Conceptual Framework of Energy Security Assessment in Korea

Kee-Hwan MOON, Whan-Sam CHUNG, Seung-Su KIM
Division of Nuclear Policy Studies
Korea Atomic Energy Research Institute, Daejon, R.O.Korea
e–mail: mkh@kaeri.re.kr, wschung@kaeri.re.kr, sskim5@kaeri.re.kr

1. Introduction

Korea's electric power is an essential source of energy, supplying 21.4% of the energy required by the manufacturing industry, 43.4% of that required for commerce, and 59.5% of that required by the public sector in 2014. Korea relies heavily on imports of energy sources because of its lack of natural resources. Its land area is limited, making it difficult to utilize renewable energy. Moreover, it is difficult to trade electricity through grid connections with neighbouring countries.
Considering the key role of electric power in Korea and the circumstances of its power generation industry, we must understand the contribution of each fuel used in power plants to energy sustainability. Energy mix strategies for the power generation expansion should be established based on this understanding for the nation to enhance its energy security.

2. Conceptual framework for comparing energy security

The definition of energy security varies among institutions and researchers. The International Energy Agency(IEA) defines energy security as "the physical availability of supplies to satisfy demand at a given price(2001)", "uninterrupted availability of energy sources at an affordable price(2011)". The World Bank defines it as "ensuring countries can sustainably produce and use energy at a reasonable cost." Kruyt(2009) defined it as the "availability of energy to an economy, accessibility, costs, and environmental sustainability" and Koyama and Kutani(2012) defines it as "securing the amount of energy required for people's life, economic, and social activities, defense and other purposes for acceptable prices". Kim(2008) defined the concept as "the state of the ability to secure proper energy sources at a reasonable price without the risks of supply suspension". Sovacool(2011) proposes that energy security ought to be comprised of five dimensions related to availability, affordability, technology development, sustainability, and regulation. And then break these five dimensions down into 20 components as shown in Table 1.
Korea has limited natural energy resources, a small land area, and an isolated electricity supply network. To make a conceptual framework for comparing the contribution to national energy security by electricity supply option, under the these situations, this study defines and applies four dimensions(STEG) as follows: reliability in supply(*S*), technology complementarity(*T*), economic competitiveness(*E*), and environmental sustainability(*G*). Reliability in supply assesses the stability of the supply of energy, based on the procurement of a sufficient amount of energy to meet the demand and ease of stockpiling energy. Technology complementarity is a dimension used to examine the technological suitability; it is evaluated using the ratio of capital cost to the power generation cost and/or the forced outage rate. Economic competitiveness includes the price stability of fuels and the instable indicators such as price volatility, as well as low prices and economic ripple effects. Environmental sustainability is used to assess the effects on natural environmental in terms of greenhouse gas(GHG), required sites, and accident rates. This study presents the following four dimensions and six indicators to measure them, as in Table below.

Table 1: Dimension, components, and indicators for energy security

Dimension*	Component*	Indicators**
Availability	Security of supply and production, Dependency, Diversification	Reliability in supply
Technology Development & Efficiency	Innovation and research, Safety and reliability, Resilience and adaptive capacity , Efficiency and energy intensity, Investment and employment	Technological complementarity
Affordability	Price stability, Access and equity, Decentralization, Low prices	Economic competitiveness Industrial impacts
Environmental Sustainability	Land use, Water, Climate change, Pollution	GHG emissions Site availability
Regulation and Governance	Governance, Trade and regional interconnectivity, Competition and markets, Knowledge and access to information	(not considered)

* : Proposed dimension and component by Sovacool
** : Proposed indicators in this study

3. Quantifying methods of nuclear energy security indicators in Korea

The reliability on the supply side is affected by political stability in energy-exporting countries and by the diversity of energy-supplying countries. A number of indicators for supply diversity have been used in economics to identify the concentration level of the markets. This study used the Herfindahl-Hirschman Index (HHI), one of the most widely used indicators, and

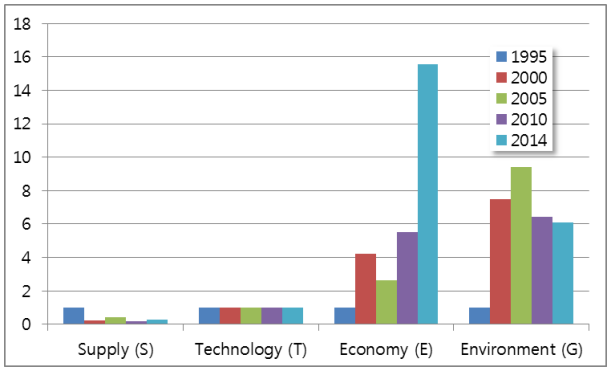
evaluated the diversity of energy importing countries. Russia and Canada supply almost 75% of uranium, the nuclear fuel, and the share of the United States drastically fell from 17.2% in 2000 to 5.0% in 2014.

This study introduces the technology dimension as a means to identify the possibility to supplement a lack of natural resources with technologies, when considering of the inherent conditions of Korea as a country with limited natural resources. In order to measure the technological dependence of nuclear power plant currently operating in Korea, this dimension utilizes the changes in generation efficiency in measuring the proportion of fuel costs and the technological level. Despite the lack of natural energy resources, South Korea records the world's 6th level of national competitiveness in the science and technology field, as evaluated by the IMD online in 2015 (IMD (2015)). The country therefore needs to endeavour to develop technology-intensive energy sources in order to improve its stable energy supply. This study evaluated technology-intensive energy sources based on the proportion of capital cost and maintenance cost, excluding the proportion of fuel costs from the actual generation costs of energy source. The change of energy security dimensions for Korea's nuclear is as shown in following figure.

The economic competitiveness is calculated with the fuel cost from actual generation cost and the variance of import fuel prices since 1995, while the industrial impacts at the domestic level is estimated using the background linkage effect of the relevant energy source. While discussing energy security, the economic dimension is one of the most important factors in any country. For Korea, this dimension is deemed to have the second most important value next to the stable supply of energy sources. The actual generation cost of nuclear has increased rapidly. This is because compensation costs were added from 2014.

In this study, the indicators in environmental sustainability dimension consist of the GHG emissions over the entire life cycle of the fuels and the site availability of power plants operating in Korea. The discussion of the GHG indicator cites the 1999 and 2010 studies by the Central Research Institute of Electric Power Industry in Japan, and the land use data was calculated using survey data of nuclear power plants in. Korea has the 21st highest population density in the world. In addition, with the world's 9th largest trade volume, Korea is required to join in the global efforts to cope with climate change, such as reducing GHG emissions. In this regard, the dimension of the environment is now of great importance in Korea.

Figure 1 shows a sample calculation of energy security by each dimension by nuclear power. In order to simplify, the same weight is applied among indicators within each dimension.



Remarks) letter in parentheses for each dimension refers direction to enhance national energy security.

Figure 1: Changes of nuclear energy security by each dimension

4. Conclusions

This study derives the conceptual framework to quantify energy security levels for nuclear power generation in Korea and employ them in evaluating the national energy security. And sample calculation of nuclear energy security indicators is performed. The implications drawn from the evaluation are as follows.

Nuclear power demonstrates dominance in the dimensions of economy and technology as the related technologies have entered into the stage of maturity. Without constant technological innovation, however, sustainability of nuclear sources will not be guaranteed. Nuclear has in the middle in terms of *SS*, but their high volatility impels Korea to pursue the diversification of energy suppliers.

The energy security indicators suggested in this study are anticipated to contribute to establishing an energy security policy based on a comprehensive understanding of the energy security status in Korea. In the future, it will be necessary to establish specific scenarios for a decrease of regional conflicts and a post-2020 climate change conventions and conduct realistic and dynamic analyses. Even though the technology dimension, including the attributes of the technology development, will be a more important component, it has been applied only to simple indicators in this study. It has a limit. Proper technological property can be embodied not only for statistical data but also dynamic trends of innovation, safety, resilience, and efficiency. This will then serve as a more meaningful measure in the energy policy.

In addition, it is essential to draw comprehensive indicators by incorporating the results from individual indicators and produce policy data about the priority of energy sources in terms of energy security in general.

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