Multi-Criteria Assessment of Electricity Sector Transition in Korea

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Overview

The Korean government has announced its new energy transition plan, the 8th Basic Plan for long-term Electricity supply and demand (BPE), that is aimed at creating clean and safe energy system. The plan involves reducing dependency on nuclear and coal energy sources, and more reliance on the less carbon-intensive natural gas combined cycle and renewable sources. This plan has come under criticism from different groups of stakeholders based on their perspectives. While some groups worry about the increase in the cost of electricity supply, others speculate on its sustainability and cleanliness. This has necessitated the creation of evaluation tool that can assess the energy mix taking various aspects into consideration.

In this study, we developed a multi-criteria decision making (MCDM) model linked with an energy system model. The energy system model is an optimization model with cost data and technology specific information that have been adopted in the actual planning. The energy system model generates government policies and the scenarios using goal programming. The scenarios include government policies (7th & 8th BPE), and other scenarios that are comparable to the energy transition policy. The MCDM model evaluates the energy mix in each scenario. By comparing the government policies and other relevant scenarios such as coal phase-out and nuclear phase-out, this study will reveal the trade-offs among conflicting values and present possible improvements in the energy transition policy.

Methods

There have been a few attempts to link the energy system model with the MCDM model (Ribeiro et al.,2013; Lehtveer et al., 2015). While the previous studies used the general cost minimizing energy model, we used goal programming. Our model minimized the total deviation from the predefined economic and environmental goals. The economic goal is to minimize the total cost of the portfolio under the 7th BPE, and the environmental goal is meeting the 2030 electricity sector emission target that is aligned with a nationally determined contribution (NDC). In order to make the scenario comparison consistent, we fixed the electricity demand forecast until 2030.

The MCDM model reflects seven attributes that represent the technical, economic, environmental, and social aspects of major power generating technologies in 2030, which will be coal, nuclear, natural gas, solar, and wind. The overall assessment was based on the value function method. First, the generation technology score of each attribute was normalized from 0 to 1. Next, this score was multiplied by the amount of power generated from a certain technology in each scenario. Finally, the relative importance of each attribute in the Korean context was reflected using expert group survey results in literature. To analyze the sensitivity of the system, we assigned five times the weight on each criterion to verify whether the preference among the scenarios changed.

Results

In terms of economics, the energy transition policy incurs an additional 10.2 % of the cost incurred by the 7th BPE, while other alternative scenarios incur additional costs in the range of 8.2 % ~ 29.2 %. The carbon intensity of electricity in 7th BPE was 0.393 kg/kWh while that in 8th BPE was 0.391 kg/kWh. Since the energy transition policy accorded a higher priority on reducing dependency on nuclear resources over coal, lower carbon emission from coal power has negated the highly increasing deployment of power generations using natural gas. Where cost-emission optimization is concerned, scenarios with coal phase-out and 7th BPE dominate over other scenarios.

In the multi-criteria analysis including other social aspects, the energy transition policy (8th BPE) outperforms the previous policy (7th BPE) owing to the higher social acceptability and lower investment cost. However, the drawback of the energy transition policy is its increasing operation cost and large land requirement to meet additional renewable deployments, which can be critical constraint to the Korea. The coal phase-out scenario was the most preferred scenario in the MCDM model in addition to being one of the more efficient ones in the energy system model. Even if the energy transition policy is better than government's previous policy when analyzed from the MCDM perspective, it is essential to reduce coal consumption.

Conclusions

When compared with other previous policies, the energy transition policy in Korea balances environmental and other social values albeit with an increase in cost. Notably, the energy transition mix shows high social acceptability and low investment cost. However, the primary source of carbon reduction is a reduction in demand for electricity, rather than a change in the electricity mix. Scenarios show that emphasizing on coal reduction is preferable in designing energy transition system not only in terms of carbon intensity but also in other aspects. The nuclear phase-out policy is undervalued, since the environmental aspects focus on air pollutants and do not cover radioactive waste. Considering the increasing portion of renewables in the energy system, future studies need to include security of electricity supply as a criterion.

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