOACTIVE WASTE MANAGEMENT IN REP. OF KOREA

1. NATIONAL FRAMEWORK FOR THE MANAGEMENT AND REGULATION OF RADIOACTIVE WASTE AND DECOMMISSIONING

1.1 National framework

1.1.1 Overview of national policy

The Korean government has strived to secure a disposal site for the safe management of radioactive waste since the early 1980s. The 249th meeting of the Atomic Energy Commission (AEC) held in September 1998 established the "National Radioactive Waste Management Policy", which aims at completing the construction of a Low and Intermediate Level Radioactive Waste (LILW) disposal facility by 2008, and a centralized spent fuel interim-storage facility by 2016; site selection was not successful, however. Therefore, a revision of the policy was made at the 253rd AEC meeting held on December 17, 2004, stipulating the completion of the construction of the LILW disposal facility by 2008. Nonetheless, the national policy for spent fuel management including the construction of the centralized spent fuel interim-storage facility is to be decided in a timely manner based upon the national consensus through public consultation among stakeholders. A summary of the national policy statements includes the following:

1) Direct control by the government

   – Radioactive waste, which needs long-term safe management, shall be managed under the responsibility of the government.

2) Top priority under safety

   – Radioactive waste shall be safely managed in due consideration of the biological and environmental impact so as to protect individuals, society, and the environment from the harmful effects of radiation and to observe international norms on the safety of radioactive waste management.

3) Minimization of radioactive waste generation

   – Radioactive waste generation shall be minimized.

4) "Polluter pays" principle

   – The expenses related to radioactive waste management shall be levied on the radioactive waste generator at the point of radioactive waste generation, without imposing undue burden on future generations.

5) Transparency of the site selection process

   – Radioactive waste shall be managed transparently and openly, and the radioactive waste management project shall be promoted with regard to harmony with the local community, and to community development.

1.1.2 Overview of relevant institutions

The governmental organizations concerned with nuclear activities, as shown in Figure 1-1, are mainly formed of administrative authorities; the Nuclear Safety and Security Commission (NSSC) is responsible for overall nuclear safety and security regulations, the Ministry of Trade, Industry and Energy (MOTIE) supervises the nuclear power generation and radioactive waste management programs, and the Ministry of Science, ICT and Future Planning (MSIP) is responsible for nuclear R&D programs. There is also the Atomic Energy Promotion Commission (AEPC) under the jurisdiction of the Prime Minister, as an organization for decision-making on national nuclear promotion and radioactive waste management.

The NSSC has the responsibility for the regulation in accordance with the Nuclear Safety Act (NSA), Act on Physical Protection and Radiological Emergency (APPRE), and the Nuclear Liability Act. The nuclear safety regulatory organizations are mainly composed of the NSSC, the Korea Institute of Nuclear Safety (KINS) as an expert organization of nuclear safety regulation, and the Korea Institute of Nuclear Non-proliferation and Control (KINAC) as an expert organization for the physical protection, safeguard of nuclear facilities including nuclear materials and for the control of exports and imports.

The MOTIE shoulders responsibility for the nuclear power industry and for radioactive waste management in accordance with the Electric Business Act (EBA) and the Radioactive Waste Management Act (RWMA) respectively. The Korea Hydro & Nuclear Power Co., Ltd (KHNP) affiliated under the Korea Electric Power Corporation (KEPCO) is responsible for the construction and operation of Nuclear Power Plants (NPP) and the management of radioactive waste generated from NPPs in the interim. The KEPCO Engineering & Construction Company (KEPCO E&C) supports engineering, maintenance, and facility operation of NPPs. And KEPCO Nuclear Fuel (KEPCO NF) fabricates all fuels for the domestic NPPs. The Korea Radioactive Waste Agency (KORAD, previously KRMC) was established in 2009 as the exclusive radioactive waste management agency to ensure the safe and effective management of radioactive waste in accordance with RWMA. The Korea Atomic Energy Research Institute (KAERI) under the supervision of the MSIP conducts nuclear R&D projects in accordance with the Nuclear Promotion Act (NPA).

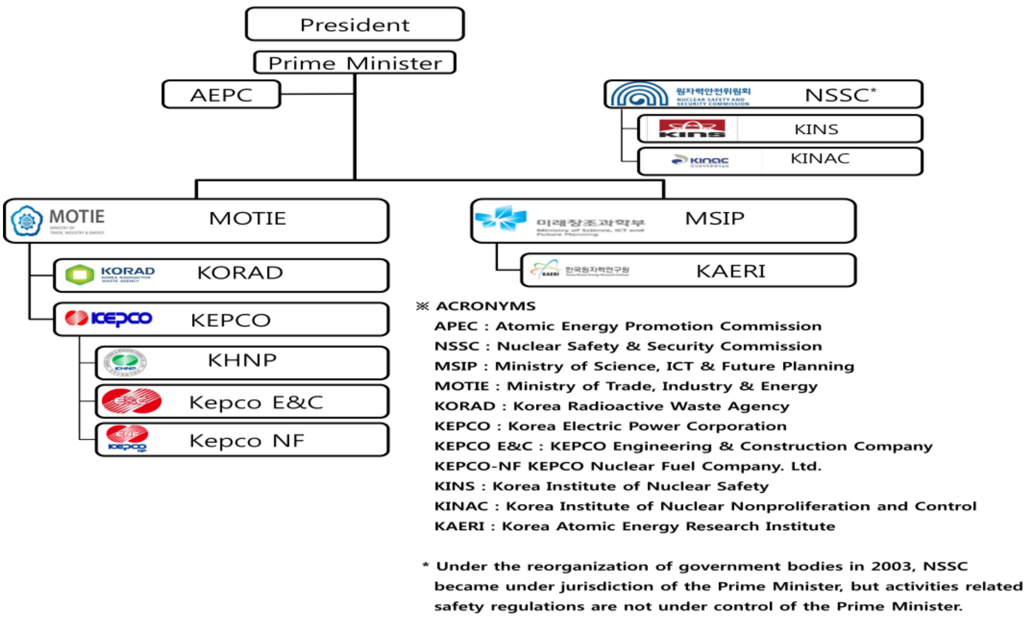

Figure 1-1 Governmental organizations related to radioactive waste management

1.2 Technical regulatory organisations

1.2.1 Regulatory function

The NSSC assumes the responsibility for establishing the licensing criteria for the construction and operation of radioactive waste management facilities, developing regulations for operational safety measures, and securing radioactive waste safety management at every stage of the site selection, design, construction, operation, closure, and post-closure of radioactive waste disposal facilities. The NSSC entrusts professional technology fields of nuclear safety regulation described above and R&D for safety regulation of radioactive waste management to KINS. And KINAC was entrusted physical protection, safeguard of nuclear facilities including nuclear materials and for the control of export and import by NSSC.

1.2.2 Organisation and resources

The NSSC is composed of nine members including the Chairman. The Chairman and one member are standing members. The standing member holds an additional position of the Secretary General. The Secretariat, which deals with the general affairs of the Commission, consists of two bureaus (i.e. Nuclear Regulatory Bureau and Radiation Emergency Bureau) and nine divisions with the staff of 93 (as of June 2013), to implement the responsibilities and functions of safety regulation under the provision of the NSSC Enforcement Regulation (Enforcement Regulation on the NSSC and its Subordinate Organizations). And the NSSC operates the advisory committee on nuclear safety and security consisting of 15 members. The Nuclear Regulatory Bureau manages the Nuclear Safety Policy Division establishing plans and revising laws and policies regarding nuclear safety, and the Nuclear Safety Division conducting nuclear regulation such as licensing and inspection of nuclear reactors and nuclear fuel cycle facilities, and the Safety Standard Division constructing and managing safety standards. The Radiation Safety Division under the Radiation Emergency Bureau is responsible for safety regulation of facilities and activities related to radioactive waste management and decommissioning.

KINS was established as an independent technical support organization in February 1990, according to the enactment of the Korea Institute of Nuclear Safety Act to conduct nuclear safety regulation as entrusted by the Nuclear Safety Act and the Act on Physical Protection and Radiological Emergency. KINS consists of one office, nine divisions, and 36 departments/teams/centers with 429 staff members (as of June 2013). To share its safety regulation technology and experience with the international community, KINS opened in January 2008 the International Nuclear Safety School, which has also functioned as the IAEA's Asian training centre since its conclusion of a Nuclear Safety Cooperation Agreement with the IAEA. The safety regulations of radioactive waste management facilities are under the responsibility of the "Radioactive Waste Safety Evaluation Department" in KINS. The budget, which is required for nuclear safety regulation business and relevant research projects, is covered by regulatory fees by relevant nuclear users and government subsidies in accordance with the Nuclear Safety Act.

KINAC was initially operated as the "Technology Center for Nuclear Control" at KAERI and seceded in January 2005. According to the newly legislated NSA, KINAC is entrusted activities concerning nuclear security by the NSSC since October 2011. KINAC consists of 2 headquarters and 12 divisions.

1.3 National implementing organisations

1.3.1 Scope of responsibility

According to the 249th meeting of the AEC, the Government of the Republic of Korea adopted the nation's ultimate responsibility for radioactive waste management in light of the importance that the long-term safe management of these wastes is required. Based on this principle, the MOTIE carries out the management policies on radioactive waste treatment, storage, and disposal, which are prepared by the MOTIE in consultation with related organizations. The KHNP manages radioactive waste in the interim; the KORAD was established with the responsibility of the exclusive management of radioactive waste.

According to the "Nuclear Safety Policy Statement", the ultimate responsibility for the safety of a nuclear installation rests with the operating organization, and is in no way diluted by the separate activities and responsibilities of designers, suppliers, constructors, and regulators. The Government has an overall responsibility for ensuring the protection of the public health and the environment from radiation hazards that may occur in the development of nuclear energy.

1.3.2 Organisation and resources

As the sole nuclear power generating company in Korea, the KHNP has 7 divisions in its headquarters, 4 nuclear power sites, 1 hydro power site, and 4 special offices including the Human Resources Development Institute and a Radiation Health Research Institute. At the head office, the KHNP operates a Radiation Safety Team, consisting of approximately 15 staff members exclusively in charge of the safe treatment of radioactive waste generated in the course of operating an NPP under the Power Generation Division, and the Radiological Emergency Response Team consisting of approximately 5 staff members under the Emergency Management Office to take exclusive charge of radiation emergency measures for nuclear power reactor facilities. At the NPP, the Radiation Safety Team has approximately 20 staff members and engages in health physics, radiation protection, and radioactive waste management, and 5 members are in charge of waste management operations such as radioactive waste treatment and temporary storage. For maintenance of radioactive waste related facilities, the KHNP consults with radiation management agencies handling radioactive waste in connection with partners such as KEPCO Plant Service & Engineering Co., LTD (KPS) to provide technical support.

The KORAD is composed of a head office, which has 3 divisions, the Wolsong LILW Disposal Center, R&D Institute and the Fund Management Center, which is an annexed agency for managing the Radioactive Waste Management Fund. The KORAD is currently constructing an LILW disposal facility and planning to complete phase 1 of the construction by the end of June 2014. The KORAD has a total of 270 staff members; 164 in the head office, 69 in the Wolsong LILW Disposal Center, 26 in R&D Institute, and 9 in the Fund Management Center. At the main office, the Radioactive Waste Management Division, which supervises and supports construction and operation of the LILW disposal facilities, is comprised of approximately 45 staff members, the Future Project and Policy Division has 25 staff members engaged in establishing radioactive waste management strategy and SNF management. The Wolsong LILW Disposal Center is in charge of the construction and operation of the LILW disposal facilities. With approximately 25 people, the R&D Institute carries out the technology development. The Receipt & Operation Office consists of 7 staff members and handles the receipt, storage, treatment, and transport of radioactive waste. The Radiation Safety & Environment Team has 10 staff members and handles radiation safety management, environmental surveys, and emergency exercises of the disposal facility. The divisions of the head office, institute and Wolsong disposal center maintain an organic cooperation system. The RWMA requires that the radioactive waste generator bear incurring management expenses incurred in relation to waste treatment and disposal at the point of waste delivery to the KORAD as the disposal licensee.

2. LEGAL FRAMEWORK

2.1 Primary legislation and general regulations

The Korean government declared in the Nuclear Safety Policy Statement established and announced in 1994 that the major premise is to secure safety in the utilization and development of nuclear energy, and all organizations and persons engaged in nuclear activities have to thoroughly adhere to the principles of priority to safety. The statement remains effective to date as the backbone of the safety first policy in the utilization of nuclear energy in Korea.

Article 3 (Establishment of a Comprehensive Plan for Nuclear Safety) of the NSA requires the NSSC to establish, in every 5 years, a comprehensive plan which should be a national plan to set out mid- to long-term policy directions to achieve nuclear safety in the nation. The NSSC, therefore, prepared in October, 2012 its first comprehensive plan to achieve the objectives set in its establishment and also to respond to the changing environment at home and abroad brought mainly by the Fukushima accident, including the feedback of lessons learned from it. Included in the plan are the items concerning nuclear safety: 1) status and outlook, 2) policy goals and basic directions, 3) tasks and action plans by area, and 4) budget requirements and financing.

National laws related to the development and safety regulation of spent fuel and radioactive waste management facilities include the Nuclear Promotion Act (NPA) and the Nuclear Safety Act (NSA) as well as the Electricity Business Act (EBA), the Radioactive Waste Management Act (RWMA), the Act on Environmental Impact Assessment and others as shown in Table 2-1. In 2011, the Atomic Energy Act (AEA) was divided into the NPA, which describes basic laws concerning nuclear energy promotion, and the NSA, which describes the basic laws concerning nuclear regulations. All the provisions on safety regulation and radiation protection for radioactive waste management are stipulated in the NSA All the provisions on safety regulation and radiation protection are stipulated in the NSA.

The NSA was enacted as the main law concerning the safety regulations for spent fuel and radioactive waste. The NSA is composed of 11 chapters including the general rules, the establishment and enforcement of a comprehensive plan for nuclear safety, and the construction and operation of reactors and related facilities, and it describes the basic matters concerning nuclear safety regulations.

The legal framework for Nuclear Safety, as shown in Figure 2-1, consists of four stages: Act (the Nuclear Safety Act), Presidential Decree (the Enforcement Decree of the same Act), Prime Minister's Regulation (the Enforcement Regulations of the same Act), the NSSC Regulation (the Enforcement Regulations Concerning the Technical Standards of Nuclear Reactor Facilities, etc., the Enforcement Regulations Concerning the Technical Standards of Radiological Safety Management, etc., and NSSC Notice). The NSSC Notice prescribes specific issues including regulatory requirements and technical standards, as entrusted by the same Act, the same Decree and the same Regulation. Provisions on the permission for the construction and operation of radioactive waste storage, processing and disposal facilities facilities are also stipulated in the NSA and its subsequent regulations.

Table 2-1. Laws concerning nuclear regulation

Title	Major Contents	Competent Authorities	Remarks
Nuclear Safety Act	Basic law on the nuclear safety regulations	NSSC	In 2011, the AEA was amended as the NPA, and the NSA was legislated based on provisions of the AEA concerning nuclear regulation.
Nuclear Promotion Act	Basic law on the nuclear power program	MSIP	
Act on Physical Protection and Radiological Emergency	Establishes more effective system for physical protection of nuclear material and nuclear facilities, and provides legal and institutional basis for preventing radiological disaster and preparing countermeasures against radiological emergency	NSSC	-
Nuclear Liability Act	Provides the procedures and the extent of compensation for any damages which an individual has suffered from a nuclear accident	NSSC	-
Act on Indemnification Agreement for Nuclear Liability	Provides the particulars on a contract between the government and the operator to make up any compensation not covered by insurance	NSSC	-
Radioactive Waste Management Act	Provides procedures related to radioactive waste management	MOTIE	Refers to the NSA for the safety regulations of radioactive waste management facilities
Electricity Business Act	Provides the basic system of electricity business	MOTIE	Specifies the basic system of the Electricity Business Act including nuclear power plants
Electric Source Development Promotion Act	Provides special cases relevant to the development of electric sources	MOTIE	Prior designation notice of nuclear site
Basic Act of Environmental Policy	Mother law of the environmental preservation policy	ME	The NSA is entrusted with the particulars on measures to prevent radiological contamination
Act on Environmental Impact Assessment	Provides the extent and procedures to assess environmental impact according to the Basic Act of Environmental Policy	ME	Assessment of environmental impacts excluding radiological impacts
Framework Act on Fire Services	Provides for general matters on the prevention, precaution and the extinguishment of fires	NEMA	The requirements for safety management of inflammables
Basic Act on Civil Defense	Provides for general matters on the civil defense system	MOSPA	Preparedness against disasters due to nuclear accidents is included in the basic civil defense plan
Basic Act on Management of Disasters and Safety	Provides for general matters on the control of man-made disasters	MOSPA	It prescribes corrective or complementary measures for violations in the implementation of the basic civil defense plan
Industrial Accident Compensation Insurance Act	Provides insurance to compensate workers in case of an industrial disaster	MOEL	Nuclear workers are to be compensated in accordance with the compensation standards in the NSA.
Industrial Safety and Health Act	Provides for the preservation and enhancement of workers' health and safety	MOEL	The NSA is entrusted with the particulars on radiological safety
Building Act	Provides for general matters on construction	MOLIT	When the sites of disposal facilities have obtained prior approval, they are to be seen as having obtained construction permission in accordance with Building Act

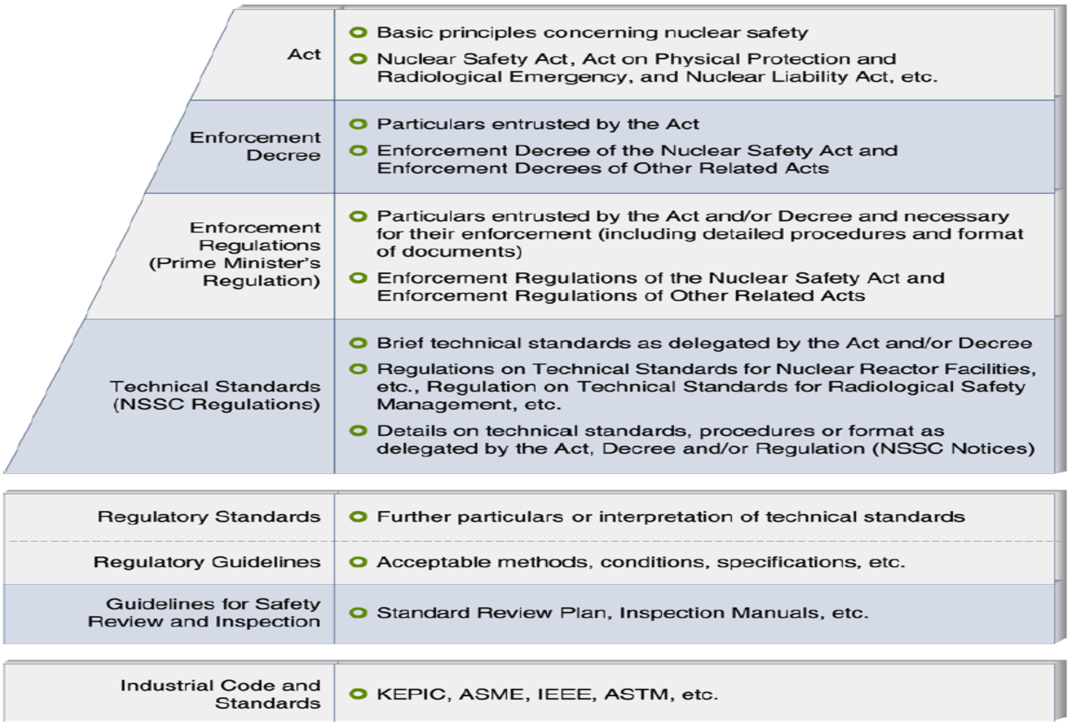

Figure 2-1. Legal Framework for Nuclear Safety Regulation

On the other hand, the RWMA, which integrates and systematically organizes matters concerned with the management of radioactive waste, was established and announced on March 28, 2008. The foundation of the RWMA provides the basis for the management of LILW, the establishment of the KORAD, and the establishment of the Radioactive Waste Management Fund. This Act came into effect on January 1, 2009, and consists of four stages: the RWMA and its Enforcement Decree and Enforcement Regulations and Notices of the MOTIE, as shown in Figure 2-2. The RWMA, amended in December 2009, provides the basis for the procedures to gather a wide range of opinions concerning matters to anticipate social conflict, such as the management of spent fuel to aid in the process of establishing a master plan for radioactive waste management.

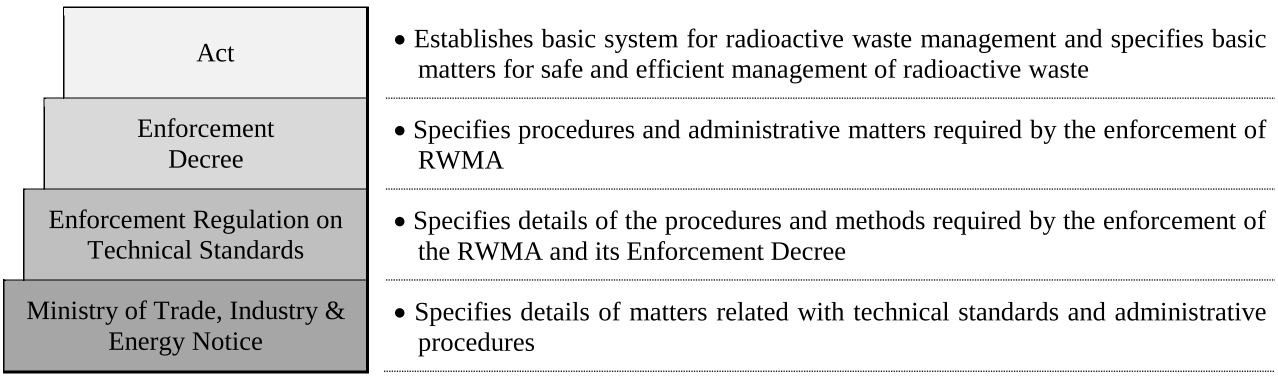

Figure 2-2. Legal hierarchy of the Radioactive Waste Management Act (RWMA)

2.2 Regulations concerning specific facilities and activities

Enforcement Regulation of the NSA, Regulations on Technical Standards for Nuclear Reactor Facilities, etc. and Regulations on Technical Standards for Radiological Safety Management, etc. prescribe detailed procedures and methods necessary for implementing the NSA and the Enforcement Decree of the NSA, and the detailed technical standards thereof.

- Detailed provisions on the detailed procedures and methods necessary for implementing the NSA and the Enforcement Decree of the NSA, and on particulars regarding the control and management of radioactive wastes, packaging and transportation of radioactive materials, etc. (Enforcement Regulation)

- Detailed provisions on measures related to the structure, equipment, and performance of radioactive waste processing and storage facilities, for reactor and related facilities, and nuclear fuel cycle facilities (Technical Standards for Nuclear Reactor Facilities, etc.)

- Detailed provisions on measures related to radioactive waste management plans in operation for reactor and related facilities, and nuclear fuel cycle facilities (Technical Standards for Nuclear Reactor Facilities, etc.)

- Detailed provisions on particulars regarding the facilities, equipment, and performance of near surface disposal, geological disposal, spent fuel management facilities (Technical Standards for Radiological Safety Management, etc.)

- Provisions on performance standards for disposal facilities, for example, radiation monitoring, drainage, fire protection, and emergency power systems (Technical Standards for Radiological Safety Management, etc.)

The Notices of the NSSC present the detailed technical standards of radioactive waste management specified in the NSA, the Enforcement Decree of the NSA, and the NSSC's Regulations. The principal notices related to radioactive waste management are as follows, but not limited to:

- Siting Criteria for Low and Intermediate Level Radioactive Waste Disposal Facilities

- Acceptance Criteria for Low and Intermediate Level Radioactive Waste

- Radiological Protection Criteria for Long-term Safety on Low and Intermediate Level Radioactive Waste Disposal

- Regulations for the Clearance of Radioactive Waste.

2.3 Guidance on implementation

The Notices of the NSSC present guidance and detailed technical standards for radioactive waste management specified in the NSA and its subsequent regulations. The Notices of the MOTIE stipulate matters authorized by the higher law, and the standards and procedures required by the implementation.

3. WASTE MANAGEMENT STRATEGY AND CURRENT PRACTICE

3.1 Waste classification and inventory

3.1.1 Waste classification

The Nuclear Safety Act (NSA) defines “Radioactive Waste” as radioactive materials or materials contaminated with radioactive materials as the object of disposal, including spent fuel. The Enforcement Decree of the NSA defines high-level radioactive waste (HLW) as radioactive waste whose radioactivity concentration and heat generation exceed the limits specified by NSSC. The limiting values on radioactivity concentration and heat generation rate are specified in the NSSC Notice No. 2013-49 (Radiation.001, Standards for Radiation Protection, Etc.) as follows, and the HLW is a radioactive waste to accord simultaneously with the following conditions:

- **Radioactivity** : ≥ 4,000 Bq/g for α-emitting radionuclide having a half-life longer than 20 years
- **Heat generation rate** : ≥ 2 kW/m^3

The NSA also defines the clearance level adopted from the “exempt waste” concept of the IAEA radioactive waste classification. The clearance levels in Korea are such that the annual individual dose shall be lower than 0.01 mSv/y, and the total collective dose shall be lower than 1 person-Sv/y, concurrently. These are identical to the levels specified in the IAEA Safety Series No. 115 (1996).

In December 2013, the NSSC approved the draft revision of radioactive waste classification system, which specifies LILW further into the Very Low Level radioactive Waste (VLLW), the Low Level radioactive Waste (LLW) and the Intermediate Level radioactive Waste (ILW), and are now in consideration of amending relevant regulations

3.1.2 Inventory of radioactive waste

Whether to directly dispose of or recycle spent fuel has not yet been decided. Because the 253rd meeting of AEC stipulated that a national policy for spent fuel management will be decided on later in consideration of the domestic and international technology development, spent fuel is being stored at a reactor site under the KHNP's responsibility.

The existing storage capacity for Pressurized Water Reactors (PWRs) as of December 2013 is 21,995 assemblies. Active nuclear energy utilization has caused a significant spent fuel accumulation problem. The cumulative amount of PWR spent fuel is 14,744 assemblies as of Dec. 2013.

The existing storage capacity of spent fuel pools for CANDU reactors as of December 2013 is 169,632 bundles. For the storage of CANDU spent fuel, dry storage facilities have been installed since 1991 to expand the storage space. 300 silo units and 7 modules of MACSTOR/KN-400 were constructed. One silo unit can accommodate 540 bundles of CANDU spent fuel, and one module of MACSTOR/KN-400 can accommodate 24,000 bundles of CANDU spent fuel. The CANDU spent fuel was stockpiled into 378,040 bundles as of Dec. 2013.

For PWRs, spent fuels are now stored at each NPP pool, but all storage pools are expected to reach their full capacity within the next decade. Also, the storage capacities for CANDU spent fuel are expected to be saturated within the next decade as well. To expand the storage space at plant sites, re-racking and transhipment to neighbouring plants in each reactor site are to be utilized as a short-term solution until a national spent fuel management policy is decided. The amount of spent fuel stored at each reactor site as of Dec. 2013 is described in Table 3-1.

Table 3-1. Inventory of Spent Fuel generated from NPPs (as of Dec. 2013)

Nuclear Power Station*		HLW (Spent Fuel)	
Location	Number of Reactors	Storage Capacity (Assemblies)	Cumulative Amount (Assemblies)
Kori	6	6,494	5,154
Hanbit	6	7,912	5,141
Haunl	6	7,066	4,385
Wolsong	5	500,155	378,104
Total	23	521,627	392,784

Nuclear power plants that are currently in operation are equipped with gaseous, liquid, and solid waste treatment facilities and on-site storage facilities to ensure the safe management of radioactive waste generated in the process of operation. The on-site solid radioactive waste storage facility is a concrete slab-type building with separate storage for waste according to the radioactivity level, and is equipped with a radiation monitoring system. At the end of 2013, 94,772 drums (200 liter/drum) of LILW were generated and stored at four NPPs sites. The amount of radioactive wastes generated from each reactor site as of Dec. 2013 is described in Table 3-2.

Table 3-2. Inventory of LILW generated from NPPs (as of Dec. 2013)

Nuclear Power Station*		LILW	
Location	Number of Reactors	Storage Capacity (drums)	Cumulative Amount (drums)
Kori	6	60,200	42,105
Hanbit	6	23,300	22,383
Haunl	6	18,929	17,989
Wolsong	5	13,240	12,295
Total	23	115,669	94,772

3.2 Waste management strategy and practices

3.2.1 Spent fuel management

Spent fuel generated from NPPs is stored in the spent fuel storage facility in each unit. The storage capacity for spent fuel has been expanded as a consequence of the delayed construction schedule of the away-from-reactor interim storage in accordance with the conclusions of the 249th and 253rd meetings of the AEC. For PWRs, high-density storage racks have been installed in temporary storage pool to expand storage capacity. Since the storage capacity of the spent fuel pools at Kori Units 1 and 2 has been reached, the spent fuel generated from both units has been transferred to the storage pools at neighbouring Kori Units 3 and 4. For PHWRs at the Wolsong site, an on-site dry storage facility has been in operation. One-hundred of these canisters were additionally constructed in November 2006 for a total capacity of 162,000 bundles within 300 concrete canisters to resolve the problem of capacity shortage of the pre-existing spent fuel pools of Wolsong Units 1, 2, 3 and 4. Additionally, 7 modules of MACSTOR-400 (Modular Air-Cooled STORage 400) with a total capacity of 168,000 bundles were constructed in February 2010 and are currently operated.

Spent fuel is also generated from the operation of research reactors such as KRR Korea Research Reactor) Units -1 and 2, and HANARO (High-flux Advanced Neutron Application Reactor). All of the 299 spent fuel rods from KRR-1 and 2 in storage were sent back to the USA in June 1998 as decommissioning projects of the research reactors were undertaken. The HANARO research reactor is equipped with a spent fuel pool capable of storing spent fuels from the 20- year operation of HANARO. The spent fuel pool in HANARO can store spent fuel from the HANARO operation, as well as fuels that have been irradiated and examined at HANARO and related facilities.

Most solid radioactive waste consists of dry active waste (DAW) and secondary process waste. DAW is generated during the maintenance and repair of contaminated systems, and includes items such as used parts, papers, clothes, gloves, and shoes. Secondary waste is generated from the liquid radioactive waste treatment system and included concentrated waste from evaporators, spent resin from demineralizers, and spent filters from liquid purification systems. DAW is compressed into drums using a conventional compactor (capacity: 30 ton). For Hanul Units 5 and 6, vitrifiable miscellaneous solid waste is vitrified using a “LILW vitrification facility.” The use of a vitrification facility reduces the waste volume by approximately 90%. Waste condensate and spent resin had been solidified mainly with cement during a fixed period of time in the past (~ 1995); afterward, however, the waste condensates generated from the reactors for power generation were completely dried in a drying facility and stabilized with paraffin. Nonetheless, paraffin stabilization will be discontinued in the future considering permanent disposal stability. In the future, waste condensates will be disposed of in a manner that can enhance permanent disposal stability. Spent resin is kept in a highly integrated or equivalent container after drying in a spent resin drying facility. Spent filters are stored in a shielding container.

3.2.2 Radioactive waste management

3.2.2.1 Nuclear power plants

Gaseous radioactive waste is mainly generated from the degassing of the primary system and ventilation systems in the radiation controlled area of NPPs. Gaseous waste from the primary system shall be treated by a gas decay tank or charcoal delay bed to reduce radioactivity, and released into the atmosphere through a radiation monitor. Gaseous waste from the building ventilation system is also to be discharged into the environment as well as through a high-efficiency particulate filter and charcoal filter under continuous monitoring into the environment. The gaseous effluent being released into the atmosphere at the restricted area boundary shall satisfy the maximum radioactivity concentration, the Effluent Control Limit (ECL) specified by the Notice of the NSSC. The licensee shall conduct a periodic evaluation of the anticipated off-site dose owing to gaseous effluent released into the environment, and routinely report the results to the regulatory body.

Liquid radioactive waste is mainly generated from the cleanup and maintenance process of the reactor coolant and related systems containing radioactivity. In general, liquid radioactive waste is treated with evaporators, demineralizers, filters, and/or reverses osmosis equipment. The effluent is released into the sea after monitoring. The Notice of the NSSC prescribes the ECL for the liquid effluent being discharged into the environment at the restricted area boundary. Operators shall conduct periodic assessments for the expected off-site dose owing to the liquid effluent discharged into the environment, and routinely report the results to the regulatory body.

3.2.2.2 Research facilities

KAERI has several facilities where radioactive materials are handled, such as the HANARO research reactor, post irradiation examination facility (PIEF), radioisotope production facility (RIPF), irradiated material examination facility (IMEF), nuclear fuel fabrication facility for research reactors, and other laboratories. Additionally, it operates a radioactive waste treatment facility for the treatment and storage of radioactive waste.

In each facility, a ventilation system is equipped with filters to treat off-gas prior to its release into the atmosphere. The stacks of each facility, as the final outlets, have continuous air monitors. When the radioactivity concentration of off-gas exceeds the internal guidelines, the operation of the ventilation system should be stopped to keep the public dose rate lower than the target limits.

The liquid waste generated from each facility of KAERI is collected into the tanks of the facilities and transferred to the radioactive waste treatment facility. All waste is evaporated using the evaporator in the facility. The resulting condensate is processed during solar evaporate, and the residue is bituminized. No liquid waste is discharged into the environment.

The solid radioactive waste, generated from each facility of KAERI, except the spent fuel, is transferred to the radioactive waste treatment and storage facilities. Solid radioactive waste with a higher radiation dose rate than the internal guidelines is packed in 50L stainless steel drums, and kept in a concrete monolith with an adequate shielding capacity. Solid radioactive waste, the radiation dose rate of which is below the internal guidelines, is packed into 200-liter steel drums through waste compaction, and kept in the storage facility. Combustible waste generated in the decommissioning process of research reactors 1, 2, and the uranium conversion facility (UCF) will be incinerated.

3.2.2.3 Nuclear fuel fabrication facility

Any radioactive material from gaseous radioactive effluent shall be treated through a filter in the ventilation system before its release into the outside environment through the stack. As usual, gaseous radioactive waste is properly controlled so that the resulting off-site exposure dose does not exceed the regulatory limits through the blockage of release if the preset limits are exceeded, under the continuous monitoring of radioactivity within the gaseous effluent.

Liquid waste is separated into two kinds of waste, PWR type waste from the PWR fuel fabrication facility and PHWR type waste from the Pressurized Heavy Water Reactor (PHWR) fuel fabrication facility. They are treated by several treatment systems such as lime precipitation, polymer coagulation, and/or centrifugation in accordance with their characteristics. Treated liquid waste falling below the release limits may be subjected to batch-wise discharge. Data, such as the discharge volume, and the release amounts of radioactivity are recorded and maintained.

Most solid waste from the fuel fabrication facility consists of protective articles such as clothes, gloves, metals generated during the facility repair, and lime deposits. They are classified into miscellaneous waste, metals, synthetics, lime deposits, wood, glass, etc., and packed in 200-liter steel drums, which are then stored in the waste storage facility after measuring the radioactivity, weight, surface contamination level, and radiation dose rate for each package.

3.2.2.4 *RI waste management facility*

Radioisotope (RI) is used in two forms: sealed source and unsealed source. Unsealed radioactive source waste is classified into combustibles, incombustibles, non-compactable, spent filters, animal carcasses, organic liquid waste, and inorganic liquid waste.

Of all the waste generated by RI users, both sealed and unsealed disused source waste is collected and delivered to the KORA directly by RI users or through a consignment agency. The KORAD stores and manages the RI waste in the RI safely in the centralized RI waste management facility.

To improve the storage efficiency of the RI waste management facility, part of the RI waste in storage is treated for volume reduction. The compressible waste is compacted. Combustible waste that conforms to the requirement of the regulatory limit is handled within the site. For safe and efficient storage, some discarded sealed sources are stored in a special container after separating the source part from the source canister.

3.2.2.5 *LILW disposal facility*

The LILW disposal facility that is currently under construction will dispose of the LILW generated from power generation and research facilities, nuclear fuel processing facilities, and facilities using RI. The total capacity of the LILW disposal facility is 800,000 drums; 100,000 drums will be disposed of through the rock cavern disposal facilities in the first phase.

LILW will be disposed of separately in 6 silos depending on the size and characteristics of the waste to maintain disposal container integrity and minimize the empty gap between the packaging containers. For loading efficiency, 16-Pack (4×4) disposal containers for 200-liter drums and 9-Pack (3×3) disposal containers for 320-liter drums are used. The waste drums are placed inside the disposal containers, which are handled with remote equipment such as a crane.

3.3 Waste management issues at national level

The government decided "to establish an LILW disposal facility and spent fuel interim-storage facility separately while going ahead with spent fuel management under a national consensus based on medium- and long-term review considering the direction of national policies and the trend of domestic and foreign technology development" in accordance with the resolution of the 253rd AEC in December 2004. According to this decision, the establishment of spent fuel management polices is very exigent. To resolve this issue, the task force for a consensus of the stakeholders and the Conflict Management Committee under the National Energy Commission headed by the President were organized in 2007. The recommendation report submitted by the task force cited the practicality of giving priority to the interim-storage management plan for stakeholder consensus until the best and verified final management plans are drawn, since it takes quite a long time for the final decision to be made and implemented regarding how to manage spent fuel. Also a project collecting expert advice is conducted to fulfil an in-depth review of alternatives for spent fuel management in 2009. In November 2011, the Policy Forum on SNF management was organized by government. After a 10-month review of SNF management options and the gathering of the public opinions, a recommendation report was submitted to the government. Based on its recommendation, the public engagement started with the launch of the Public Engagement Commission on SNF management (PECOS) last year.

PECOS consists of 15 members, who are experts in human & social science and technical engineering, representatives recommended by NGO and residents in NPP areas. The commission plays a role of deciding principles and methods of the public engagement program, initiating public consultation and discussion, and submitting recommendation to government after in-depth review and analysis on SNF management options.
Main purpose of the public engagement is to draw up the consent-based national plan on SNF management in order to protect people in a safe way. The topic to be discussed during the public engagement is how to manage SNF safely. In fact, all of the management options that could protect people from possible dangers due to SNF could be discussed.
And PECOS will collect intensive opinions from all walks of life, such as public, experts, stakeholders, residents in NPP areas and NGOs.

Through these activities, the national policy for spent fuel management including the construction of an interim storage facility for spent fuel shall be decided in a timely manner based on a national consensus through public consultation among stakeholders.

3.4 Research and development

3.4.1 Research infrastructure

Waste management research is conducted through various institutions such as KAERI conducting R&D programs concerning comprehensive technology for safe management of radioactive waste, KINS concerning safety and regulation, KORAD concerning the implementation of waste management facilities, and so on. The budget for these R&D programs is allocated from the Nuclear Energy Research and Development Fund, and Radioactive Waste Management Funds.

As a leading research institution, KAERI conducts R&D programs on pyroprocess articulated with fast reactors, transfer and storage systems of spent nuclear fuel, a geological disposal system, and so on. Also, KAERI has several facilities where radioactive materials are handled, such as the HANARO research reactor, post irradiation examination facility (PIEF), radioisotope production facility (RIPF), irradiated material examination facility (IMEF), nuclear fuel fabrication facility for research reactors, and other laboratories. And mock-up facilities for demonstrating pyroprocess, PyRoprocess Integrated inactive Demonstration facility (PRIDE), and integral test loop facility for demonstrating SFR, Sodium Integral Effect Test Loop for Safety Simulation and Assessment-1 (STELLA-1), have been constructed in KAERI.

KAERI has been also performing basic R&D programs for HLW disposal. The long-term HLW disposal study started in 1997, and the 3rd phase of the R&D ended in February, 2012. The Korean Reference disposal system to accommodate spent nuclear fuels generated from PWRs and PHWRs was developed in the 2nd phase of R&D. The conceptual design of the Advanced Korean Reference Disposal system used to accommodate all kinds of wastes from advanced fuel cycle was developed in the 3rd phase of R&D and reviewed by the IAEA. In the 4th phase of R&D, the demonstration, and development of the safety case and design enhancement of A-KRS will be conducted. KAERI has a general URL which was designated as a partner facility of IAEA URF Network, the KAERI Underground Research Tunnel (KURT), an infrastructure for the validation of disposal technology. The KURT tour program has been organized and is open to all interested parties. KAERI is planning an extension of KURT facility to carry out various in-situ tests and experiments from 2015. The construction work will be done at the end of 2014. The Phase-II in-situ test and experiments is planned to develop and demonstrate the proposed disposal concept and technologies.

3.4.2 Contents of R&D plans

The major current research topics are as follows;

Pyroprocess and sodium-cooled fast reactor technology

- KAERI is focusing its effort on the development of pyroprocess technology, which separates and refines various nuclear materials contained in spent fuel with an electrochemical method at a high temperature. Proliferation resistance of pyroprocess has been internationally recognized owing to the impossibility to recover plutonium. In addition to secure international transparency for non-proliferation of pyroprocess, collaborative research programs with various countries including USA are conducted. The separated and refined materials can be used in fast reactors. KAERI is developing SFR technologies.

Advancement of A-KRS

- KAERI is conducting systematic and intensive R&D programs for HLW disposal. At present, the overall objective of R&D activities related to A-KRS is to develop an advanced reference geological disposal system for pyro-processing wastes. This includes performance improvement of EBS, confidence enhancement of safety assessment, field-test technology development, and MWCF (major water conducting features) characterization in KURT. An R&D program has been started to enhance the performance of engineered barrier system in A-KRS by 20% and construct an in-situ demonstration facility for the EBS in KURT. KAERI have been developing the site characterization techniques considering the uncertainty associated with the heterogeneity and discontinuity of the rocks, through a laboratory experiment, a field test, a long-term tracer test and a numerical modeling. Also, the development of the safety case including development of complex exposure scenarios has been conducted to improve reliability of safety of HLW.

3.5 Financing of radioactive waste management

3.5.1 Framework and responsibilities

3.5.1.1 Nuclear power plants

Since 1983, NPP licensees have deposited the cost required for the disposal of LILW, spent fuel generated in NPP decommissioning and operation processes on a yearly basis and have accumulated this cost as in-house liability in accordance with the provisions of Electricity Business Act.

As per the RWMA legislated in 2008, however, such in-house liability is converted into the Radioactive Waste Management Fund and Management as of Jan. 1, 2009. According to the RWMA, those who have generated radioactive waste shall transfer the cost of maintaining radioactive waste to the KORAD, and the corporations will pay this maintenance cost to the fund. However, as for the spent fuel generated by NPP licensees, to implement projects related to the management of spent fuel smoothly, the cost of managing such fuel has been imposed on NPP licensees as the spent fuel management costs and reverted to the fund.

The appropriate cost is determined every two years by government, KORAD, KHNP, etc, by applying an annual escalator to the costs for disposal of LILW, interim storage and disposal of spent fuel, and decommissioning of NPP.

3.5.1.2 The others

All research facilities at KAERI for spent fuel management, radioactive waste treatment, and waste storage are in operation with the organizational project fund coming from the government budget.

Under the RWMA, the radioactive waste generator shall pay the disposal site radioactive waste management expenses at the delivery point of the radioactive waste. To cope with the disposal of the waste generated, the KEPCO NF has been reserving expenses for radioactive waste every quarter.

The RWMA stipulates that the radioactive waste generator bear the management expenses incurred in relation to waste treatment and disposal at the point of delivering the waste to the KORAD as the sole licensee for radioactive waste disposal.

3.5.2 Status of financing schemes

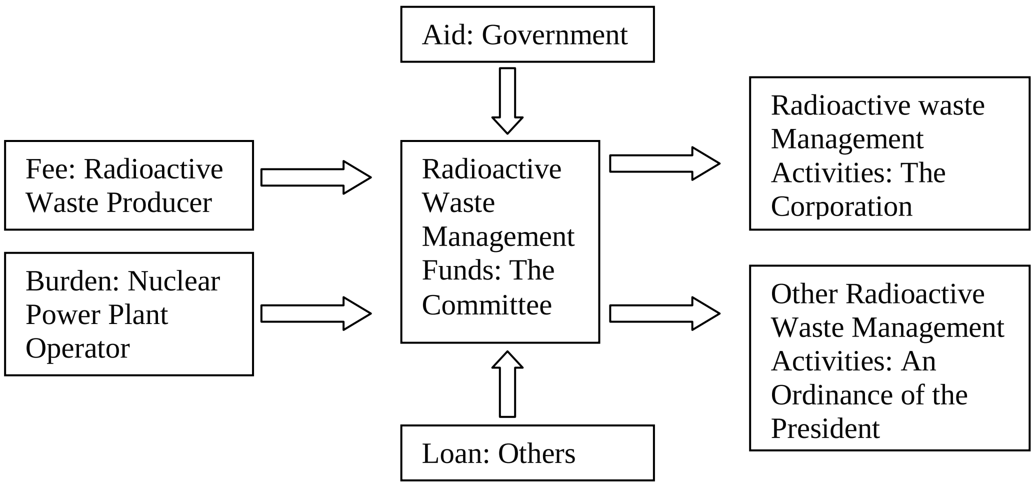

Fig. 3-1 Korea structure for radioactive waste management in Korea

4. DECOMMISSIONING STRATEGY AND CURRENT PRACTICE

4.1 Decommissioning strategy

Until now, we completed the decommissioning of UCF and KRR-1and 2 are under decommissioning. The decommissioning policy and strategy for KRR-1 and 2 involve the following: (1) immediate decommissioning, (2) unrestricted release of the site and building from regulatory control upon completion of the decommissioning, (3) minimization of the decommissioning wastes, (4) preparation for the upcoming decommissioning of large nuclear facilities through the development of related technologies, and (5) transference of decommissioning techniques and experiences to industries.

4.2 Status of decommissioning projects

While decommissioning activities of KRR-2 were completed in 2009, decommissioning of the reactor structures and internals of KRR-1 was newly launched in the middle of 2011. KRR-1, a research reactor with a thermal power of 250 kW, faced a permanent shutdown in Jan. 1995, after reaching first criticality in Mar. 1962, and was chosen to be preserved as a monument after a free-release of the building and site. This project is scheduled to be carried out from 2011 to 2014, with a budget of 3 million USD. Radioactive wastes from the decommissioning of KRR-1 (except reactor core) and KRR-2 were classified according to their characteristics and radioactivity levels, packed into 200-liter drums or 4 m^3 containers, and stored in the reactor hall of KRR-2.

The UCF, which is located at the Daejeon KAERI site, was constructed in 1982 for the development of fuel fabrication technologies for PHWR. Its capacity is 100 tons of uranium oxide per year. Its decommissioning plan was submitted to MEST in October 2002 and approved in July 2004. Radioactive waste from the decommissioned UCF, which is contaminated only with natural uranium, is stored in a waste storage building and will be sent to the final disposal site after a volume reduction and an appropriate treatment for final disposal.

4.3 Decommissioning issues at national level

We experienced the decommissioning of research reactor a uranium conversion plant and some basic and common decommissioning technologies were secured through those decommissioning project. However, after the Fukushima nuclear accident, decommissioning of the practical nuclear power plants is becoming important issue in Korea. Some plants now in operation may have no longer life time extension due to the political and social objections. Therefore to be prepared for the upcoming decommissioning of NPPs, we need to secure a regulatory framework for a safe decommissioning and the practical technologies to carry out the safe and economical decommissioning.

4.4 Research and development

4.4.1 Research infrastructure

There is no definite decision yet for a decommissioning of power reactors, and therefore no specific organization for the decommissioning of an NPP exists in Korea. The NPP operators plan to make use of an organization consisting of operating plant staff members for the future decommissioning of plants.

KAERI, as a responsible operator of the facilities, has carried out projects for the decommissioning of KRR-1, 2 and the UCF, along with development of related technologies and demonstration studies. To do so, KAERI set up the “Decontamination and Decommissioning Research Division”, comprising 29 regular members. Additionally, retirees of KAERI with ample experience in reactor operation have been tasked with the safe dismantling of the reactor.

Based on the laws, KINS is implementing safety regulations on the decommissioning of nuclear facilities and performing R&D on a safety evaluation for the decommissioning of large nuclear facilities through funded nuclear R&D projects. From 2012, KINS has been performing a regulatory framework improvement for a safe decommissioning of Korean NPPs. We will revise the Nuclear Safety Act for decommissioning by the end of 2013 and will complete the development of NSSC Notices for decommissioning by 2017.

4.4.2 Contents of R&D plans

The project management technologies, including manpower control, waste tracing, and radiation protection were developed. In addition to the projects of decommissioning, the development of new technologies was carried out, which covers the developments of a concrete sludge treatment, a melting treatment of metallic waste by a high frequency induction furnace, and a bio-denitration process of lagoon sludge as an alternative process of the thermal treatment process, which has now been adopted. After the nuclear accident in Fukushima, to be prepared for a possible upcoming decommissioning of commercial power reactors, KAERI have started to develop the key technologies for a safe and economical decommissioning of NPPs. The key technologies are system and component decontamination technologies, remote and integrated dismantling technologies, decommissioning waste treatment technologies and site remediation technologies.

4.5 Financing

To secure stable resources for the decommissioning and the safe management of decommissioning waste, NPP operators have now been depositing expenses for decommission of NPPs in accordance with the RWMA. According to article 17 of RWMA, the appropriation money for decommissioning NPPs is accumulated on a yearly basis.

Decommissioning of research facilities such as KRR-1, 2 and the UCF constructed and operated by KAERI, was funded by the Korean government, was. The government provided all financial resources required for the safe decommissioning of the facilities. In 1996, KAERI reported its basic plan to the MSIP, received financial support from the government, and began to decommission research reactors in 1997. The decommissioning of a uranium conversion facility operated by KAERI was also funded by the government.