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Preparation of Nuclear Industry for Environmental Performance Evaluation

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Abstract

Nuclear energy has been the major electric source due to the insufficient domestic resources. Korean government has to consist the national long-term nuclear power program for the sustainable development. On the other side, the government-led energy industry faces new circumstances due to the increasing demand on the environmental protection. Energy policy is addressing environmental issues and energy conservation has come to be regarded as an important element of environmental policy. According to current situation, concern for environmental preservation has increased the demand for more efficient management and environmentally sound and sustainable development of nuclear energy. Therefore, this paper shows the necessity of introducing the environmental management tool to the nuclear industry and the international trend of the government energy policy related to the environmental aspect. Finally, it is suggested that the application of the environmental management technique to nuclear power generation system with the sample case study and this result could be used as the source materials for the further development of comparative assessment of nuclear and non-nuclear energy as well as decision-making of back-end fuel cycle alternatives.

1. Outlook for Energy Supply

The electricity demand in Korea has grown rapidly each year during the last decade. In order to cope with the future electricity demands, the long-term power development plan has been updated bi-annually.

The total generation capacity in Korea was 285,224 GWh at the end of 2001. 39.3% from nuclear, 38.7% from coal, 9.8% from oil and 12.2% from hydro and others [Figure 1.]. The installed capacity at the end of 2001 was 50.8 GWe. The share was 27.0% by nuclear, 30.5% by coal, 3.0% by LNG, 8.8% by oil, 22.5% by combined cycle and 8.2% by hydro and others [Figure 2].

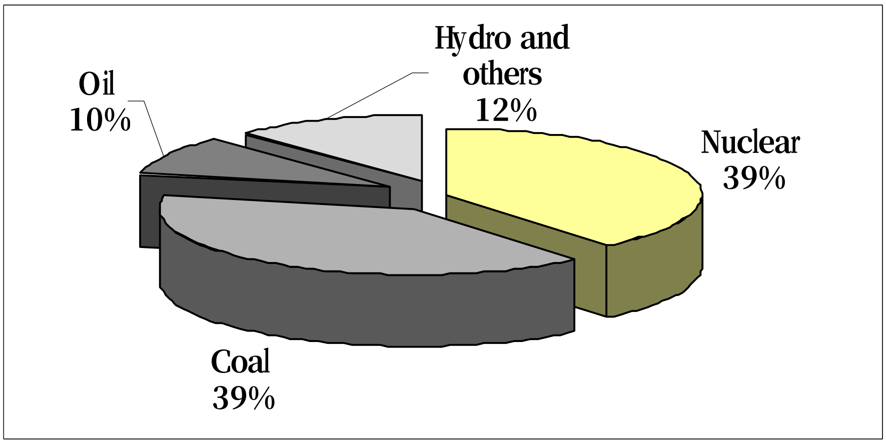

Figure 1. Total Generation of Electricity (as of 2001)
(Source : Korea Energy Economics Institute, 2002)

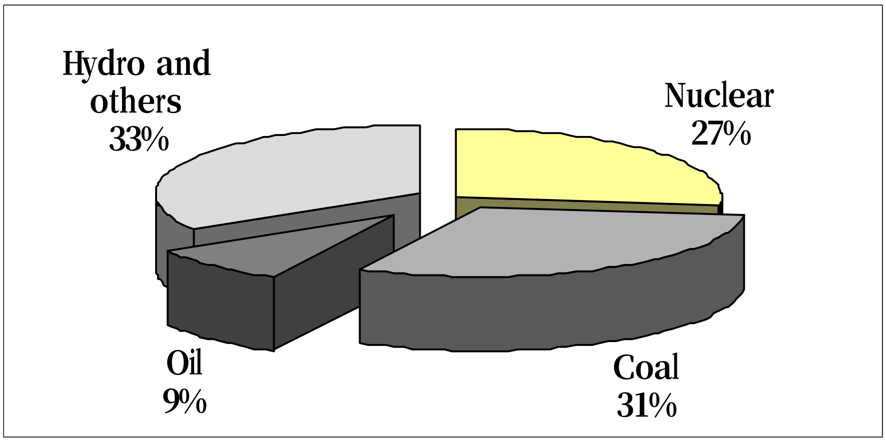

Figure 2. Total Installed Capacity of Electricity (as of 2001)
(Source : Korea Energy Economics Institute, 2002)

Total energy demand is expected to increase by 3.2% annually by the end of 2010, while annual economic growth rate is expected as 6%. International regulation on the environment makes the share of LNG and nuclear power consumption grower. Although oil will continue to be the major energy resource, the share of oil will be dropped by 7% because of increasing consumer preference for clean fuels. The increasing demand for electricity mainly will be absorbed by nuclear power and the most important consideration in the future will be the environmental friendliness [Table 1].

The long-term nuclear power development plan by the year of 2015 is fixed. Eighteen nuclear power plants (14 PWRs and 4 PHWRs) have been in operation since 1978 when the first nuclear power plant started its operation at the Kori site. The total generation capacity of nuclear in 2002 is as much as 15 GWe. By 2015, total nuclear stations with 28 units (22 PWRs and 6 PHWRs) will be connected to the grid in Korea [Table 2].

Table 1. Trends of Primary Energy Supply by Source

(Unit : million TOE, %)
(Source : Korea Energy Economics Institute, 2002)

	1990	**2000**	**2010**	**'00 – '10 Annual Growth Rate (%)**
Oil	50.2 (53.8)	100.3 (52.0)	123.7 (46.9)	2.1
Anthracite Coal	9.9 (10.7)	3.1 (1.6)	2.6 (0.9)	-1.8
Bituminous Coal	14.4 (15.5)	39.8 (20.6)	58.9 (22.3)	4.0
LNG	3.0 (3.2)	18.9 (9.8)	32.1 (12.2)	5.4
Hydro	1.6 (1.7)	1.4 (0.7)	1.2 (0.4)	-1.9
Nuclear	13.2 (14.2)	27.2 (14.1)	39.5 (15.0)	3.8
Others	0.8 (0.9)	2.1 (1.1)	5.6 (2.1)	10.1
Total	93.2 (100.0)	192.9 (100.0)	263.6 (100.0)	3.2

Table 2. Current Status of Nuclear Power

(Source : Korea Hydro and Nuclear Power Web-Site, 2002)

	Ratio (%)	**Site**	**Units**	**Installed Capacity (MW)**
In operation	58	Kori Younggwang Ulchin Wolsung	18	15,716
Under construction	7	Ulchin	2	2,000
Preparation	25	New Kori New Wolsung	4 2	6,800
Planning	10	TBD	2	2,800
Total	100	-	28 Until 2015	27,316

Therefore, as the Korean nuclear power program is expanding, more radioactive wastes released to environment and arising of spent fuels are expected. These wastes problems have been hot issues for continuing the nuclear program and obstacles for obtaining public consents. The unique and effective way for solving these problems is to make efforts of government and industry to improve the image of "nuclear or radwastes" into more environmentally attractive.

2. Changes of Energy Policy Goals

The technology development in the environmental aspect has become the key factor for competitiveness, i.e., environmental friendliness is one of the most important considerations in technology development. Under the monopolised system of the past, there was little motivation for individual companies to manage the company. The focus was on government-led common technology development and policies were focused on establishing a stable energy supply and demand for economic growth. However, increasing demand for energy and concerns on the environment, energy policies are shifting toward sustainable development, which considers both economics and environmental protection [Figure 3].

Figure 3. Changes of Energy Policy Goals

Environmental performance of companies consistently correlates well with their images. Especially electric industry including power generation company has been considered as major polluter. So decision maker in these companies as well as government should keep their efforts steadily to improve their environmental performance, which is eco-efficiency.

According to this trend, new environmental regime is adopted internationally. Historically, environmental concerns were generally treated the same as other social concerns. This concept adds a new dimension that challenges this paradigm. Eco-efficiency is the theorized tendency of companies that meet environmental challenges to deliver superior profitability. The test is not only to manage risk, but also to have the managerial ability, at both the strategic and operational levels, to identify and capture upside opportunities for additional profit and competitive advantages.

Performance evaluation of company has focused on the financial affair until now, however, concerns of environmental protection need company's efforts on environmental management. Performance evaluation related to environmental ratings identifies environmental risks, management quality and profit opportunity such as Eco-value. This will rate company (from AAA to CCC, total nine levels) and uncover hidden value potential for investor and public.

One of the leading companies in environmental performance evaluation is Innovest group in USA. This group evaluated recently the electric company, Florida Power & Light - FPL [Figure 4]. Eco-value of power generation company is rated based on ISO 14001 standards. Testing procedures follow LCA (Life Cycle Assessment) framework. Consideration factors include compliance, emissions, waste generation and industry benchmarks.

In Korea, Eco-Frontier company as the only domestic agent of Innovest group is preparing the detail procedures about environmental performance evaluation and will evaluate environmental performance of 200 companies.

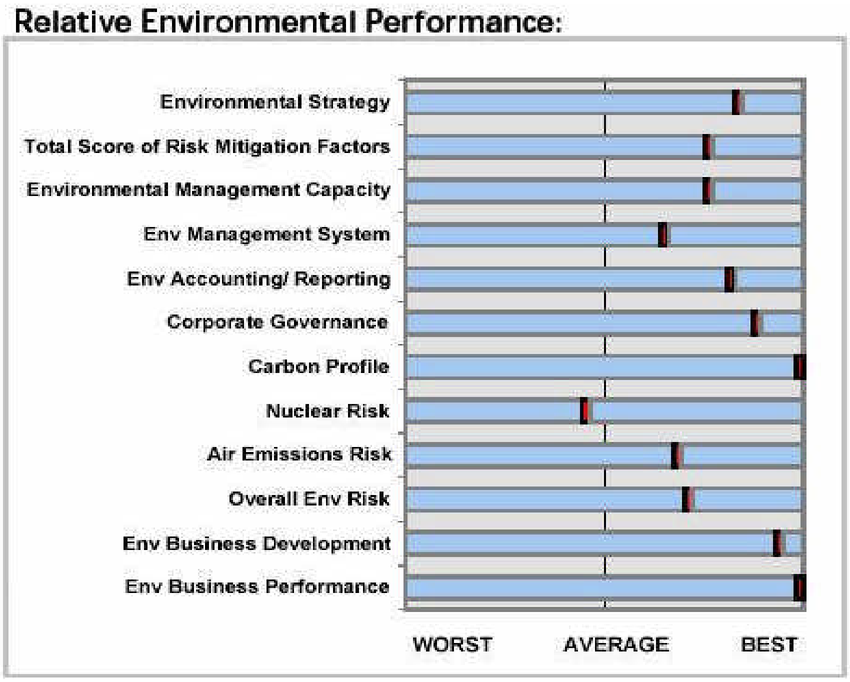

Figure 4. Example of FPL Eco-Value

(Source : Innovest group web-site, 2003)

3. Introduction of EMS to Nuclear Industry

Public would make an attempt to help the environment and would willing to pay higher prices for these products. So the information on how the product was derived and product was produced through which environmentally benign techniques should be open to public. This technique known as green labeling rapidly became an established part of marketplace. The eco-labeling was developed by ISO and the ISO 14000 series makes it a meaningful tool for efficient environmental stewardship. ISO 14000 is a series of standards and one of guidance documents is Environmental Management System (EMS). And LCA is adopted as the most appropriate EMS tool in ISO 14000 series.

In accordance with progress, LCA has received much attention in industries. Most industrial processes consume electricity. It is often found that electricity consumed during use of electrical appliances predominates in the total primary energy consumption and emissions of these products' life cycles. Thus, the results of inventories analyses of industrial products are usually sensitive to data on electricity. So, it is quite important for LCA practitioners to develop reliable life cycle inventories for electricity. However, only a few figures concerning emissions related to electricity have been reported.

Especially for nuclear energy, it is the major source of electricity generation in Korea due to the lack of domestic energy resources. In recent years, concern for environmental preservation has increased the demand for more efficient management and environmentally sound and sustainable development of nuclear energy. As the Korean government has not determined yet the preferred nuclear fuel cycle option, it is necessary to develop and apply an appropriate environmental management tool to environmental impacts of available options.

4. Application Field to Nuclear Industry

Korean government has faced the significant problems arising from the spent fuel management, which results from the absence of the fixed back-end fuel cycle policy. Through the series of efforts such as fuel burn-up increase, storage rack expansion and dry storage construction, Korea delayed the decision so far. Nevertheless, the amount of spent fuel arising from nuclear power plants in Korea is a tremendous problem. In order to accommodate its needs, Korea must take the necessary initiative to solve its problem for the management of its spent fuel considering the environmental impact.

Therefore, reprocessing and DUPIC options are necessary to be considered together with the once-through option. If the reprocessing facility is to be constructed, there is the definite advantage to ease the spent fuel discharging problem and to reduce the uranium resources utilization. However wastes arising through the reprocessing process such as PUREX or DUPIC will be increased due to the additional necessary process comparing with the once-through cycle. Therefore, these wastes from additional processes will cause the environmental impact while saving of raw materials through reprocessing will take a role as the environmental benefits. LCA is useful to assess and compare the environmental impact and benefits.

Also, LCA is applicable to the remediation of contaminated sites such as disposal site of radioactive wastes or nuclear facility. Decontamination and decommissioning (D&D) process could be analyzed by LCA. Also this work suggests a new methodology for environmental assessment and makes it possible to establish the extensive infra-database related with the nuclear power generation system.

Additionally because construction planning of new power plants is dependent on the market price and competitive pricing among the electrical resources may cause the unbalance of electricity supply planning, electricity security should be reviewed by the estimation of future cost for electricity generation and energy mix strategy. In order to support decision-making of this problem, integrated environmental and economic analysis model need to be developed. To achieve this aim, LCA for the environmental analysis and economic analysis on unit price for 1GWh electricity generation would be coupled explicitly.

5. Result of Case Study

The goal is to introduce LCA methodology to the back end fuel cycle alternatives of once through and DUPIC. The functional unit is defined as the delivery of 1GWh electricity generated from 11 PWRs to consumers.

Data related with the fuel cycles prior to the fuel fabrication are from the report of CEPN (Centre D' etude sur L' evaluation). Korea Nuclear Fuel Co. Ltd. (KNFC) is in charge of the fabrication of fuels in Korea and so provides the data for Korean nuclear fuel fabrications. Data not available in Korea such as chemicals emitted to environment are adopted from the data of the Franco-Belge de Fabrication de Combustibles (FBFC) of Pierrelatte in France and the non-radioactive discharge data of BNFL.

Non-radiological as well as radiological impact assessments are carried out in terms of ten kinds of environmental categories such as Abiotic Resource Depletion (AD), Global Worming (GW), Ozone Depletion (OD), Acidification (AC), Human Toxicity by Air (HTA), Human Toxicity by Water (HTW), Aquatic Ecotoxicity (ECA), Nutrification (NU), and Radiological Impact (RI).

The contribution of the nuclear power generation system to abiotic resources depletion is two or three times higher than other environmental impacts, which is mainly due to the depletion of uranium ore. We have been interested in the results of greenhouse gas emission for the non-radiological assessment of nuclear energy, however, effect scores of human toxicity potential and ecotoxicity potential are turned out to be also high. Even though the relative significance factor for the radiological impact potential shows relatively high values, weighting impact of radiological impact potential is not so significant [Table 3].

As a result, once-through fuel cycle turned out to cause the environmental impact of 4.32E-3 based on the un-dimensionally weighted value. Also, the important environmental impacts in un-dimensionally weighted impact that could be associated with once-through fuel cycle currently implemented in Korea turned out to be AD (4.12E-3), HTA (9.19E-5), ECA (4.8E-5), NU (3.43E-5) and HTW (1.29E-5). RI (1.06E-7) was less significant than other categories, even though a high relative significance factor was assigned. The significant environmental category was AD caused by the utilization of uranium resources that was the major contributor of

95.4% to total environmental impacts, and the environmentally dominant stage was found to be mining/milling stage. Also 99% of RI turned to be caused by mining/milling stage and power plant operation, and the most radiologically significant pathway was internal exposure, especially due to the inhalation of air [Table 4].

Table 3. Simple Comparison of Environmental Impact between Once-through and DUPIC

		AD	GW	OD	HTA	HTW	ECA	AC	NU	RI
EI*	O/T	7.33+1 *	2.80+1	6.14-4	4.08+1	5.50+0	1.41+1	4.63+0	7.01+0	1.36-6
	DUPIC	2.02+2	8.52+1	1.76-3	1.17+2	1.56+1	4.04+1	1.28+1	1.94+1	3.66-6
WI	O/T	4.12-3	8.26-7	1.24-6	9.19-5	1.29-5	4.80-5	9.41-6	3.43-5	6.50-7
	DUPIC	1.14-2	2.51-6	3.54-6	2.63-4	3.66-5	1.37-4	2.60-5	9.48-5	1.75-6

* : 7.33+1 means 7.33E+1, EI, and WI mean Environmental and Weighting Impact.

Table 4. Environmentally Dominant Stages for Once-Through Fuel Cycle

Impact Category	**ADP** [95.39%]	**GWP** [0.02%]	**ODP** [0.03%]	**HCA** [2.13%]	**HCW** [0.3%]
Stage	Mining/Milling (96%)	Fabrication (94%)	Fabrication (99%)	Conversion (77%)	Mining/Milling (78%)
Impact Category	**ECA** [1.11%]	**ACP** [0.22%]	**NP** [0.798%]	**RP** [0.002%]	
Stage	Mining/Milling (98%)	NPP (99%)	NPP (99%)	Mining/Milling (67%)	

6. Conclusion

The increasing demand for electricity mainly will be absorbed by nuclear power and the most important consideration in the future will be the environmental friendliness. Concerns on the environment are making energy policies shift toward sustainable development, which considers both economics and environmental protection. Especially power generation company has been considered as major polluter. So decision maker as well as government should keep their efforts steadily to improve their eco-efficiency by preparing the EMS such as LCA. So this paper shows some case study on the back-end fuel cycle option. Of course this study is preliminarily carried out and it is necessary to be supplemented steadily. However, this approach of environmental performance evaluation could improve image of power generation company and disclosure the hidden value for public.

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