

Foresight Study on the Energy Sector in South Korea: With a Focus on Establishing Strategic Scenarios and Preparing Response Strategies

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Abstract

This study, by utilizing network analysis, clarified the relationship between influencing factors of the future energy sector from a multi-dimensional perspective. Scenario planning and hierarchical analysis were used with key uncertainty factors (KUF) to create three predictable strategic scenarios for the year 2030 in South Korea (optimistic, business as usual, and pessimistic) and common strategies that need to be urgently pursued as well as the priority of maximum risk avoidance strategies for each scenario were presented.

Specifically, this study presents the global economic trend, changes in industrial structure, and energy pricing as key uncertainty factors. In addition, to prepare effective policy alternatives for the future energy sector, it points out that, in addition to implementation of changes in industrial structure and national energy demand management strategies, securing of fundamental energy efficiency technology should be applied to government policy with top priority. The implications and limitations of the study were then discussed based on these findings.

Keywords: energy, network, key uncertainty factor, scenario planning

1. Introduction

Since the launch of the Lee Myung-Bak Administration, Korea has designated green growth as a key agenda for its new long-term strategy for national growth and has exerted pan-ministerial efforts to achieve this. Based on the need to secure a reliable source of energy to support economic growth and to meet the demands of future generations, the government's energy policy focuses particularly on energy security, energy efficiency, and environmental protection (Prime Minister's Office et al., 2008a).

However, the recent worldwide increase in energy demand and the emergence of new global paradigms

such as climate change, greenhouse gas reduction, and energy security increases uncertainty in Korea's future energy outlook (Prime Minister's Office et al., 2008a; 2008b). Considering Korea's dependence on overseas energy sources, it is likely that the country's future energy sector will be influenced by macroscopic exogenous variables. Because of this, the government, utilizing strategic future foresight, must exert more effort into developing new growth engines and securing core technology. In this sense, this study, considering its topic of "establishing strategies by foresighting the energy sector's future," is a timely attempt.

As is widely known, technology foresight provides a rational perspective of the speed and direction of

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technological advancement based on consideration of changes in the future social environment and consumer needs and can provide information useful to establishing long-term plans for sectors that are mutually relevant. Recently, in addition to being used by governments, technology foresight has become an essential tool of corporations in establishing long-term growth strategies.

In Korea, many studies have been carried out to deduce science and technology foresight, but most were unable to fully represent the wide variety of possible future scenarios and establish appropriate responsive measures due to difficulties in methodologies (Sang-Sung Nam, Byung-Yong Hwang and Han-Lim Choi, 2009). In particular, in the energy sector, quickening technology change cycles and uncertainty in the environment for technology development have become the biggest factors hampering the accuracy of future foresights.

To address these issues, this study seeks to utilize a scenario-based methodology and process instead of the conclusive future foresight carried out widely in the past using the Delphi method. Scenario planning, because it takes uncertainty into consideration, is an appropriate method for mid- to long-term foresight. In addition, because it has the advantage of allowing researchers to tell decision makers what will likely happen in the future regarding a specific issue in which complex factors are intertwined in a fashion similar to telling a story, it can be used as an effective learning tool for stakeholders.

With the above problems in mind, this paper seeks to select factors that influence the future energy sector and deduce key uncertainty factors (KUF) from a multi-dimensional perspective. It also seeks to present a variety of strategic scenarios and strategies based on key uncertainty factors (KUF).

In addition, this paper, which focuses on the energy sector, seeks to provide basic data for the establishment of Korea's science and technology policies and civilian technology development strategies as well as contribute to the methodology modification of the 4th National Science and Technology Foresight in Korea.

The scope of study was limited to Korea's future energy sector, with the range of the timeline set from the present to 2030, considering that this study is a mid- to long-term technology foresight.

2. Theoretical Background

2.1 Energy Sector Issues and Trends

Since man first discovered fire, energy has been one of his most basic tools for maintaining his way of life. It would not be an exaggeration to say that we use energy to engage in virtually all our activities. However, the amount of energy that exists in the world is limited, and demand for energy is increasing rapidly as China and developing nations make strides toward economic advancement and as the world's population continues to increase. Consumption of energy on such a massive scale intensifies global warming, which in turn leads to serious side effects such as abnormal climate changes. Futurologists predict that this trend will continue to intensify (NIC, 2008; DCDC, 2007; Tekes, 2006).

According to the International Energy Agency (IEA), which produces energy forecasts by taking into consideration factors such as worldwide energy supply/demand and political and economic trends, during the period from 1990 to 2005, global energy consumption increased 23%, with steep increases in the transportation and service sectors (37% increase) and electricity consumption increasing 54%. Moreover, the IEA predicts that the global economy will grow fourfold by 2025, with the economies of China and developing nations growing tenfold. Ultimately, it forecasts that in 2050, the world's demand for crude oil will have increased by 70% and carbon dioxide emissions by as much as 130% of current levels (IEA 2008a, 2008b, 2008c, 2009).

Such an increase in worldwide energy consumption leads to two major problems. The first is the depletion of fossil fuels and a rise in energy pricing systems due to imbalance in energy supply and demand. China already surpassed the U.S. in 2009 to become the world's largest energy consumer. From 2000 to 2008, China's energy consumption grew more than fourfold from the previous decade. Moreover, as China's current per capita energy consumption is merely one-third that of the OECD average, it is very likely that its level of energy consumption will increase further (IEA, 2010).

The IEA (2009) forecasted that, as a result, the price of crude oil will reach 224 dollars per barrel in 2035.

The second problem is environmental change due to the increase in energy consumption. The UN Intergovernmental Panel on Climate Change (IPCC) announced in a 2007 report that the world's average temperature had risen by 0.74°C over the past 100 years, and that the upward trend continues. As man's consumption of energy increases, so will greenhouse gas emissions and energy pricing systems. This will lead to climate change, which will destroy the world's ecosystems and lead to a surge in natural and environmental disasters. And this may cripple the global economy, which has been maintained by consuming energy.

To solve the global energy problem, transnational and voluntary efforts are required, and fortunately, the first step toward such was taken in the form of the Kyoto Protocol of 1997 in which developed nations agreed to reduce greenhouse gas emissions. But transnational efforts are far from sufficient, as seen in the UN Climate Change Conference held in Copenhagen in 2009 (IEA, 2010). Nevertheless, in the same report, the IEA predicts that policy pledges and plans for reducing greenhouse gas and adjusting energy demand recently announced by governments will have significant impact on curbing energy demand and carbon dioxide emissions, provided they are executed. The IEA predicted that in such a case, global demand for primary energy will grow by an average of just 1.2% each year during the period from 2008 to 2035, much less than the 2% annual average recorded in the years prior to 2008.

In response to transnational efforts, the U.S. passed the Energy Independence and Security Act in 2007 and has since been making various efforts to enhance energy efficiency and reduce greenhouse gas such as those to improve the energy efficiency of automobiles, lighting, and commercial buildings. Japan established the "Action Plan for Building a Low-Carbon Society" in 2008 and has set a goal of reducing its carbon emission level by 60~80% by 2050 (Cabinet Secretariat, 2008). The EU, since 2007, under the slogan "20% Energy Savings by 2020," has established

plans to subsidize energy efficiency improvements costs, promote the use of energy-efficient appliances, and develop incentive schemes.

Meanwhile, Korea, in 2008, by announcing the 1st Korean National Energy Master Plan, adopted a future-oriented energy policy direction with the goal of realizing low-carbon green growth (Prime Minister's Office et al., 2008a). Specifically, in order to tackle the looming energy threat, the country has established and is executing strategies to raise national energy efficiency by 47% so that its energy efficiency matches that of developed nations, to lower dependency on fossil fuels such as oil and coal, and to substantially increase the use of nuclear and new and renewable energy.

In addition, it continues to exert efforts to develop energy-related technologies and reduce energy consumption, examples being the establishment of the National Program for Green Technology Research and Development (Ministry of Education, Science, and Technology et al., 2009) and the Basic Plan for Rational Energy Utilization (Prime Minister's Office et al., 2008b).

2.2 Scenario-based strategic foresight

Technology foresight utilizes various foresight methodologies such as the Delphi method, cross-impact analysis, scenario planning, expert panels, environment scanning, and trend extrapolation. These methodologies have evolved into a variety of forms to suit each country's political situation, culture, and R&D system. In the early years of technology foresight, Japan led the use of the Delphi method; but the recent spread of scenario planning and environment scanning has led to its gradual disuse.

Most foresight methods including the previously employed Delphi method, because they focus on a limited area of a phenomenon or effect, have tended to ignore uncertainties that can arise on a general level. However, scenario planning presents a few extreme cases to represent the future and therefore is a method that enables flexible response to all possible situations.

This methodology is seeing more use as modern

science and technology, which is complex and rapidly advancing, increases uncertainty in future society. This study also utilizes the scenario method, considering uncertainty in the energy sector and quickened technology development cycles.

As is widely known, the scenario method is currently being used by strategy makers at major corporations and government agencies in the U.S. and Europe. The global oil giant Shell weathered the 1970s' oil shock relatively better than its competitors because it had done scenario planning that had factored in potential high oil prices (Boldock, 1999; Schoemaker, 1993). In Korea, Hyun Yim (2009) used this method for observational research on the new and renewable energy sector.

However, the reliability of this methodology depends on scientific and systematic deduction of key uncertainty factors that influence the future (Sang-Sung Nam, Byung-Yong Hwang and Han-Lim Choi, 2009), and studies up until now have been shown to be lacking in this regard. This study, to aid the deduction of future scenarios and responsive measures based on scientific evidence, utilized statistical and quantitative analytical methods with consideration of the general stages of scenario planning.

With regard to the use of the above analytical methods, first, in selecting and analyzing the relationship between multi-dimensional influencing factors in the future energy sector, this study utilized the STEEP analysis and network analysis methods. STEEP analysis involves selecting key variables in the five horizontal areas of society, technology, economy, ecology, and politics to identify the factors that affect the macroscopic environment of the future energy sector. Meanwhile, network analysis emphasizes the connective relationships between the agents inside the system, enabling a systematic view of the overall structure and components of society (Knoke & Kuklinski, 1983). The greatest advantage of network analysis is that it enables the discovery and graphing of hidden structural connection patterns through analysis of the relationship between agents or nodes. In other words, by analyzing the relationship between agents or nodes on the general level, it is possible to identify the structural characteristics of the relationship

between nodes in relation to the flow of resources and information, while by identifying factors that are structurally important, it is also possible to deduce policy implications based on network efficiency or strategic importance (Scott, 2000; Hanneman, 2001; Chi-Sung Park, 2006; Kil-Kon Ko, 2007).

Next, to deduce key uncertainty factors, this study conducted a matrix analysis on the level of uncertainty/influence of each factor that influences decision-making in the future energy sector.

Third, in regard to strategies for the future energy sector, this paper prioritized strategies by utilizing the Analytic Hierarchy Process (AHP).

The specifics of the analyses conducted using the above methodologies will be covered in the following chapter.

3. Environment analysis of the energy sector and deduction of key uncertainty factors

3.1 Analysis of influencing factors in the energy sector

3.1.1 Selection of influencing factors

While factors that influence decision-making for foresight can be identified from various perspectives, the general trend nowadays is to divide them into macroscopic environmental factors such as strengthened environmental regulations, trade regulation policies, and change in lifestyles and microscopic environmental factors such as changes in product prices and the development of new technology.

To identify key variables that influence decision-making in the future energy sector, this study conducted text mining and analyzed keywords. The keywords were extracted by analyzing words that saw frequent use in related literature, and their distribution in literature and URLs was analyzed.

Next, using the results of text mining, a STEEP analysis was conducted through wiki-based on-line discussions. This led to the identification of 14 factors, the conceptual validity of which, in consideration of Korea's situation, was verified by the Energy Sector Future Foresight Committee. The wiki, first developed in 1994 by Ward Cunningham, is a web-

Table 1 Factors that influence the future energy sector

Area	No.	Factor	Detailed variables
Society	1	Increase in energy demand	1-1 Increase in energy demand due to population growth 1-2 Increase in energy demand due to population aging 1-3 Increase in energy demand due to change to urban-centered social system 1-4 Increase in energy demand due to change to decentralized social system 1-5 Increase in energy demand due to increase in income
	2	Change in lifestyle	2-1 More awareness toward using clean energy 2-2 More awareness toward using nuclear energy 2-3 Rise of eco-consumerism
Technology	3	Resource development technology	3-1 Expansion of resource development into deep-sea, deep-earth, and space 3-2 Development of efficient resource gathering and utilization technology
	4	Development of renewable energy technology	4-1 Development of technology for production, supply, and utilization of economically feasible new energy 4-2 Development of technology for production, supply, and utilization of economically feasible renewable energy 4-3 Development of clean coal technology
	5	Energy efficiency enhancement technology	5-1 Sustainability of existing energy efficiency improvement technology paradigm 5-2 Practical application of innovative energy production/transmission/storage technology 5-3 Development of low-power technology
	6	Development of nuclear power technology	6-1 Development and proliferation of nuclear power technology such as nuclear fusion 6-2 Securing of nuclear reprocessing technology
Economy	7	Global economic trend	7-1 Increase of uncertainty in the business cycle 7-2 Increase in energy consumption and supply 7-3 Expansion of the low-price BRICs and TWT (Turkey, Vietnam, Thailand) markets
	8	Change in industrial structure	8-1 Advancement of the industrial structure and an increase in the need to conserve energy in all industries 8-2 Increase in investment to development energy-related technologies 8-3 Growth of the carbon market
	9	Energy pricing system	9-1 Rise in fossil fuel prices due to diminishing fossil fuel reserves 9-2 Strengthened governance structures at major oil companies
Ecology	10	Increase in awareness of seriousness of climate change	10-1 Stronger international agreements to curb climate change and reduce greenhouse gas production 10-2 Realization of low-carbon, eco-friendly energy systems
	11	Need to prevent pollution	11-1 Increase in awareness of the seriousness of air, soil, and marine pollution 11-2 Rise in waste recycling
Politics	12	Energy policy	12-1 Adoption of energy policy based on demand management 12-2 Policies to enhance society's acceptability of nuclear power 12-3 Strengthened energy efficiency certification system and encouragement to raise efficiency
	13	Domestic/overseas political structure	13-1 Increase of uncertainty in the North Korea factor 13-2 Emergence of environmental parties 13-3 Spread of energy treaties among NEA countries 13-4 Spread of free trade through FTAs, etc. 13-5 Reinforcement of trade barriers through green index, etc.
	14	Energy security	14-1 Stronger competition from resource consumers such as BRIC countries in securing resources 14-2 Emergence of resource nationalism 14-3 Increase in capacity to self-supply key energy sources

Source: Produced by the authors through discussion with the Energy Sector Future Foresight Committee

based information sharing system that facilitates interaction among participants in the collaboration process, encourages participation, and also contributes to collecting information and systemizing the collected information.

Table 1 is a list of the 14 factors that influence decision-making in the future energy sector identified through the above process.

As can be seen in Table 1, although the influencing factors of the five areas appear at first to be independent, they are in fact interconnected and thus they affect one another. The effects of a change in a factor in one area do not remain confined to that area: the change affects all the other areas of the system as well.

For example, the relationship between ‘society’ and ‘economy’ is that ‘society,’ to ensure a stable source of energy, demands ‘politics’ secure resources, ensure an adequate level of energy independence, and establish a decentralized power system that is eco-friendly and provides more options to the consumer. ‘Politics’ affects ‘economy’ by executing energy policies such as those that introduce RPS to encourage the use of clean energy and adjust energy pricing systems to meet the demands of ‘society.’ ‘Economy’ affects ‘society’ by changing energy consumption patterns and shifting toward a low energy consumption industry structure.

Regarding the relationship between ‘economy’ and ‘environment,’ ‘economy’ increases pollution in order to produce goods, while as the level of economic development rises, public awareness toward protecting the environment increases and thus affects ‘environment.’ ‘Environment’ affects ‘economy’ through green technology, eco-friendly markets, carbon markets, and tougher environmental standards for trade. ‘Environment,’ through eco-friendly political parties or civic groups, also demands that ‘politics’ implement clean energy policies and take measures against climate change. Upon receiving such demands, ‘politics’ affects ‘economy’ and ‘technology’ through a variety of policies, leading to the development of green energy technology and the development of nuclear power technology, which in turn affects ‘economy.’

‘Technology’ affects ‘environment’ through development of nuclear and eco-friendly technologies,

and ‘environment’ affects ‘economy’ through energy policies.

In the following pages, this paper will take a closer look at the above dynamics through analysis of the relationship between the influencing factors of the future energy sector.

3.1.2 Analysis of the relationship between influencing factors

The network analysis in this study was carried out using UCINET6, a social network analysis program, while NetDraw was used to convert the results of the analysis into a sociogram. The factors used in the survey were identified as influencing factors of the future energy sector, and the survey itself measured the top three influencing factors as well as the level of influence (on a scale of 5). Of a total of 22 sets of replies received from members of the Energy Sector Future Foresight Committee, excluding two that were found to be unsuitable to be used as data, 20 were used in the network analysis.

The network analysis was conducted with a focus on sociogram analysis for diagramming the connection patterns of the agents and on analyzing centrality, which is a structural characteristic.

a. Network sociogram analysis

A sociogram of the network of future energy sector factors was produced to examine the characteristics of the connection between factors. Figure 1 is the sociogram of the entire network based on survey data.

According to the sociogram, ‘energy pricing system’ and ‘change in industrial structure,’ both of which are economic factors, ‘increase in energy demand,’ which is a social factor, and ‘energy policy,’ which is a political factor, display high levels of centrality. However, ‘increase in energy demand’ and ‘change in lifestyle,’ both social factors, do not exhibit a strong relationship in the network sociogram.

The strength of the relationship (line) between each factor (node) is represented by the thickness of the line. Factor pairs exhibiting strong relationships are as follows: energy pricing system - increase in energy demand; global economic trend - increased in energy demand; energy pricing system - change in industrial

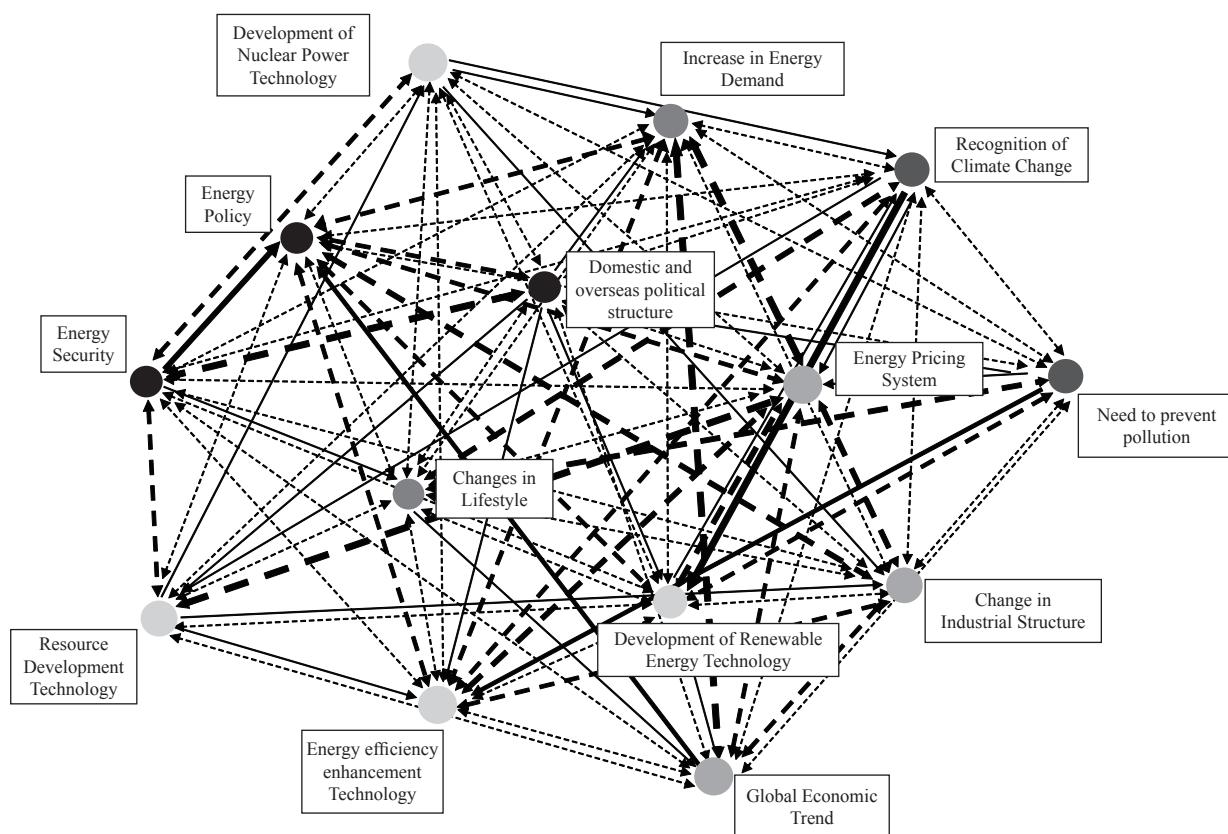


Figure 1 Network sociogram of the future energy sector

structure; resource development technology - energy pricing system; domestic/overseas political structure - energy security; and development of renewable energy technology - increase in awareness of seriousness of climate change.

In addition, increase in energy demand→energy pricing system (weight 64) was shown to have the strongest relationship, followed by increase in awareness of seriousness of climate change→development of renewable energy technology (weight 61).

b. Degree (indegree/outdegree) centrality analysis

Centrality is an index that is widely used in connection with the concept of influence of power. In most empirical analyses, agents or nodes with a high level of centrality are usually people or factors that possess special socio-economic status. A higher level of centrality translates to better survival or performance (Yong-Hak Kim, 2007).

Degree centrality is determined by the total number of nodes connected to a specific node, and is a concept for displaying regional centrality. Therefore,

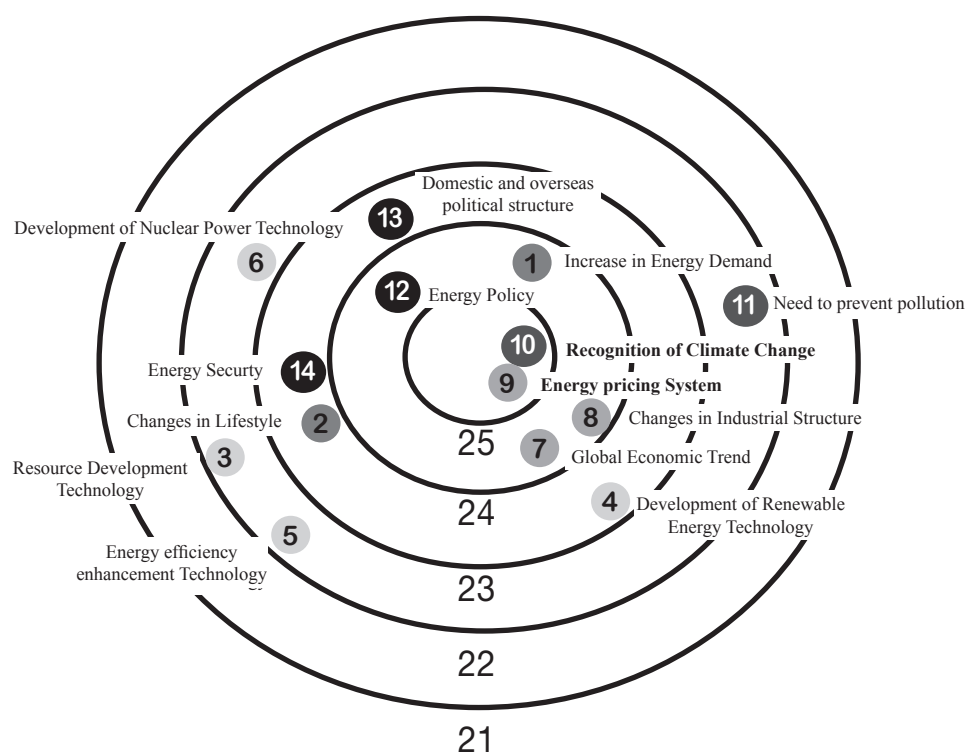
because it is based on the number of nearby connected nodes, degree centrality shows a node's level of connectivity with other nodes and is a concept for identifying the location and importance of a node (Wasserman & Faust, 1994).

Table 2 is the result of degree centrality analysis of future energy sector factors.

First, outdegree centrality can be defined as the level of influence a factor has on another factor in the network structure. Outdegree centrality of future energy sector factors was found to be in the following order: energy pricing system→increase in awareness of seriousness of climate change→global economic trend→increase in energy demand, energy policy→change in industrial structure→domestic/overseas political structure, change in lifestyle, energy security→development of renewable energy technology→development of nuclear power technology→energy efficiency enhancement technology, need to prevent pollution, resource development technology. This is displayed in diagram in Figure 2.

Table 2 Degree (indegree/outdegree) centrality of future energy sector factors

	Factor	OutDegree	InDegree	OutDegree (Norm.)	InDegree (Norm.)
9	Energy pricing system	212.000	405.000	25.481	48.678
10	Increase in awareness of seriousness of climate change	211.000	144.000	25.361	17.308
7	Global economic trend	204.000	68.000	24.519	8.173
1	Increase in energy demand	203.000	282.000	24.399	33.894
12	Energy policy	203.000	365.000	24.399	43.870
8	Change in industrial structure	202.000	277.000	24.279	33.293
13	Domestic/overseas political structure	196.000	74.000	23.558	8.894
2	Change in lifestyle	196.000	159.000	23.558	19.111
14	Energy security	196.000	189.000	23.558	27.716
4	Development of renewable energy technology	193.000	280.000	23.197	33.654
6	Development of nuclear power technology	189.000	88.000	22.716	10.577
5	Energy efficiency enhancement technology	188.000	264.000	22.596	31.731
11	Need to prevent pollution	188.000	77.000	22.596	9.255
3	Resource development technology	188.000	95.000	22.356	11.418

**Figure 2** Outdegree centrality of the future energy sector factor network

Indegree centrality is the level of influence a factor receives from another factor in the network structure. Indegree centrality of future energy sector factors was found to be in the following order: energy pricing system←energy policy←increase in energy demand←development of renewable energy technology←change in industrial structure←energy efficiency enhancement technology←energy security←change in lifestyle←increase in awareness of seriousness of climate change←resource development technology←development of nuclear power technology←need to prevent pollution←domestic/overseas political structure←global economic trend. This is displayed in diagram in Figure 3.

The above analysis shows that ‘energy pricing system’ has the highest level of both outdegree centrality and indegree centrality among future energy sector factors.

Meanwhile, centrality, which shows the network’s level of centralization, is calculated by dividing the degree of connectivity of the network by the maximum logical value and multiplying the results

by 100. Regarding degree centrality, the outdegree centrality of future energy sector factors was 1.858% while indegree centrality was 26.840%, indicating a trend toward indegree.

c. Betweenness centrality analysis

Betweenness centrality is calculated based on the number of lines containing nodes among the shortest lines connecting two nodes in the network. Betweenness centrality is a key index for identifying central factors in the network. A node positioned in the shortest distance connecting other nodes has the potential to control other nodes, and betweenness centrality shows the amount of influence individual nodes have on the network by playing the role of intermediaries or mediators (Chang-Hyun Kang, 2001).

Table 3 shows the results of betweenness centrality analysis of influencing factors of the future energy sector. Centrality, or the level of centralization, was found to be 0.54%, indicating that the level of betweenness centrality is very weak.

Betweenness centrality analysis of the influencing factors of the future energy sector showed ‘change

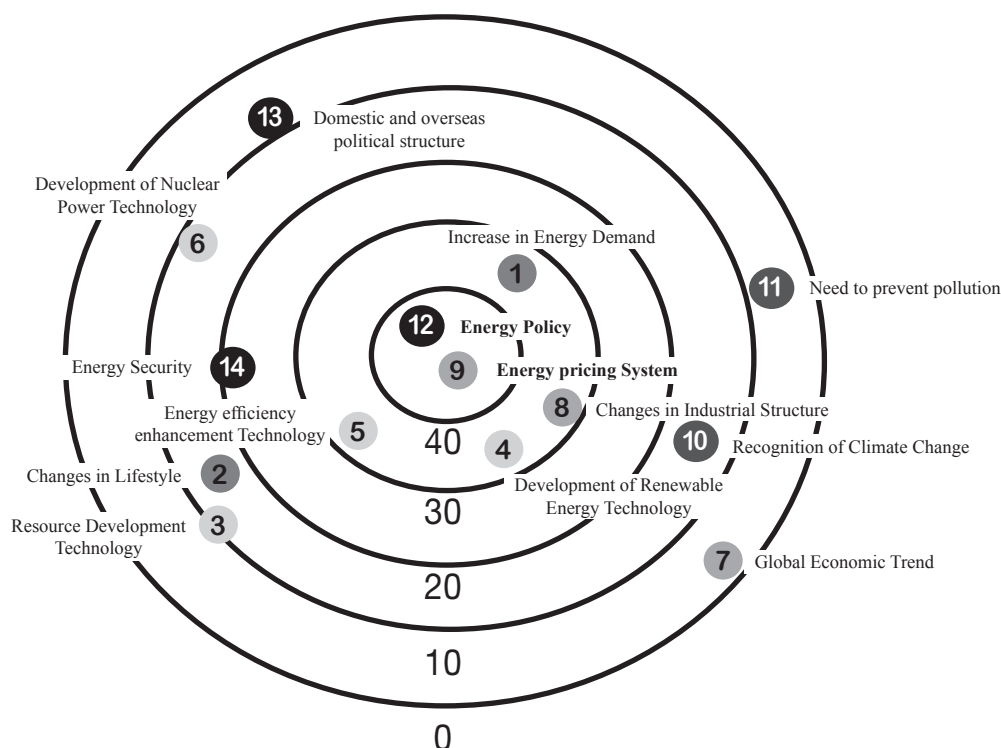


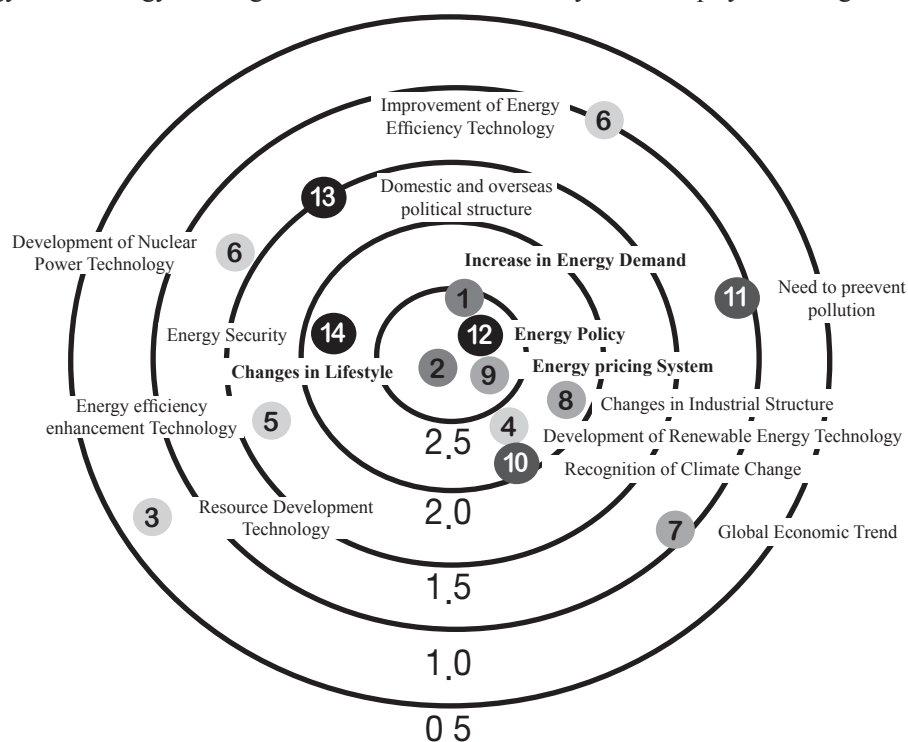
Figure 3 Indegree centrality of the future energy sector factor network

Table 3 Betweenness centrality of the influencing factors of the future energy sector

	Factor	Betweenness	nBetweenness
2	Change in lifestyle	2.707	1.735
12	Energy policy	2.581	1.654
1	Increase in energy demand	2.556	1.638
9	Energy pricing system	2.508	1.607
4	Development of renewable energy technology	2.385	1.529
8	Change in industrial structure	2.371	1.520
14	Energy security	2.129	1.364
10	Increase in awareness of seriousness of climate change	2.079	1.333
5	Energy efficiency enhancement technology	1.683	1.079
13	Domestic/overseas political structure	1.544	0.990
6	Development of nuclear power technology	1.462	0.937
11	Need to prevent pollution	1.115	0.715
7	Global economic trend	1.083	0.694
3	Resource development technology	0.797	0.511

in lifestyle' to have the highest level of betweenness centrality. This means that 'change in lifestyle' plays the role of an intermediary between other factors. The ranking of betweenness centrality following change in lifestyle was energy policy→increase in energy demand→energy pricing system→development of renewable energy technology→change in industrial

structure→energy security→increase in awareness of seriousness of climate change→energy efficiency enhancement technology→domestic/overseas political structure→development of nuclear power technology→need to prevent pollution→global economic trend→resource development technology. The results of the analysis are displayed in diagram in Figure 4.

**Figure 4** Betweenness centrality of the future energy sector factor network

3.2 Deduction of key uncertainty factors

This chapter will focus on deducing key uncertainty factors required for creating future energy sector scenarios by establishing axes of uncertainty.

Key uncertainty factors can be defined as exogenous environment variables in future energy sector foresight that possess high levels of uncertainty within a predictable range and have relatively high influence on policy-making. The level of uncertainty in influencing factors of the future energy sector was analyzed from the time perspective of 'speed of change' and the environmental perspective of 'diversity of stakeholders,' while the level of uncertainty was analyzed from the perspectives of contribution to efficiency and indirect impact such as the impact on other industries, employment, and training. Through such analyses, profiles of the level of influence and uncertainty of influencing factors were created and key uncertainty factors were identified.

In order to collect data, a structured questionnaire

based on the influencing factors of the future energy sector was prepared and presented to energy sector-related academic experts and researchers during the period from September 20, 2009 to October 20, 2009. The survey's target group totaled 80 people, and analysis of the demographic characteristics of the group showed 80.0% of the respondents to be male and 55.0% of respondents to be in their 30s. In terms of level of education, 56.3% of the respondents had at least a doctorate degree, while 71.3% of the respondents worked in research institutes and 65.0% were researchers. With regard to career experience, 56.3% replied that they had less than ten years of experience.

Comparative analysis of the average value for each dimension was carried out, and the results were put together with the level of uncertainty and influence as axes to identify the relative position of each factor. Table 4 shows the average value for the level of uncertainty and influence of each factor.

Analysis of average values showed 'global economic

Table 4 Analysis on level of uncertainty and influence of factors that influence the future energy sector

Factor	Average*		Percentage (%)	
	Uncertainty	Influence	Uncertainty	Influence
Increase in energy demand	3.55	3.49	71.00	69.75
Change in lifestyle	3.26	3.13	65.25	62.63
Resource development technology	2.98	3.19	59.63	63.80
Development of renewable energy technology	3.48	3.75	69.63	74.94
Energy efficiency enhancement technology	3.28	3.91	65.63	78.23
Development of nuclear power technology	3.23	3.13	64.63	62.66
Global economic trend	4.04	3.49	80.75	69.88
Change in industrial structure	3.64	3.71	72.75	74.13
Energy pricing system	3.68	3.56	73.50	71.25
Increase in awareness of seriousness of climate change	3.64	3.37	72.88	67.34
Need to prevent pollution	3.16	2.79	63.25	55.75
Energy policy	3.43	3.80	68.63	76.08
Domestic/overseas political structure	3.28	2.73	65.50	54.63
Energy security	3.59	3.14	71.75	62.75

* Out of a full score of 5

Source: calculated by comparison of the average of each dimension

trend' to be the factor with the highest level of uncertainty and 'resource development technology' to be that with the lowest level of uncertainty. Meanwhile, the factor with the highest level of influence was 'energy efficiency enhancement technology,' while that with the lowest level of influence was 'domestic/overseas political structure.' Based on the author's experience, it seems correct to regard the factors showing low influence as areas that require more assistance from the government in the course of its execution of strategies for building a sustainable future energy society rather than as factors that are of less importance.

The created uncertainty and influence level variables were mapped and analyzed for similarities in terms of types of uncertainty and influence. Figure 5 is a two-dimensional diagram showing the relative positions of the 14 factors based on level of uncertainty and influence.

As seen in Figure 5, 'energy pricing system' and 'change in industrial structure' were found to have relatively

higher levels of uncertainty and influence than other factors. On the other hand, 'need to prevent pollution' and 'domestic/overseas political structure' were found to have relatively lower levels of uncertainty and influence.

Finally, the 14 factors that influence the future energy sector were categorized according to their level of uncertainty and influence: Factors that have low levels of uncertainty and high levels of influence were designated as predetermined factors while factors that have both high levels of uncertainty and influence were marked as key uncertainty factors.

In scenario planning, factors designated as key uncertainty factors because they bring great changes in the scenario according to their direction of progression, tend to function as markers that separate one scenario from another.

In addition, predetermined factors, because their influence is strong regardless of the type of situation that might arise in the future, can belong in all

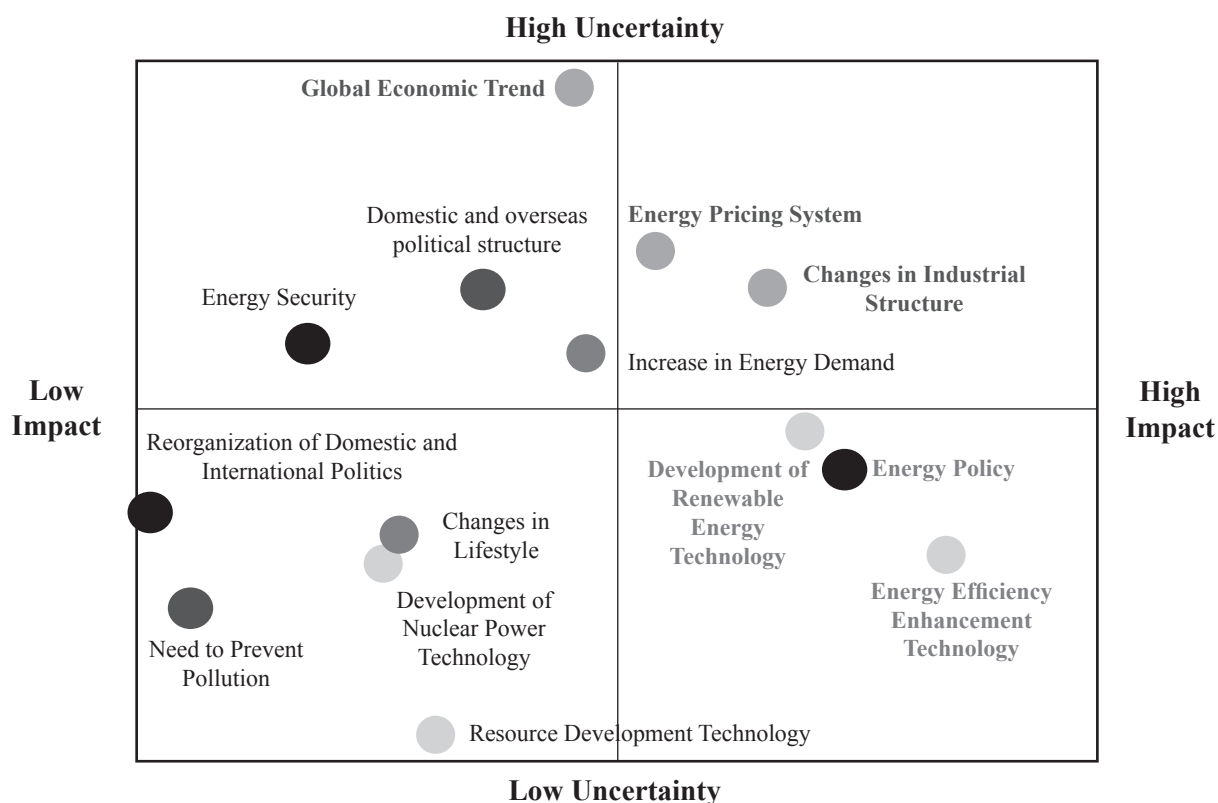


Figure 5 Relative position of factors that influence the future energy sector based on level of uncertainty and influence

Table 5 Influence vs. uncertainty of factors that influence the future energy sector

		Uncertainty		
		Low	Intermediate	High
Influence	High	4. Development of renewable energy technology 5. Energy efficiency enhancement technology 12. Energy policy (Predetermined factor)		8. Change in industrial structure 9. Energy pricing system (Key uncertainty factor)
	Intermediate		1. Increase in energy demand	7. Global economic trend (Key uncertainty factor)
	Low	2. Change in lifestyle 3. Resource development technology 6. Development of nuclear power technology 11. Need to prevent pollution 13. Domestic/overseas political structure	10. Increase in awareness of seriousness of climate change 14. Energy security	

possible scenarios.

Table 5 shows the designated key uncertainty factors and predetermined factors.

As it can be seen in the above table, ‘global economic trend,’ ‘change in industrial structure,’ and ‘energy pricing system’ can be designated as key uncertainty factors, while ‘development of renewable energy technology,’ ‘energy efficiency enhancement technology,’ and ‘energy policy’ can be designated as predetermined factors.

4. Strategies deduced through strategic scenario planning

4.1 Scenario planning through establishment of axes of uncertainty

Scenario planning is a tool for assessing plausible future situations in the form of a select combination of events (Van der Heijden, 1996). Scenarios should not be vague predictions for justifying actions that are already being taken, but rather situations that are equally possible of becoming reality in the future.

From this perspective, based on the results of

Table 5, the three key uncertainty factors of ‘global economic trend,’ ‘change in industrial structure,’ and ‘energy pricing system’ were identified as the axes of uncertainty on which each scenario was constructed with two possibilities for each axis, as shown in Table 6.

However, when there are three or more uncertainty axes, the number of possible scenarios created based on each possibility becomes at least eight, as shown in Table 7, and this is too many. Therefore, it is necessary to discard those scenarios that are logically inconsistent. While it is generally appropriate to prepare somewhere in the area of three scenarios, regardless of how many scenarios are used, they must be able to provide strategies or implications useful to decision-making.

Table 6 Two possibilities for the three axes of uncertainty

Axes of uncertainty	Possibility	
	+	-
Energy pricing system	Decrease	Increase
Change in industrial structure	Success	Failure
Global economic trend	Growth	Recession

Table 7 Eight scenarios based on three uncertainty factors

Scenario	Axes of uncertainty		
	Energy pricing system	Change in industrial structure	Global economic trend
1 (Scenario A: Optimistic)	+ (Decrease)	+ (Success)	+ (Growth)
2	+	+	- (Recession)
3	+	- (Failure)	+
4	+	- (Failure)	- (Recession)
5	- (Increase)	+	+
6 (Scenario B: Business as usual)	- (Increase)	+ (Success)	- (Recession)
7	- (Increase)	- (Failure)	+
8 (Scenario C: Pessimistic)	- (Increase)	- (Failure)	- (Recession)

Of the eight possible scenarios, this study, as shown in Table 7, through discussion with the Energy Sector Future Foresight Committee, selected two extreme scenarios (Optimistic, Pessimistic) and one status quo scenario (Business as usual) to represent all the possible situations that can occur in the future.

Next, the stories for each scenario were created based on the axes of uncertainty, with each scenario remaining different from the other. Scenario stories must be must written out as if the situation is actually occurring at a point in time in the future in order to give the reader a sense of plausibility. In writing out the scenario stories, this study utilized information gathered through analysis of the priority and connectivity of the future energy sector factors.

Table 8 Comparison of scenarios for the future energy sector

Scenario A (Optimistic)	
Title	A Future as Bright as the Sun
Details	Korea becomes energy independent thanks to its development of energy-efficient technology in line with economic growth and transforms into a developed nation
Signs	<ul style="list-style-type: none"> • Korea recovers from the recession faster than other countries and maintains high economic growth based on its superiority in the automobile, heavy industries, electronics, and IT sectors • Energy policies based on better public awareness toward the environment and development of energy efficient technology in key industries based on abundant capital create a virtuous cycle • The country continues growth through creation of energy-related new markets and industries based on high technical barriers and achieves energy independence • Korea becomes an energy powerhouse and joins the ranks of the developed nations
Opportunity	Drop in production costs, increase in exports, economic growth, development of energy-efficient technology, securing of international status, change in lifestyle due to better environment/energy awareness
Threat	Tougher pressure from competing nations (environmental regulations, trade barriers, nuclear regulations, etc.)
Scenario B (Business as usual)	
Title	Patience and Effort for a Better Future
Details	Despite a recession and rising energy pricing systems, Korea maintains its current status through development of energy-efficient technology and good handling of industrial structure reorganization
Signs	<ul style="list-style-type: none"> • Korea falls into recession as the global economy falls into a long-term recession following a temporary recovery • As the drop in exports leads to contraction of the domestic market, companies experience difficulties and execute mass layoffs and restructuring • Energy demand falls due to the recession, but rising oil prices lead to better public awareness toward energy efficiency and the environment • Demand for energy-efficient products increases due to rising oil prices, and companies invest more in enhancing energy efficiency, triggering a shift toward a low energy consumption industrial structure • Current status is maintained even despite an economic crisis thanks to good response to rising energy pricing systems
Opportunity	Securing of energy efficiency enhancement technology, slight drop in dependence on overseas energy
Threat	Slight increase in production costs, decrease in exports

Table 8 Comparison of scenarios for the future energy sector (cont'd)

Scenario C (Pessimistic)	
Title	The Sky Is Clear but the Future Is Gloomy
Details	The economy collapses as the country is unable to invest in energy efficiency due to a recession and spike in energy pricing systems and it fails to change its industrial structure
Signs	<ul style="list-style-type: none"> As the global economy falls into a prolonged recession, the export-driven Korean economy is hit hard and companies see profits diminish As the emergence of BRIC nations and international conflicts related to resource nationalism affect the energy supply/demand system, energy pricing systems spike despite the recession Rapid decrease in incomes of companies and the public hamper investment in energy-efficient technology and execution of related policies and leads to failure to change the country's industrial structure Due to the failure to continuously develop energy-efficient technology, government policy shifts to direct regulation of the energy market The Korean economy collapses from its loss of a profit structure
Opportunity factors	Less pressure from competing nations (environmental regulations, trade barriers, nuclear regulations, etc.)
Threat factors	Drop in exports, recession, increase in production costs, drop in international status, more dependence on overseas energy

Due to space limitations, the stereotyped events that occur in the system based on changes in the uncertainty factors that influence the future energy sector are provided in Table 8 with information such as title, details, signs, opportunity factors, and threat factors.

4.2 Common strategies and strategies to avoid maximum risk

In this chapter, this study will seek to establish a variety of strategies from the scenarios, and through analysis of relative priority, deduce common strategies and strategies for avoiding maximum risk. Common strategies are strategies that can be applied to all three scenarios. Strategies for avoiding maximum risk are strategies for scenario C, which is the worst-case scenario for the country.

Table 9 presents various strategies for the three scenarios confirmed through discussion with the Energy Sector Future Foresight Committee. These strategies consist of four macroscopic strategies and ten lower-level strategies.

Next, the relative priority of the strategies was deduced through an AHP survey in which the Energy Sector Future Foresight Committee participated. Of the total of 23 reply sets, three were deemed unsuitable to be used as data, and 20 were used for the analysis.

4.2.1 Analysis of priority of common strategies

a. Results of analysis of levels 1 and 2

Analysis of common strategies was done on the level 1 strategies 'supporting industry,' 'developing technology,' 'managing demand,' and 'international cooperation,' the results of which are shown in Table 9, followed by analysis of the priority of lower-level strategies in level 2. The results of the analyses of levels 1 and 2 are shown in Table 10.

Table 10 Priority of level 1 and level 2 common strategies

level 1 strategy	level 1 priority	level 1 ranking	level 2 strategy	level 2 priority	level 2 ranking
Supporting industry	0.36638	2	Encouraging change in industrial structure	0.59518	1
			Strengthening energy competitiveness of existing industries	0.40482	2
Developing technology	0.38466	1	Securing core/source technology	0.58770	1
			Increasing clean use of fossil fuel and nuclear energy	0.21741	2
			Balancing investment in energy efficiency technology development	0.19489	3
Managing demand	0.16446	3	Encouraging voluntary participation	0.23509	3
			Raising awareness of energy efficiency	0.37563	2
			Strong state energy demand management	0.38928	1
International cooperation	0.08451	4	Strengthening national status	0.25875	2
			Strengthening resource diplomacy	0.74125	1

Table 9 Strategies deduced from scenarios

level 1	level 2	level 3
Supporting industry	Encouraging change in industrial structure	Supporting technology transfer and industrialization
		Fostering parts industry
		Introducing energy efficiency certification and grading systems
		Introducing incentives for energy-efficient products and industries
		Facilitating exports
	Strengthening energy competitiveness of existing industries	Providing financial/tax support to strengthen competitiveness and increase marketing
		Encouraging consortiums between companies and research institutes for joint research
		Establishing energy efficiency policy roadmap
		Reshuffling governance structure for improving energy efficiency
		Facilitating development of energy-conserving products and technology
Developing technology	Securing core/source technology	Increasing government support for R&D budget/facilities
		Fostering talent (training)
		Strengthening basic/source technology research and seeking technology convergence
		Establishing energy efficiency enhancement technology roadmap
		Establishing research bases
	Increasing clean use of fossil fuel and nuclear energy	Clean coal
		Developing carbon capturing and storage technology
		Increasing nuclear power generation
	Balancing investment in energy efficiency technology development	Establishing strategic technology development policies
		Reconsidering investment priorities
Managing Demand	Encouraging voluntary participation	Developing energy recycling and collecting technology
		Creating energy-efficient lifestyle
		Innovating energy consumption system
	Raising awareness of energy efficiency	Supporting NGOs and civic groups
		Providing incentives for energy conservation/carbon emission reduction
		Eco-friendly energy education and PR
	Strong state energy demand management	Innovating supply management in each sector (industrial buildings, transportation, electricity, etc.)
		Turning energy conservation into a part of life and a social norm through regulation and incentives
		Introducing top-runner system for energy efficiency
		Establishing price system that considers social equity
International cooperation	Strengthening national status	Establishing national energy supply/demand management system
		Developing energy diplomacy capacity
		International system for cooperation (identifying countries where demand for energy efficiency enhancement is high)
	Strengthening resource diplomacy	Supporting global climate change strategies and policies
		Engaging in joint resource research, exploration, and development with resource-rich nations and entering new markets such as Africa
		Establishing foundation for entering overseas markets and strengthening PR activities

In the analysis of level 1 strategies, ‘developing technology’ was found to have the highest priority, followed by ‘supporting industry’ and ‘managing demand.’ The positioning of ‘developing technology’ at top ranking reflects consensus among respondents that development of energy efficiency enhancement technology is key to future government policies for the energy sector. The CR value for the analysis of level 1 strategies was 0.00405, indicating that the replies of the survey respondents are reliable.

In the analysis of the level 2 strategies, first, analysis of lower-level strategies for ‘developing technology’ revealed ‘encouraging change in the industrial structure’ as having priority over ‘strengthening the energy competitiveness of existing industries.’ This result reflects the consensus of respondents that it is more efficient to shift the direction of future government policies from strengthening the energy competitiveness of existing industries to seeking transformation into a low-energy-consumption industry structure.

Second, analysis of the lower-level strategies for ‘developing technology’ revealed ‘securing core/source technology’ as having higher priority over other factors. This result shows that securing core and source technology is vital to becoming an energy powerhouse.

The CR value for the analysis of the 2nd stage was 0.00508, indicating that the replies of the survey respondents are reliable.

Third, in the analysis of lower-level strategies for ‘managing demand,’ while individual factors did not display much difference in priority, ‘strong state energy demand management’ and ‘raising awareness of energy efficiency’ exhibited higher priority than others. The CR value for the analysis of ‘managing demand’ was 0.01350, indicating that the replies of the survey respondents are reliable.

Fourth, analysis of lower-level strategies for ‘international cooperation’ showed ‘strengthening resource diplomacy’ having greater priority over ‘strengthening international status.’

b. Result of integrated analysis of levels 1 and 2

Table 11 shows the results of integrated analysis of level 1 and level 2 common strategies. Integrated

Table 11 Integrated analysis of level 1 and level 2 common strategies

Strategy	Priority	Ranking
Encouraging change in industrial structure	0.21806	2
Strengthening energy competitiveness of existing industries	0.14832	3
Securing core/source technology	0.22606	1
Increasing clean use of fossil fuel and nuclear energy	0.08363	4
Balancing investment in energy efficiency technology development	0.07496	5
Encouraging voluntary participation	0.03866	9
Raising awareness of energy efficiency	0.06178	8
Strong state energy demand management	0.06402	6
Strengthening national status	0.02187	10
Strengthening resource diplomacy	0.06264	7

analysis assesses overall priority.

The results of integrated analysis show ‘securing core/source technology’ to have the highest priority, followed in order of higher priority by ‘encouraging change in industrial structure,’ ‘strengthening energy competitiveness of existing industries,’ and ‘increasing clean use of fossil fuel and nuclear energy’. In addition, it can be observed that lower-level strategies under ‘supporting industry’ and ‘developing technology’ in the analysis of level 1 strategies are also shown as priority strategies in the integrated analysis of level 1 and level 2 strategies.

Based on the above results, ‘securing core/source technology’ and ‘encouraging change in the industrial structure’ can be deduced as strategies that can be commonly applied to all three scenarios for the future energy sector.

4.2.2 Analysis of priority of strategies for avoiding maximum risk

a. Results of analysis of levels 1 and 2

Analysis of strategies for avoiding maximum risk was done on the level 1 strategies ‘supporting industry,’ ‘developing technology,’ ‘managing demand,’ and ‘international cooperation’ with the results shown in Table 9, followed by analysis of the priority lower-

Table 12 Result of analysis of level 1 and level 2 strategies for avoiding maximum risk

level 1 strategy	level 1 priority	level 1 ranking	level 2 strategy	level 2 priority	level 2 ranking
Supporting industry	0.47300	1	Encouraging change in industrial structure	0.65921	1
			Strengthening energy competitiveness of existing industries	0.34079	2
Developing technology	0.21275	2	Securing core/source technology	0.47222	1
			Increasing clean use of fossil fuel and nuclear energy	0.31925	2
			Balancing investment in energy efficiency technology development	0.20853	3
Managing demand	0.2005	3	Encouraging voluntary participation	0.11548	3
			Raising awareness of energy efficiency	0.26609	2
			Strong state energy demand management	0.61843	1
International cooperation	0.11410	4	Strengthening national status	0.18671	2
			Strengthening resource diplomacy	0.81329	1

level strategies in level 2. The results of the analyses of levels 1 and 2 are shown in Table 12.

In the analysis of level 1 strategies, ‘supporting industry’ was found to have a far greater priority than other strategies, followed by ‘developing technology’ ranked second by a small margin over ‘managing demand.’ The CR value for the analysis of level 1 strategies was 0.00661, indicating that the replies of the respondents are reliable. In addition, the importance of ‘supporting industry’ and ‘managing demand’ was much higher than in the case of common strategies, while the importance of ‘developing technology’ was lower, indicating that ‘supporting industry’ and ‘managing demand’ become relatively more important in a maximum risk-situation.

In the analysis of the level 2 strategies, first, analysis of lower-level strategies for ‘developing industry’ revealed ‘encouraging change in the industrial structure’ to have far greater priority over ‘strengthening the energy competitiveness of existing industries,’ indicating that fundamental strategies such as ‘encouraging change in the industrial structure’ are necessary even under difficult situations. In addition, although similar to the analysis of common strategies, the priority of ‘encouraging change in the industrial structure’ is

slightly higher.

Second, analysis of lower-level strategies for ‘developing technology’ revealed ‘securing core/source technology’ to have the highest priority, followed by ‘increasing clean use of fossil fuel and nuclear energy.’ The CR value of the analysis of ‘developing technology’ was 0.03718, indicating that the replies of the survey respondents are reliable. In addition, the priority of ‘securing core/source technology’ was found to be lower and ‘increasing clean use of fossil fuel and nuclear energy’ higher than in the analysis of common strategies, implying the need to exert efforts to use existing resources and energy sources more effectively.

Third, in the analysis of lower-level strategies for ‘managing demand,’ ‘strong state energy demand management’ was found to have far greater priority over ‘raising awareness of energy efficiency’ and ‘encouraging voluntary participation,’ showing that state management of energy demand based on a degree of enforcement is more necessary than voluntary participation. The CR value for the analysis of ‘managing demand’ was 0.02953, indicating that the replies of the survey respondents are reliable. In addition, it can be observed that while ‘raising awareness of energy efficiency’ and ‘strong state energy management’ show similar levels of priority among common strategies, the priority of ‘strong state energy management’ increases greatly in the event of a maximum risk situation.

Fourth, analysis of lower-level strategies for ‘international cooperation’ showed ‘strengthening resource diplomacy’ having greater priority over ‘strengthening international status,’ just as in the analysis of common strategies. This shows that despite changes in surrounding conditions and considering Korea’s resource situation, engaging in practical diplomacy by strengthening resource diplomacy is more important than seeking international status as an energy powerhouse.

b. Result of integrated analysis of levels 1 and 2

Table 13 shows the results of integrated analysis of level 1 and level 2 strategies for avoiding maximum risk. Integrated analysis assesses overall priority.

Table 13 Integrated analysis of level 1 and level 2 strategies for avoiding maximum risk

Strategy	Scenario C: Pessimistic	
	Priority	Ranking
Encouraging change in industrial structure	0.31181	1
Strengthening energy competitiveness of existing industries	0.16120	2
Securing core/source technology	0.10047	4
Increasing clean use of fossil fuel and nuclear energy	0.06792	6
Balancing investment in energy efficiency technology development	0.04437	8
Encouraging voluntary participation	0.02311	9
Raising awareness of energy efficiency	0.05326	7
Strong state energy demand management	0.12378	3
Strengthening national status	0.02130	10
Strengthening resource diplomacy	0.09280	5

The results of integrated analysis show ‘encouraging change in industrial structure’ as the most important strategy for avoiding maximum risk by a high margin. ‘Strengthening the energy competitiveness of existing industries’ and ‘strong state energy demand management’ ranked second and third respectively, showing the need for the stronger energy competitiveness of existing industries and state management of energy demand as energy-related risks increase.

Meanwhile, ‘securing core/source technology’ and ‘strengthening resource diplomacy’ ranked fourth and fifth respectively, confirming the need for omni-directional strategies covering industrial support, technology development, demand management, and international cooperation.

5. Conclusions

This study, through scenario-based strategic future foresight, conducted a qualitative analysis of Korea’s future energy sector in 2030. Based on STEEP analysis and network analysis, this study defined environmental uncertainty factors that influence the future energy sector from a multi-dimensional perspective in the areas of politics, economy, society, environment, and

technology, and deduced key uncertainty factors from those factors. This study also confirmed that ‘global economic trend,’ ‘change in industrial structure,’ and ‘energy pricing system’ are the key uncertainty factors of the future energy sector.

Next, by utilizing scenario planning, this study produced scenarios for the year 2030 based on the key uncertainty factors that were deduced. Scenario A (Optimistic) is the most desired scenario in which energy pricing systems fall, the global economy grows, and Korea successfully transforms into a low-energy consuming nation. It is a scenario that all other countries desire as well. Scenario B (Business as usual) is the case in which Korea succeeds in changing its industrial structure, but energy pricing systems rise and the global economy falls into recession. In this scenario, energy pricing systems rise due to a spike in fossil fuel prices and the global economy sinks into recession. Scenario C (Pessimistic) is the worst case scenario in which energy pricing systems rise, Korea fails to change its industrial structure, and the global economy falls into recession. In this scenario, the global economy sinks into recession as energy pricing systems rise due to a spike in fossil fuel prices and Korea fails to transform into a low-energy consuming nation.

Meanwhile, this study also presents strategies for each scenario that the government must urgently implement, as well as their order of priority, through supplementary use of hierarchical analysis. The results of this analysis show that developing core/source technology for achieving energy efficiency to be a common strategy for all three scenarios that should be given top priority in government policies and that Korea is in urgent need of transforming its industrial structure into one that consumes less energy.

This study suggests that realizing strong state-level management of energy demand, raising awareness in energy efficiency, and strengthening resource diplomacy should also be designated as key policy goals.

In addition, as energy-related risks increase, fundamental strategies such as seeking change in industrial structure are required as strategies for avoiding maximum risk, while support for industries and strong state-level management of energy demand

are also important.

Such strategies should be executed alongside the resource diplomacy and omni-directional energy strategies that require international cooperation.

Finally, in order to facilitate the use of the findings of this study and to reinforce their validity, it will be necessary for future studies to conduct policy verification through analysis of the differences between or among the three scenarios that are deduced by applying different input variables. It will also be necessary to conduct research on promising future energy technologies. It is the wish of the authors that the results of this study be discussed among participants in the policy-making process and thus contribute to establishing effective policies for Korea's future energy sector.

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