THE STATUS OF THE RADIOACTIVE WASTE MANAGEMENT IN KOREA

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Abstract

In Korea, fourteen nuclear reactors are in operation and by 2015, a total of twenty eight nuclear reactors will be in operation. The current nuclear share occupies about 34.2 % of the total generating capacity of electricity and 46.3 % of the total production of electricity. The active nuclear program causes an inevitable increase in the build-up of radioactive waste, including spent fuel. Therefore, the reliable and effective management of radioactive waste and spent fuel has become a key for the continuous growth of the nuclear power program. By 2000, a total of 84 413 drums of low and intermediate level waste (LILW) shall be generated and it shall drastically increase to 256 520 drums by 2020. Also, the cumulative amount of spent fuel shall reach 4,623 MTU in 2000 and jump to 18 615 MTU by 2020. By the new national planning, AFR storage facilities for spent fuels shall be built by 2016 and a repository for LILW radioactive disposal shall be in operation by 2008. Even though Korea has a "wait and see" policy for spent fuel management, several alternative studies on spent fuel management such as DUPIC have been carried out. In parallel, R&D activities to develop the needed technologies for the permanent disposal of spent fuel and HLW have been implemented. In addition, active R&D on the treatment of radioactive waste from the various nuclear fuel cycle as well as the decontamination and the decommissioning of nuclear facilities are in progress. Many of these studies are pursued in the form of international collaboration with prominent overseas organizations.

1. INTRODUCTION

In Korea, nuclear research reactors have been in operation since the first research reactor, TRIGA MARK-II type, started to operate in 1965. The third research reactor, HANARO, began to operate in 1995, while other research reactors have been shut down for their decommissioning in the future. From these reactors, radioisotopes (RI) have also been produced to meet a part of the internal demand in medical, industrial, educational and research fields since 1963.

In addition, the nuclear power plant industry in Korea has grown dramatically since the first commercial nuclear power plant, Kori #1, started to operate in 1978. Fourteen nuclear power plants (11 PWRs and 3 CANDUs) are now in operation and four plants (3 PWRs and 1 CANDU) are under construction. According to the Long-term Nuclear Power Generation Plan announced by MOCIE (Ministry of Commerce, Industry and Energy) in 1998, a total of 28 nuclear power plants will be in operation by 2015. The total generating capacity is expected to be about 27.65 GW(e) by 2015. With this nuclear power program, the nuclear share will be about 34.2% of the total generating capacity of electricity and about 46.3% of the total production of electricity.

Such a growth in the nuclear power program causes an inevitable increase in radioactive waste including spent fuel. Consequently, as in many other countries, reliable and effective management of radioactive waste and spent fuel has become a key factor for the continuous growth of the nuclear power program. This paper describes the status of radioactive waste management, including the low- and intermediate-level waste program and R&D on high level waste disposal in Korea.

2. RADIO ACTIVE WASTE ARISING

2.1. Low and intermediate level waste (LILW)

Several kinds of radioactive wastes from non-power sources have been produced from the application of the isotopes and the operations of research reactors and a fuel fabrication plant. The RI application wastes have been collected and stored at the Nuclear Environment Technology Institute (NETEC) under the Korea Electric Power Company (KEPCO), separate from the operational wastes from nuclear power plants (NPP), which are being stored in the on-site storage of each NPP. Other wastes have been stored at the Korea Atomic Energy Research Institute (KAERI) and the Korean Nuclear Fuel Company (KNFC). The cumulative radioactive wastes collected from RI application, a research institute, KAERI, and a nuclear fuel fabrication plant, KNFC, are shown in Table 1.

At present, wastes from RI applications are stored in two storage buildings at NETEC, and those from KAERI are in four storage buildings on its site. Also, wastes from KNFC are stored in its storage building on the site. A program to reduce the volume of wastes by incineration and repackaging or by reclassification is systematically studied.

For the KAERI wastes, the surface dose rates of containers are comparatively high due to the hot-cell operation wastes from the post-irradiation examination of PWR fuels. The major nuclide is Cs-137, which is one of the dominant fission products in spent nuclear fuel. The spent drums are contaminated by uranium because they are utilized as containers of natural uranium oxide for CANDU fuel fabrication. The decommissioning wastes have been produced mainly from dismantling the old radioactive waste treatment facilities at the Seoul site of KAERI. Wastes from KNFC are contaminated only by uranium. The components of the combustible wastes are clothes, gloves, tissue, and etc. while non-combustible wastes consist of steel, firebrick, lime precipitate, plastic, etc.

TABLE 1. CUMULATIVE LILW BUILD-UP IN KOREA [UNIT: DRUMS]

Year	NPP	RI	KAERI	KNFC	Decommi -ssioning	Total
1997	49,868	3,152	9,352	2,800		65,172
2000	59478	4,870	15,573	4,491		84,413
2005	76,768	8,781	18,052	7,924		111,524
2010	98,048	14,527	21,215	12,304		146,094
2015	124,087	19,888	24,694	17,122	14,500	200,282
2020	150,678	26,730	28,173	21,940	29,000	256,520

2.2. Spent fuels

With the long term plan set for the Korea Nuclear Power Program in 1998, the projection of spent fuel accumulation can be summarized as shown in Fig.1. The cumulative amount of spent fuel from existing nuclear power plants has reached 3233 MTU by the end of 1997. As shown in Table II, it is expected that approximately 11 000 MTU and 19 000 MTU will be accumulated by the year 2010 and 2020, respectively. At present, the PWR spent fuels generated from nuclear power plants have been stored temporarily in storage pools at plant sites, while the CANDU spent fuels have been stored in storage pools and dry storage (concrete canister) at plant sites.

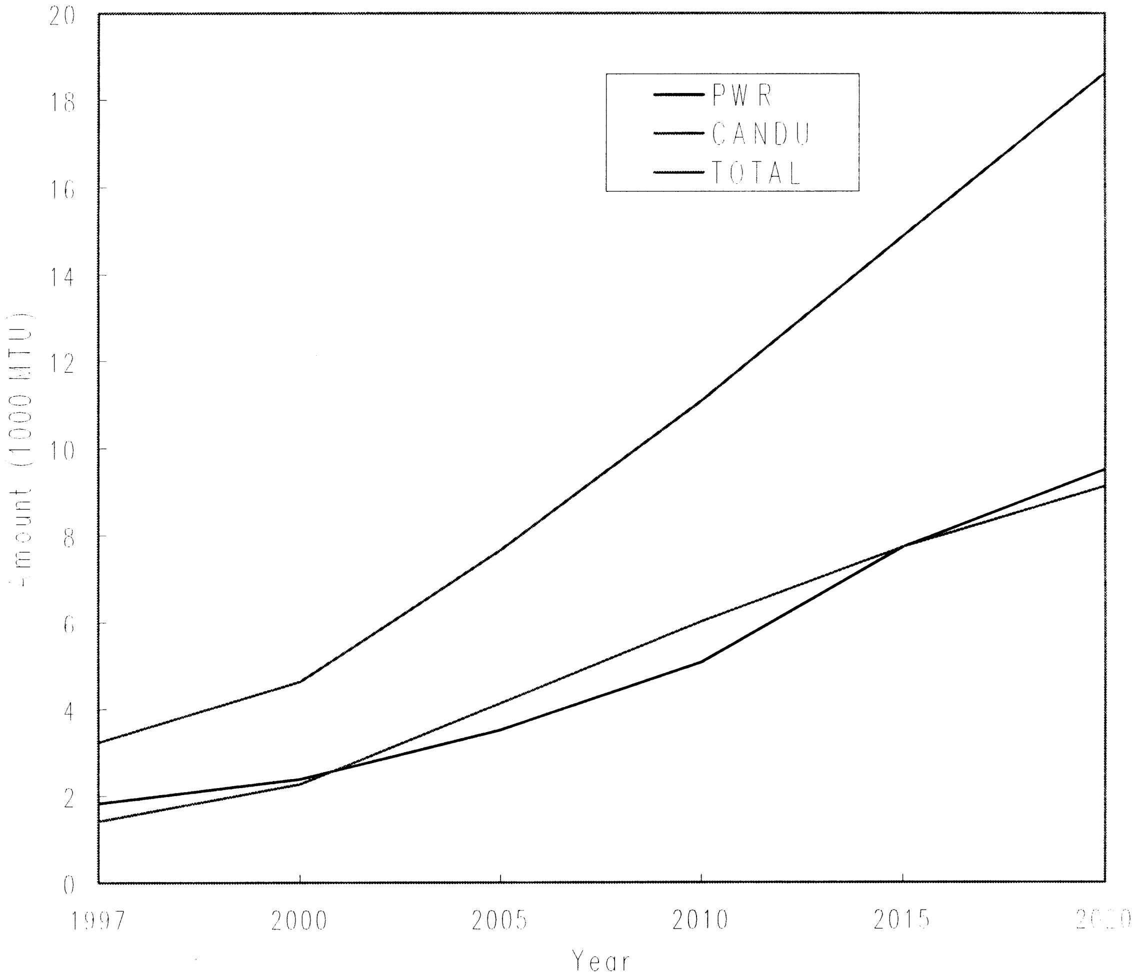
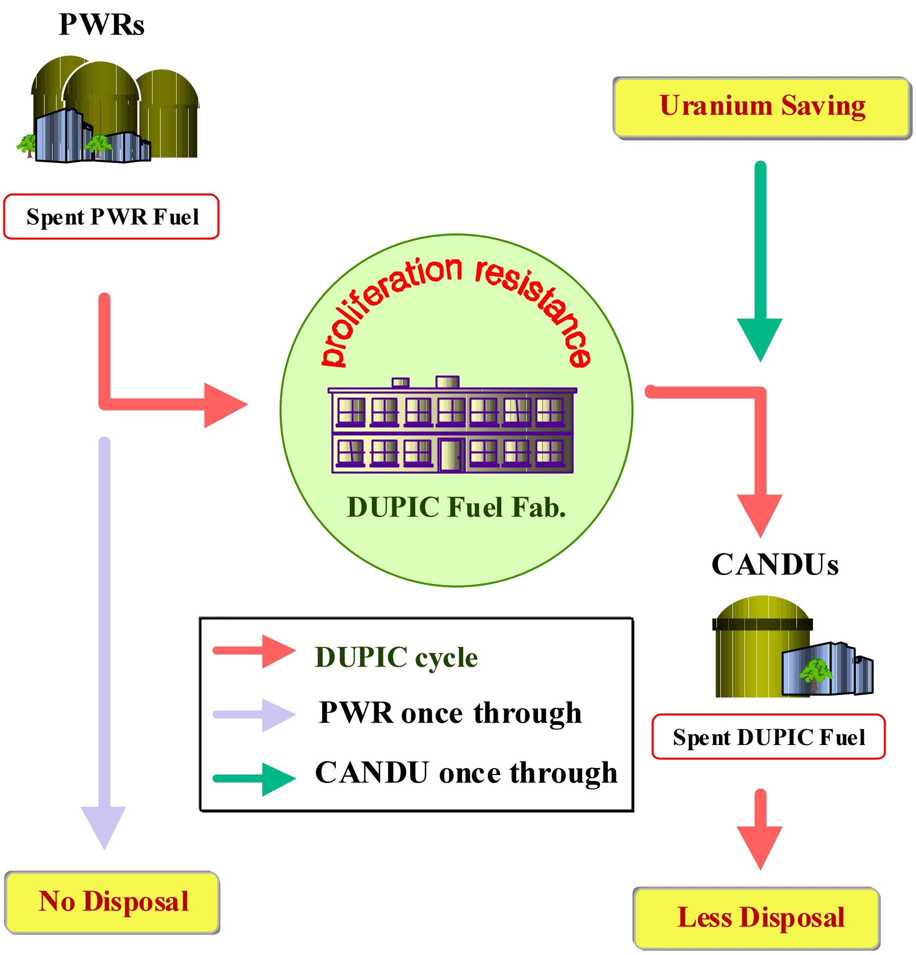


FIG. 1. The estimated accumulation of spent fuels in Korea [Unit: Mtu].

TABLE II THE ESTIMATED ACCUMULATION OF SPENT FUELS IN KOREA [UNIT:MTU]

Year	PWR		CANDU		Total	
	Annual	Cumul.	Annual	Cumul.	Annual	Cumul.
1997		1,823		1,410		3,233
2000	203	2,376	376	2,256	579	4,632
2005	258	3,518	376	4,136	634	7,654
2010	332	5,067	376	6,016	708	11,083
2015	464	7,177	282	7,708	746	14,885
2020	464	9,497	282	9,118	746	18,615



3. REGULATORY FRAMEWORK

The regulation for licensing of nuclear facilities in Korea is based on the provisions of the Atomic Energy Act, Enforcement Decree, Enforcement Regulation and Notice of the Minister of Science and Technology.

The Ministry of Science and Technology (MOST) has the prime responsibility for nuclear regulation and licensing and the enforcement has been entrusted by the government to the Korea Institute of Nuclear Safety (KINS) as the safety authority. The triangle licensing system on radioactive waste disposal, shown in Fig.2, confirms that radioactive waste will be managed safely within an appropriate legal framework, including clear allocation of responsibilities for independent regulatory functions.

4. LOW AND INTERMEDIATE LEVEL WASTE PROGRAM

One of the main purposes of site characterization is to provide data for license application and approval of the safety assessment for a proposed repository site. Thus, common investigation activities for Site Characterization Report (SCR) and Environmental Report (ER) should be arranged in such a way that investigation results can be shared for appropriate purposes. General environmental data and

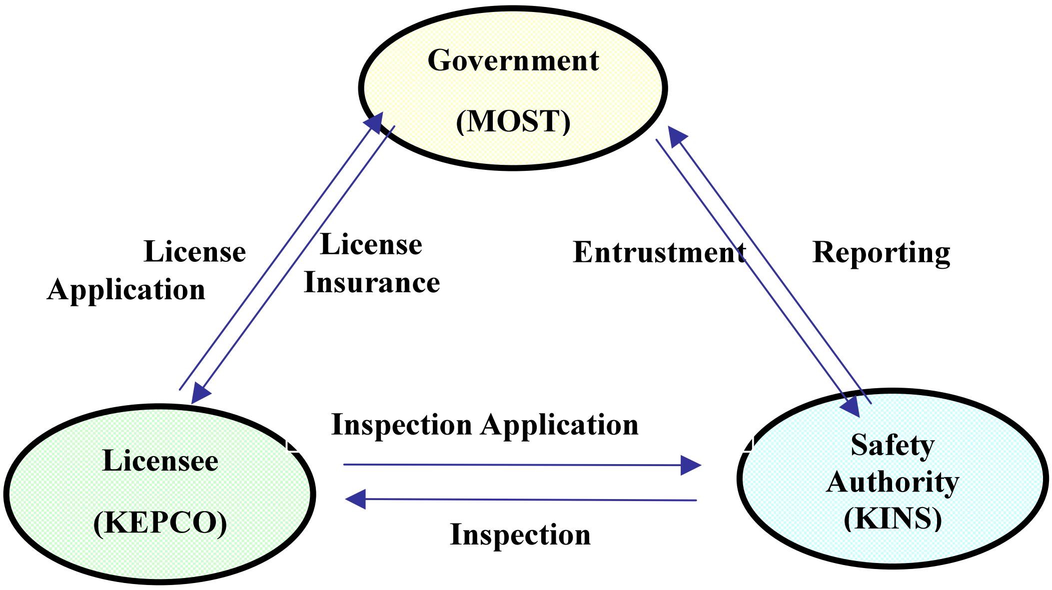


FIG.2. Fundamental framework for licensing on LILW disposal.

preliminary engineering design data are also produced. In general, the site characterization plan includes the following activities:

- To define the regional geological conditions,
- To refine the geological conditions in a site scale,
- To determine the location of the repository, and
- To clarify the site specific data, such as local geological and hydrogeological conditions.

Major site characterization activities are as follows:

- General environmental survey,
- Geological investigation,
- Seismic investigation,
- Hydrological and hydro-geological investigation,
- Geophysical investigation,
- Geo-technical investigation,
- Geo-chemical investigation.

Along with the technical development, KAERI had intensively focused on the selection of a repository site with successive national campaigns for enhancing the public awareness of radioactive waste management since 1986. However, due to the prevailing misconception of even the LILW being something like nuclear bombs, all attempts were completely hindered by strong opposition from the concerned local communities backed by anti-nuclear groups. At the end of 1994, the Government designated Guleop Island with only nine residents as a prospective site for the national site. Unfortunately, however, the final blow against the Guleop Island Project was made at the end of 1995 by the confirmation of active fault zones near and along the island during the site investigation process. After the withdrawal of Guleop Island, an attempt to investigate a new repository site will be started again in the beginning of the next century. Therefore, it may be expected that the program to build a repository for LILW will be implemented by the year 2008.

The role of overall project management for LILW was transferred from MOST and KAERI to the MOCIE and KEPCO by the amendment of the Atomic energy Law and the Electricity Enterprise Law. The NETEC was then established as a special organization of KEPCO for the implementation of the following:

- Siting for LILW disposal,
- Construction and operation of LILW disposal facility, and
- Collection and treatment of wastes from RI applications.

At present, NETEC studies on the radioactive waste management strategy to support the MOCIE for the revision of the LILW disposal program until the end of this year. This project includes reviewing disposal methods as well as the optimum size of disposal facilities to find the most suitable ones under Korean circumstances.

Incineration is an effective way to reduce the volume of burnable waste. In KAERI, a 30 kg/hr scale incinerator is used to treat the wastes generated from research institutes and hospitals. KAERI started the study of incineration technology development in 1987. Following fundamental and design studies at the early stage, the demonstration scale incinerator was installed in 1992. Since then, a step-by-step approach has been conducted to operate the facility and simultaneously test the burning of various wastes. The final permission, for treating radioisotope wastes emitting only β and γ rays, was already obtained from the government, which, however, excludes the incineration of alpha-contaminated waste. The incinerator design team in KAERI is still involved in the development of incinerators which will be applicable also to alpha-bearing burnable wastes.

5. SPENT FUEL PROGRAM IN KOREA

5.1. Spent Fuel Management Policy

Management of the increasing amount of spent fuel remains a challenge for the future of Korea in long-term perspectives. The management policy for spent fuel in Korea has been based on guidelines provided by the Korea Atomic Energy Commission (AEC), the nation's top policy-making body on nuclear energy. The Korean government has not established a definite long-term management policy on whether to recycle or to permanently dispose of spent fuels.

The AEC, as a mid- and long-term expedient, set a main goal for spent fuel interim storage. The national plan in the past, to build an away-from-reactor storage of spent fuel and a repository for radioactive waste packages, had to be deferred due to the strong hurdle of public acceptance for site acquisition. Subsequently, KEPCO has taken temporary measures to take care of the spent fuel in the reactor sites, i.e., transshipment, increasing of storage densities, addition of dry storage systems, etc. For the long term perspective, in the 249th AEC meeting held in September, 1998, a new plan was set up to build an AFR storage for the interim storage of spent fuels by 2016 and a repository for radioactive waste disposal by the year 2008, respectively.

Even though Korea has a "*wait and see policy*" for spent fuel management, several alternative studies on spent fuel management have been carried out for a long time. The DUPIC program is one of the prominent approaches among the KAERI R&D activities in this area. The program was initiated in the early nineties for analysis of the technical feasibility of the DUPIC concept, entailed by a long-term plan for the experimental verification of the concept. Main targets of the experimental work are to fabricate test fuel elements and to look at irradiation performance in a test reactor. The program is integrated with a number of associated scopes of work, such as compatibility with a CANDU reactor system, safeguards systems development, waste management, etc. A preliminary experiment for characterization of spent PWR fuel materials is now ready to look at key technical parameters that would be essential for the DUPIC fuel fabrication experiments starting next year.

In parallel, Korea continues R&D activities, assuming that disposal technology will be required for the long-term consideration of the nuclear energy strategy regardless of fuel cycle options. The R&D on the deep geological disposal of high-level radioactive wastes (HLW) has being carried out with the cooperation of relevant organizations such as national research institutes, universities and private companies as well as participants from several international collaborations.

Also, active R&D on the treatment of radioactive wastes from the nuclear fuel cycles as well as the decontamination and the decommissioning of nuclear facilities are in progress.

5.2. R&D for high level waste disposal

A site-generic concept is being developed under assumptions that an underground repository would be located in a type of crystalline rock in Korea and an appropriate multi-barrier system would be provided for the isolation of the HLW from the biosphere. To reach the target for the development of a reference deep geological repository concept suitable for Korean geological circumstances by the year 2006, the basic R&D program on four fields have been set up; performance assessment and disposal system development, geo-environmental science research, engineered barrier development, and radionuclide migration study.

- *Performance assessment and disposal system development*
  - Concept development of a reference disposal system and its optimization,
  - Development of an integrated performance assessment code including unit models for nuclide transport both in near-field and far-field barriers, and
  - Development of safety assessment technologies, and
  - Study on the geo-mechanical characteristics of rock masses around a repository, such as hydraulic and mechanical couplings.

- *Geo-environmental science*
  - Delineation of unstable tectonic zones throughout the geological history,
  - Characterization of groundwater flow in different geomorphic conditions,
  - Evaluation of deep groundwater chemistry, and
  - Establishment of site characterization methods.

- *Engineered Barriers*
  - Characterization of potential domestic buffer materials,
  - Development of a reference buffer material,
  - Development of a disposal container for HLW, and
  - Long-term behavior of waste forms and container materials under repository Conditions.

- *Radionuclide behavior in the underground environment*
  - Sorption experiments of long-lived nuclides on single minerals under various solution conditions,
  - Experimental and mechanistic sorption modeling, and
  - Fracture migration experiments in artificially and naturally fractured rocks.

- *International collaborations*

KAERI has been participating in projects and meetings organized by OECD/NEA; for example, the ASARR (Analogue Study at the Alligator River Region) project, which has been managed by Australian Nuclear Science and Technology Organization (ANSTO), and also PAAG and SEDE meetings. KAERI has also been participating in two of the IAEA's Coordinated Research Programs (CRP), titled "The extrapolation of short-term observations to time periods for isolation of long lived radioactive wastes" and "Biosphere modeling and assessment methods". In addition, for the development of the Korean disposal concept and the safety assessment, KAERI has been collaborating with foreign organizations such as AEA Tech. (U.K), AECL (Canada), SKB (Sweden) and SNL (USA).

5.3. R&D for transmutation of long lived nuclides

The long half-lives of some radionuclides ultimately cause the risks of environmental contamination due to the possible release of disposed radionuclides into the environment by a certain reason. One of the feasible approaches to cope with this problem is nuclear transmutation because it could basically eliminate the existence of long-lived radionuclides from the wastes. A few concepts for the transmutation of long-lived radionuclides are being considered at present in several countries. One of the prospective technologies for the transmutation is to utilize an accelerator-driven system, namely, a hybrid system composed of a proton accelerator and a sub-critical reactor.

In KAERI also, a research on the concept of hybrid system is carried out focusing on the sub-critical reactor. Since the nuclear fission in the sub-critical reactor does not occur by chain reaction but by the neutron supplied from the outside of the fuel system, the control of the reactor would be easier. Also, it would ease the conditions of nuclear fuels compared with those of conventional power reactors. If fuel conditions are eased, then more impurities may be allowed in the fuel material of trans-uranium, resulting in great advantages for fuel processing and preparation. The concept of the relevant fuel cycle is also being studied in order to choose the optimum process. The pyro-processing option might be preferable in the viewpoint of process simplicity, nuclear nonproliferation, and economy. However, more intensive studies would be required to develop an applicable technology.

Fig.3 illustrates a concept of transmutation system studied on in a few countries. According to this concept, the long-lived radionuclides contained in used fuel are recovered by the pyro-processing and recycled to the reactor again while remaining the waste consisting of only short-lived nuclides. This waste, therefore, would bring a great ease in disposal conditions as well as a remarkable reduction in its radiological toxicities.

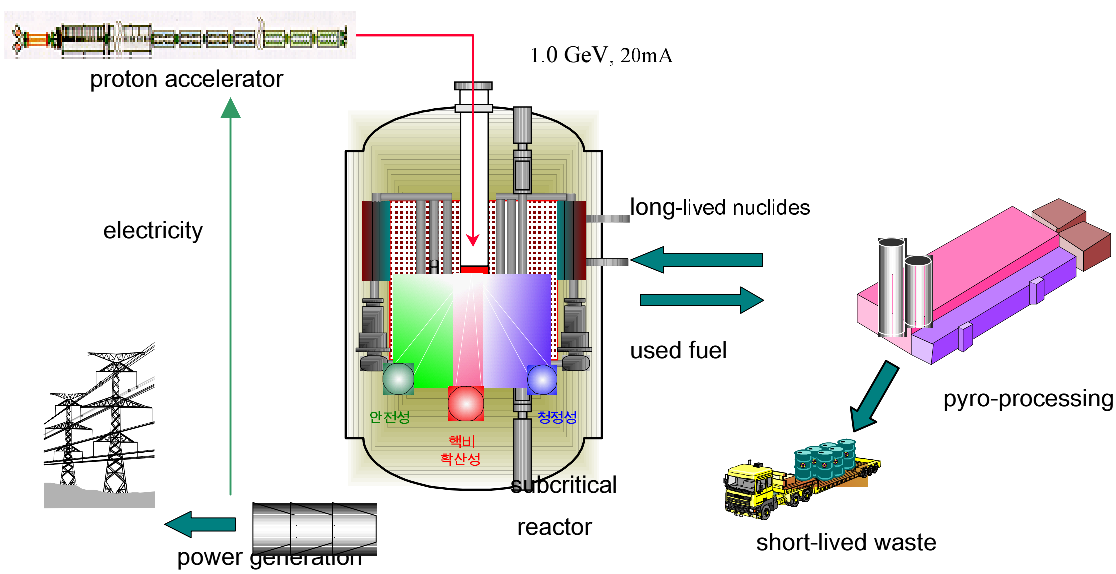


FIG.3. The concept of transmutation system based on a subcritical reactor.