Comparison of Electricity Generation Mix Considering Energy Security, Carbon Emissions Mitigation and Generating Cost : a Comparative Study between Korea and Mongolia

Hanee Ryu,Seoul National University,82 10 7706 5685, hanee@temep.snu.ac.kr
Shonkhor Dorjragchaa,Baganuur and South East regional network of the electrical distribution State owned stock company of Mongolia, 97670213987,dorj81sh@yahoo.com
Yoenbae Kim, Seoul National University, 821089486529, kimy1234@snu.ac.kr
Kyunam Kim,Korea Information Society Development Institute, 821085782720, foraddio@naver.com

Overview

The purpose of this study is to assess electricity generation mix considering multiple energy policy goals under the condition of country-specific factors. Carbon emissions reduction for climate change mitigation and energy security are key drivers as important targets of government policies for the future energy plan. Policy makers are under pressure to develop cost-effective alternatives that ensure improvement of energy security and carbon emissions mitigation considering interations between two policy objectives. Policy makers try to find a cost-effective alternative or mix of the alternatives that can achieve the targets of energy security and carbon emission mitigations. If there are lower-cost alternatives to achieve the two targets at the same time, policy decisions will move in that direction. We derive the policy implication from the comparative analysis of scenarios designed to reduce carbon dioxide affecting level of energy security with change of total cost.

Korea and Mongolia show clear difference in electricity generation structure. The country-specific characteritics like fossil fuel reserve, import dependency, renewables energy potential, and factor of threating energy security make different decision on the power generation mix in the future. This study compares and evaluates fuel alternative technologies with high possibility to be introduced in the near future(2030) in three dimensions cost, energy security and CO2 emissions. Different energy condition of each country is reflected in the analysis.

Methods

Three scenarios met the target of carbon emissions mitigation are designed for each country with changing the level of energy security and total generating cost. Mitigation target by 2030 are set to be met at 30% from 2010 emission level. This target is radical for developing countries as the maximum level required by EU. But it can show the significant shift from fossil fuel resources to the alternative ones. Option technologies' carbon emission is arranged according to IPCC inventory guideline.

To measure the level of energy security, we focus on the price risk resulting from fossil fuel resource concentration and the level of exposure to these price risks for a given country. After definition of Bohi and Toman(1996), Lefèvre(2010) and Löschel et al.(2010) deal with price component in supply demension to measure energy security. We choose the Energy Security Price Index(ESPI) and modify it to $ESPI_{gen}$ to get energy security level in the generating system of a given country.

Levelized Cost of Electricity(LCOE) of emerging technologies which will be widely deployed by 2030 as well as existing generation ones are used for calculating the projected cost of two countries. Average cost of OECD and non-OECD countries from OECD(2010) are used with assumption of IEA(2010). Even though estimates of costs subjected to great uncertainty are inevitable, it helps policy decision to be more reasonable with principle of "cost-effective" for the same target.

30% emissions reduction targets will be reached through three ways, extended applying Carbon Capture and Storage(CCS) technologies to coal fired generation plant and increased penetration of renewable energy source for both countries, expanded the role of nuclear energy for Korea and imported electricity for Mongolia as the third scenario respectively. Comparative analysis between two countries is conducted as well as between 3 scenarios of each country.

Results

The improvement of $ESPI_{gen}$ is higher in the order of SC2_KR(RE), SC3_KR(NU). SC1_KR(CCS), instituting the way to increase the share of renewable energy sources to the maximum as an alternative to fossil fuels, has the lowest proportion of the introduction of additional CCS, and so it avoids fossil fuel. Fuel mix that fossil fuels are replaced to renewables and nuclear represent better choice with meeting two targets with lower cost than SC1_KR(CCS) even though renewables has technological limitation and nuclear has social acceptance problem.

Because CCS scenario is booked for fossil fuel, it has less improvement of energy security. The higher rate of cost increase of SC1_KR(CCS) than other scenarios results from big change of CCS capacity, which have to be attached for meeting carbon mitigation targets while other technologies needs less change than CCS share.

All scenarios of Korea appear to have a positive result to the energy security, which verifies that substitution fossil fuel to the alternatives including CCS introduction reduced carbon emissions has positive effects on the energy security. In the case of Korea, improving the security indices leads to show a complementary relationship between reducing carbon emissions and the target of improving the security index in all scenarios.

The cost comes out in higher order of SC1_MN(CCS), SC2_MN(RE) and SC3_MN(IM_E), which is proportional to the size of proportion of CCS introduction. Since the average cost of renewable energy sources and the imported electricity is lower than that of CCS-attached coal-fired power plant, CCS introduction is one of the major causes for a large growth of cost. What can be found through these three scenarios is that, in Mongolia's case, it will be difficult to lead to carbon reduction without CCS introduction.

In terms of the security index all scenarios do not brings an enhancement. As the factor of security threat depends on electricity imports, replacing coal with other alternatives does not affect the security, whereas large scale of deteriorating security index appears in SC3_MN(IM_E). Thus, in this case, the relationship between security-improving targets and carbon emission targets is trade-off.

Interaction between the targets of energy security and carbon targets appear to vary depending on where the national energy security threats come from. In Korea, since carbon emission factors are identical with domestic factors to threaten the security in the proportion of fossil fuels, alternatives to replace fossil fuels in order to reduce carbon emissions are also able to reduce the security threats, showing complementary characteristics. In the case of Mongolia, the two factors are separated; carbon emissions coming from coal but security threats from electricity imports. Therefore, in an alternative to avoid domestic carbon emissions as in SC3_MN(IM_E), two targets collide and represent a significant deterioration of the energy security.

Conclusions

Fossil fuel resources result in the carbon dioxide emissions and the energy insecurity in Korea while these factors are separated in Mongolia as carbon emissions from fossil fuel and enery insecurity from imported electricity. Policies targeting two objectives, carbon emissions mitigation and enery security improvement, show complementarity in Korea but represent trade-off in Mongolia.

As a result of examining the interactions between the two objectives and related costs, discussion in Korea should be carried out concentrating on renewable energy or expanding nuclear power rather than CCS. It eventually results in the question of to what extent the share of nuclear power can be set up. Decision-making process should be concentrated on set-up of the proper proportion of nuclear power, since the level of CCS introduction and the share of renewable energy sources may vary depending on the level of nuclear power plant. As the issue evoking a lot of social costs and discussions, this requires the development and agreement on the criteria. In Mongolia, CCS introduction has been the most significant factor in any scenarios. Since enlarging CCS or renewable energy may be a better alternative when considering security, CCS proportion of introduction will vary depending on to what extent renewable energy resources will possibly be developed. Eventually there is a need in Mongolia to focus on evaluation of the ability to develop renewable energy and on development of cost-effective CCS.

References

Bohi, D.R., M.A. Toman, "The Economics of Energy Security", Norwell, Kluwer Academic Publishers, 1996.

Lefèvre, N., "Measuring Energy Security Implication of Fossil Fuel Resource Concentration", Energy Policy, Vol.39, 2010, pp.1635~1644.

Löschel, A., U. Moslener, D.T.G. Rubbelke, "Indicator of Energy Security in Industrialised countries", Energy Policy, Vol. 38, 2010, pp.1665~1671.

Organization for Economic Cooperation and Development(OECD), "Projected Costs of Generating Electricity 2010 Edition", OECD/IEA/Nuclear Energy Agency(NEA) Joint Report, Paris, 2010.

International Energy Agency(IEA), "Energy Technology Perspectives 2010", OECD/IEA, 2010.