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Long-term Optimization of a Nuclear Power Supply – Korean Case

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1. Introduction

The objective of the study is to analyze the role of nuclear power in the future electricity supply in Korea by considering various levels of electricity demands. The forecasted electricity demand in the national plan was modified in line with a sustainable development by referring to EISD(Energy Indicator for Sustainable Development)[1]. Based on the modified demand, optimal power mix was sought by using a linear optimization planning model, MESSAGE. Based on the output of the study, a policy implication was suggested.

2. Methodology

In order to analyze the Korean electricity system, we used the MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impacts) program, developed by IIASA and updated by IAEA[2]. MESSAGE is an optimization model, which can optimize a whole energy system under given constraints. It is developed based on the linear programming technique and is extended to a use in mixed integer programming techniques. In general, MESSAGE-like modes are very useful when the optimal mixes of power options are sought. However, they have some limitations in dealing with the electricity demand responses to the changes of energy prices. Therefore, the interpretation of the outcome from the model should be subject to these characteristics of the modes.

3. Establishment of Reference Case

3.1 Electricity demand in the reference case

The study covers the period of 2004-2030, which is modeled on a yearly base resulting in a total number of 26 periods. All the cost data is based on 2001 constant money, Korean Won.

The electricity demand in the reference case was estimated as follows; 2004, 2005: historical data, 2006 ~ 2017: the reference electricity demand forecast in the 2nd Basic Plan of Long Term Electricity Demand & Supply[3], 2018 ~ 2030: the electricity demand in these periods are assumed to gradually decrease from the average growth rate of the past periods 2016-2017, finally reaching 0 % growth rate in 2050. In addition, several scenarios were set up on the probable demand for electricity in the study period.

3.2 Major assumption on the power options

All the power plants, which are operating at present, are identified and aggregated by taking into consideration their fuel sources and technologies.

This study uses the economic and technical parameters of these power options from the input data employed in the Basic Plan of Long Term Electricity Demand & Supply. The most recent plan was the 3rd one, which was published in December of 2006. But the input data was not available because it has not been released officially for unknown reason. So, all the cost data except fuel was from the 1st plan, which was published in August of 2002. The fuel cost data used in the study was from the unit prices at which the KPX(Korea Power eXchange) purchased it from the wholesale power generation market on December of 2005.

It is also worth considering that nuclear and coal power plants are involved with a relatively great amount of initial investment expenditures and they have some difficulties in securing plant sites. In this sense, we introduced a constraint on the maximum power capacity available from a power option. This constraint is applied for the nuclear and coal fired power plants. They are not allowed to be introduced with more than 2000MWe in a given period.

4. Scenario Development

4.1 Electricity demand scenario

The electricity demand scenario was created to include 3 cases to consider a good deal of uncertainty with which the electricity demand is involved. A rather heuristic approach was adopted in this study to develop scenarios on the future demand of electricity. The scenario development is based on the future pattern of the electricity use per unit of GDP. The scenarios on the future electricity demand are shown in Figure 1.

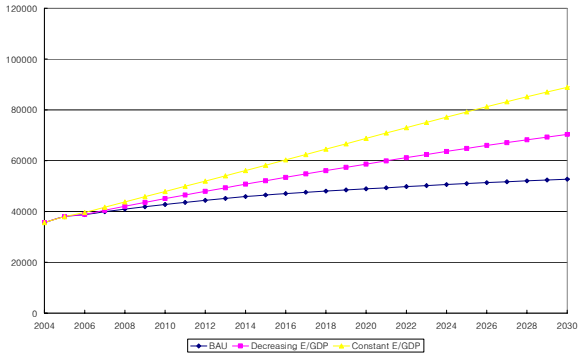

Figure 1. Scenarios on the future electricity demand

4.2 CO2 emissions scenario

Even though the Kyoto Protocol came into effect, Korea has no compulsory obligation on the reduction of GHG emissions under the framework of UNFCCC, because the country belongs to non-Annex I countries.

We assumed 2 cases in imposing a intensity target on CO2 emissions; one is the intensity target of 0.11kg-C/kWh electricity produced for a whole study period, the other is designed in a way that the intensity target becomes more stringent as time goes on. The intensity target is designed to start from 0.11kg-C/KWh in 2005 and reach a level of 0.09kg-C/kWh in 2030.

Table 1. Formulation of scenarios

CO2 limit / Demand	No limit (C0)	0.11kg-C/ kWh(C1)	0.09kg-C/ kWh(C2)
BAU(D0)	D0C0	D0C1	D0C2
Decreasing E/GDP(D1)	D1C0	D1C1	D1C2
Const. E/GDP(D2)	D2C0	D2C1	D2C2

5. Result & Discussion

5.1 Results of reference case

The results from the reference scenario show that additional nuclear power reached the maximum allowable capacity of 2000MW a year for the period of 2006-8. This fact implies that nuclear power, the most economical way of electricity production, was not fully introduced because of the constraint on the maximum allowable capacity in a year.

The result showing that a large amount of nuclear and bituminous coal power plants are favored from the first period to 2010 is totally attributable to the great economic advantage of these two power options over the other power options.

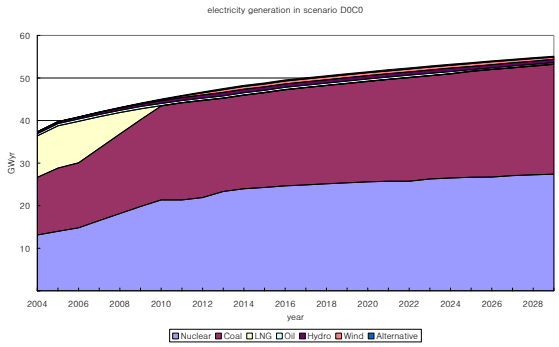

Figure 2. Electricity generation by power options in the reference case

5.2 Results from various scenarios

It is obvious that imposing restrictions on CO2 emissions provides a favor to nuclear power, because nuclear is a CO2 free way of producing electricity. However, the study results show that the restriction on CO2 made almost no contribution to the growth of nuclear power within the same scenarios on electricity demand. It is because nuclear power already reached the upper limit given to it as explained in the study result of the reference case, thanks to its better economics than the other power options considered in the study. The scale of nuclear capacity appears directly to depend on the scenarios on electricity demand. The study result indicates that higher electricity demand is always accompanied by higher nuclear power generation.

The restriction on CO2 emission does not have an influence on the nuclear power, but have a great influence on the other power options.

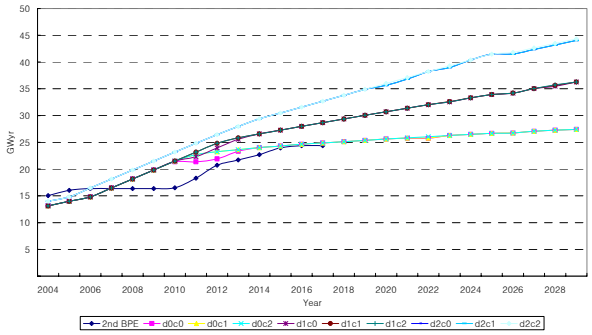

Figure 3. Nuclear generation by scenario

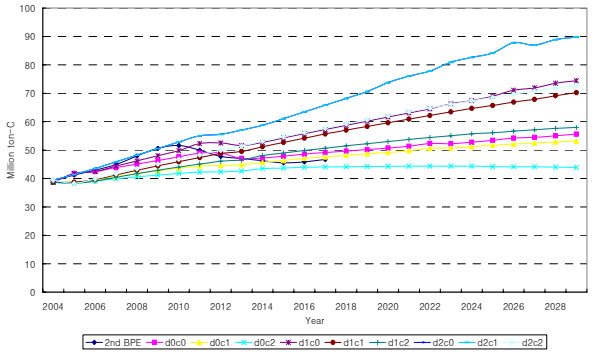

Figure 4. Carbon dioxide emission by scenario

6. Conclusion

The study shows that a higher demand for electricity scenario is always accompanied by an increased nuclear capacity. It is essential that nuclear play an important role in the electric system in Korea for ensuring a stable supply of electricity to meet the challenges to come like carbon emission regulations and a higher demand for electricity than expected in the current national electricity demand and supply plan.

REFERENCES

[1] C. Y. Lim and K. H. Moon, A speculation on the debate about the future electricity demand in Korea, KNS spring proceeding, 2005.
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[3] The 2nd basic plan of the electricity supply and demand, MOCIE, 2004