A Comparative Study on Environmental Assessment for Power Generation Systems using LCA methodology

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1. Introduction

Many kinds of energy resources are used to meet the demand of the electric power in the world and also in Korea. Public health, environmental, economic and social effect should be considered in determining a national energy policy. An integrated risk estimation methodology is required for the comparison and determination of various energy resources for electricity generation.

As a part of integrated risk estimation, this study is aimed to assess the environmental impact of the various electric power generation systems through their life cycle – construction, operation and destruction stage. The nuclear power system (PWR & PHWR), LNG power system (thermal power/ combined cycle) and bituminous power system are considered in the present study. The Life Cycle Analysis (LCA) was used to compare with the environmental impacts for these electric power generation systems. This result will be applied as environmental database for the integrated risk estimations of various power generation systems

2. Overview of LCA for Korean power generation system

Nowadays many people have studied energetically for global environmental effects, i.e. resource depletion and global warming potential, acidification potential etc. In Korea, the emission of carbon dioxide (CO_2) from energy industry including power station has been increased consistently. Also we have an interest in determining of the national energy policy from a quantified data on environmental and health effects. A Life Cycle Analysis (LCA) in selecting an alternative will be a reasonable approach from this purpose.

The LCA methodology is used for comparing environmental impacts of these options during the life cycle such as construction, operation as well as disposal stages as follows figure 1. Here, the LCA consists of life cycle inventory analysis, classification/selection process of impact categories, characterization process, and normalization process of each category. LCA can be an useful tool for environmental impact assessment of future national energy options. At the planning stage of future energy policies the results of LCA would be taken into consideration. According to data update at the construction and disposal stages the LCA needs to be conducted iteratively.

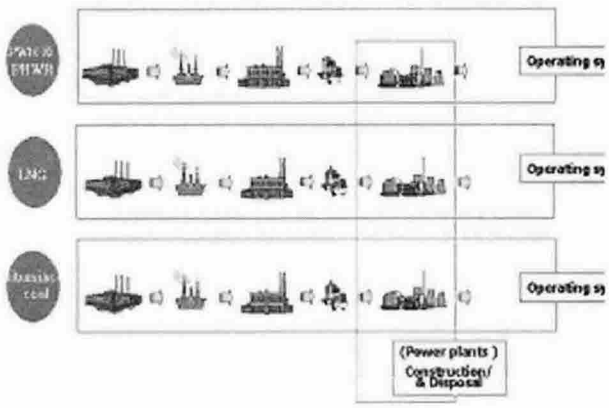

Figure 1. Scope of this study

3. Results and Discussions

We studied for an assessment of environmental impact of life cycle – construction, operation and disposal stage – for nuclear power systems, LNG power system and bituminous power system. And it was injected ISO 14040's into this LCA for an objectivity of the assessment. Table 1 show reference plants data for domestic power systems at construction/destruction and operation stages for domestic power generation systems.

Table 1. Reference plants data for domestic power systems at construction/destruction and operation stages.

Power System	PWR	PHWR	Bituminous	Combined LNG
Facility Capacity (GW)	2.0	0.7	0.5	1.8
Capacity Factor (%)	90	90	85	30
Const./Disposal stage Electricity Production (TWh)	630	220	157	567
Const./Disposal stage Concrete (k ton)	4,020	2,210	5,200	3,120
Const./Disposal stage Steel (k ton)	160	110	314	100

* Function Unit(F.U) : Electricity 1 GWh producing
* Ref. Flow = Facility Capa.(GW) X Availability (%) X 40yr X 8760 hr/yr

In this study, impact categories were chosen according to impact field, such as resource depletion, ecology balance, effect of toxicity, radiation effects in Table 2.

Table 2. Impact Inventory List from an LCA of power systems.

Impact Field	Impact Category	Abbrev.	Characterization Factor
Resources	Abiotic Resource Depletion Potential	ADP	kg Sb-eq./kg
Depletion	Global Warming Potential	GWP	kg CO_2-eq./kg
Ecology Balance	Ozone Depletion Potential	ODP	kg CFC-11-eq./kg
	Acidification Potential	AP	kg SO_2-eq./kg
	Photochemical Oxidant Creation Potential	POCP	kg C_2H_4-eq./kg
	Eutrophication Potential	EP	kg PO_4-eq./kg
Effect of Toxicity	Ecotoxicity to Terrestrial	ECT	kg soil/kg
	Ecotoxicity to Aquatic	ECA	kg water/kg
	Human Toxicity		
	Air Emission for Human Toxicity	HCA	kg body air/kg
	Water Emission for Human Toxicity	HCW	kg body water/kg
	Soil Emission for Human Toxicity	HCS	kg body soil/kg
Radiation Effects	Radiation Effect	RAD	Bq/kg

The result of normalization of LCA at construction, destruction and operation stages are shown as table 3 and fig.2. We performed environmental impact analysis for 5 power generating system, PWR & PHWR, LNG & Combined LNG system, Bituminous system. It was contained 9 impact categories, resources depletion, global warming potential, acidification potential, eutrophication potential etc. for comparison purpose.

Table 3. The Normalized Result of Life Cycle Assessment for 5 kinds of power systems.

Impact Category	PWR	PHWR	LNG	Combined LNG	Bituminous
Res.Depletion	1.17E-09	7.93E-10	2.66E-08	2.21E-08	3.50E-08
Global Warming Potential	7.42E-10	4.83E-10	1.72E-08	1.36E-08	2.83E-08
Acidification Potential	4.60E-10	3.05E-10	4.08E-09	2.60E-09	1.17E-08
Eutrophication Potential	6.92E-11	4.60E-11	1.16E-09	6.15E-10	4.86E-09
Ozon Depletion Potential	4.41E-13	7.53E-13	1.75E-12	1.35E-12	1.00E-12
Photochemical Ozone Creation Potential	2.20E-10	1.65E-10	3.34E-08	2.78E-08	1.48E-09
Terrestic Ecotoxicity Potential	2.89E-10	1.73E-11	8.81E-12	6.97E-12	1.02E-08
Aquatic Ecotoxicity Potential	6.90E-10	1.67E-09	1.13E-12	1.08E-12	7.57E-11
Human Toxicity	4.33E-12	6.27E-12	2.84E-11	1.54E-11	1.08E-10

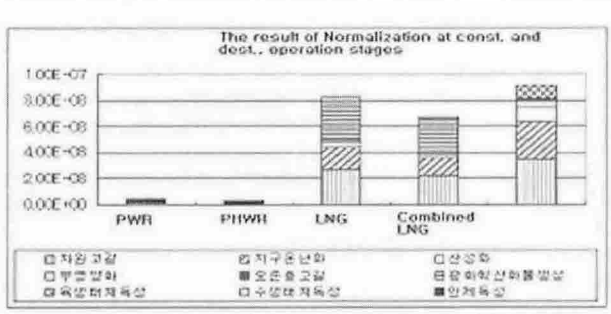

Figure 2. The normalized result of LCA for five kinds of power systems.

As the results of normalization and allocation in this LCA study, environmental impacts of a bituminous system, LNG system was high copare to nuclear power systems.. Also Resource Depletion, global warming potential and photochemical ozone creation potential were issued as environmental interest for this LCA of power generation system.

4. Conclusion

1. From this LCA study, we obtained the rankings for 5 power generation systems in order of large environmental impact as Bituminous, LNG, Combined LNG, PWR, and PHWR
2. It was turned out that the main issues for the environmental impacts are resource depletion, global warming potential and photochemical ozone creation potential.
3. At the stage of construction, LCA showed that Bituminous, PWR, PHWR, Combined LNG, and LNG, in order of large environmental impacts, are environmentally hazardous. This result is due to the amounts of steel used in the construction, which represents that the amount of steel used is the most sensitive factor to environmental impacts in the stage of construction.
4. The radiation effect is the unique feature in the nuclear power generation system and it should be still improved to reduce the environmental impacts.
5. For renewable energy power systems such as hydro, wind and photovoltaic power systems, an LCA study is being performed.

ACKNOWLEDGEMENTS

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