The Conceptual Approach to Social Science Research for Preparing for Uncertain Nuclear Safety and Regulatory Environments: Focusing on Scenario Planning

Heeyeong Chung, Youngeal Lee, Minjeong Byeon
Korea Institute of Nuclear Safety, 62 Gwahak-ro, Yuseong-gu, Daejeon 34142, Republic of Korea
**Corresponding author: s163chy@kins.re.kr*

1. Introduction

Nuclear energy has been considered an alternative that can partly substitute for fossil fuels and bridge the system of supply and demand for new and renewable energy. Especially since the Kori unit 1 plant began producing electricity in 1978, nuclear energy in South Korea has played an important role as a stable, economical, and environmentally friendly energy resource. In particular, the role of nuclear energy can be explained by the journey of nuclear energy policy in South Korea. The decision-making process of nuclear energy policy has developed gradually though the policy stance and direction, depending on each administration, is slightly different.

However, since the Moon Jae-in administration was established in 2017, the uncertainty and complexity concerning the nuclear energy policy decision-making process have been expected to increase. In contrast with the previous administrations, the Moon administration claims to advocate nuclear-free policy, and a state commission has been launched to gauge public opinions on whether we proceed to construct the Shin-Kori unit 5 and Shin-Kori unit 6 reactors. In this situation, this study aims to introduce the methodology that can anticipate and explain possible, probable, and preferable futures and worldviews, to prepare for uncertain and complicated circumstances. In particular, by using "scenario planning" among different future studies, this study tries to prepare for a rational decision-making process of international cooperation in terms of nuclear safety and regulation. This could support the necessity of social science research in resolving nuclear energy policy problems.

2. Paradigm Shift

A number of factors affect the nuclear energy policy decision-making process, and these can be divided by environmental context or institutional context. The environmental context includes external and internal environmental factors; the institutional context includes a paradigm of policy, decision-making structure, and laws and regulations [1]. These factors emerge from the social, technological, economic, ecological, and political environments, leading to influence on the nuclear energy policy decision-making process.

In particular, nuclear and radiation accidents and incidents could be the external environmental factors. The follow-up measures that every country has conducted after the Fukushima Daiichi accident in 2011 clearly shows that each country has different policy stance on nuclear energy. For example, some nuclear operating countries, including Germany, Switzerland, France, and Belgium, have decided on the gradual closure of nuclear power plants and additional investment in new and renewable energy sources as a substitute for nuclear energy; other countries, such as China, Russia, Japan, and the United States, have decided that they will continue to operate nuclear power plants. For countries embarking on the use of nuclear power, some have decided to introduce nuclear power plants as planned, while others have changed their plans [2]. Also, some domestic incidents, such as INES level 2 incidents in 1994, 2010, and 2012, respectively, and a scandal involving falsified safety tests of nuclear equipment, could have been the important internal environmental factors that have affected the nation's nuclear energy policy.

For the institutional context, the policy decision-making structure could be a typical example to show the paradigm shift in nuclear energy policy in South Korea. For example, during a dictatorial regime, the decision of nuclear energy policy was subject to a president and technocrat. That could be why the construction of nuclear power plants had smoothly proceeded without intense pushback from environmental groups and local residents despite the occurrence of nuclear accidents during that time, such as TMI accident in 1979 and Chernobyl disaster in 1986 [2].

However, since the 1990s, when the political system changed from tyranny to democracy, it has become necessary to consider various factors affecting the decision-making process of nuclear energy policy. Stakeholders can now voice their opinions freely [1]. That is, with the advent of civil society, uncertainty and complexity in decisions related to nuclear energy policy have increased.

In line with these environmental and institutional contexts, strengthening nuclear safety and nuclear regulation has become a core agenda worldwide. For example, Nuclear Safety and Security Commission (NSSC), the independent regulatory body in charge of nuclear regulation, has been established in 2011; it was established 50 years after the nuclear power was introduced to South Korea in early 1960s. Also, the Moon Jae-in administration is advocating nuclear-free policy; the Kori unit 1 reactor, the oldest reactor in South Korea, was permanently shut down, and all plans to build more nuclear power plants were scrapped.

In brief, there seems to be a clear paradigm shift in nuclear energy policy in a direction of strengthening

safety and regulation, and the uncertainty of nuclear safety and regulatory environments is expected to increase during this period of transition. Hence, this study focuses on the methodology that can anticipate and explain possible, probable futures, to prepare for uncertain nuclear safety and regulatory environments. In the following sections, the definition, procedure, and case application of scenario planning will be discussed.

3. Methodology

3.1. Definition of Scenario Planning

A "scenario" is a script for movie. In company management, however, a scenario can be the strategic plans that anticipate and explain possible and probable futures within uncertainty. In particular, scenario planning is a process that envisions scenarios by using uncertain but influential factors that can explain futures; it then establishes strategies for meaningful scenarios. Scenario planning is thus an appropriate, useful tool in dealing with uncertain future situations. Hence, it is widely used for business management strategies or national future strategies [3].

3.2. Procedure of Scenario Planning

With regard to the procedure of scenario planning, the overall process and method are set, though the methods applied in each phase may be somewhat different. The five phases are: (1) grasping core issues; (2) grasping change enablers; (3) outlining scenarios; (4) writing scenarios; and (5) establishing strategies [3].

(1) *Grasping core issues*: a "core issue" is the most important, urgent problem an organization has, and it is also an ultimate assignment to be achieved by scenario planning; hence, the core issue should be clear, concerned with long-term problems [3].

(2) *Grasping change enablers*: a change enabler is an environmental factor or uncertainty that affects the future of the core issue. In order to comprehend change enablers, a method for extracting change enablers should first be determined. We can use various methods, depending on the core issue, including STEEP analysis, PEST analysis, 5 Forces Model, and others. Second, change enablers pertinent to the core issue should be explored by using the chosen method, to extract change enablers; a brainstorming session will be useful for identifying all possible change enablers. Last, a trend and uncertainty of each change enabler should be investigated to create an outline of scenarios. Also, double extreme points of each change enabler should be derived [3].

(3) *Outlining scenario*: with regard to outlining scenarios, both the assessment of change enablers and extracting "core" change enablers should be performed. First, the assessment of change enablers is based on two items: influence and uncertainty. Using the item of influence, we can assess how much each change enabler affects the core issue, and its importance in carrying out the core issue. Also, using the item of uncertainty, we can assess the degree of uncertain situations: that is, which direction the extreme points of each change enabler will move. Second, if a change enabler has a high level of influence and uncertainty, it will be considered a "core" change enabler, a main ingredient in outlining scenarios, while if a change enabler has a high level of influence but low level of uncertainty, then it would be considered an "extra" change enabler, a secondary ingredient to outline scenarios. In particular, the outline of each scenario depends on the combination of core change enablers. For example, if three change enablers are chosen, then eight different outlines of scenario would be extracted by the cube of two. Since not all may be significant and helpful in resolving the core issue, however, we can decide to select meaningful outlines of scenario [3].

(4) *Writing scenarios*: in this phase, we write a scenario based on the relationships between core and extra change enablers. One of the key points for writing scenarios is reflecting the causal relationships between change enablers, as much as possible. By doing so, we are more likely to obtain meaningful scenarios. In addition, there is no special form of scenario. Hence, writers craft scenarios in a form that readers can easily understand and sympathize with [3].

(5) *Establishing strategies*: in this phase, we establish strategies for meaningful scenarios. That is, we should consider a myriad of necessary counter-strategies if each scenario were realized. By doing so, we can devise a strategy map that a decision maker will use as a rational decision-making tool. Also, the strategy map can be used for preparing follow-up measures more systematically, which can contribute to enhancing the efficiency of decision making [3].

4. Case Study on Application of Scenario Planning

This study suggests the results of case application by using scenario planning. However, since it is an ongoing study, the results only up to phase 2, including setting a core issue and extracting change enablers pertinent to the core issue, are presented; the remaining phases will be conducted for future study.

(1) *Setting a core issue*: considering the current situation where a clear paradigm shift in nuclear energy policy occurs, which will have effect on the nuclear safety and regulation, the core issue set by this study is "the arrangement for rational decision-making process of international cooperation for nuclear safety and regulation."

(2) *Extracting change enabler*: this study uses STEEP analysis to extract change enablers. STEEP analysis aims to predict the uncertain future by examining a phenomenon through the realms of society, technology, economy, ecology, and politics. Table 1 shows the result of extracting change enablers by focusing on macro environmental factors that affect nuclear safety

and regulation, based on STEEP analysis; 18 change enablers were extracted as shown in Table 1 [1], [2], [4], [5].

Table 1: Change enablers of nuclear safety and regulatory environments

Field	Variable	Sub-variable
Society	*1. Nuclear and radiation accidents and incidents*	Three Mile Island accident in 1979, Chernobyl disaster in 1986, Fukushima Daiichi accident in 2011, INES level 2 domestic incidents in 1994, 2010, 2012, respectively, A scandal involving falsified safety tests of nuclear equipment, Safety problems of Wolsong nuclear power plants due to Gyeongju earthquake of 2016
	2. Regulation and safety paradigm	Expansion of safety culture, Stakeholder involvement for nuclear regulatory system, Communication to the public about nuclear safety, Regulatory competence directly connected with nation branding and public acceptability of nuclear energy, Intense pushback from environmental groups and local residents regarding operation and maintenance of nuclear power plants
	3. Preference for nuclear engineering related with change in perception of nuclear power	A lack of competence of human resources for nuclear engineering due to ageing workforce, A brain drain of experts involved in construction of reactors
	4. Change in demand for energy	An increase in power demand due to various reasons: (1) population growth; (2) advent of emerging economies; (3) improvement of living standard and development of health technology; (4) technological innovation and establishment of advanced infrastructure, A problem of energy self-sufficiency
Technology	*5. Development of nuclear technology*	R&D of small and medium sized reactors (SMR), Introduction of Gen-Ⅳ and development of fusion energy, Expansion of regulatory competence needs and improvement of regulatory competence, Continuous R&D of Probabilistic Safety Assessment (PSA), Applications of radiation science and technology
	6. Development of new and renewable energy	Production, supply, and utilization technology development of new and renewable energy, Limitations of using new and renewable energy in terms of its economic feasibility
	7. Expertise and peculiarity of the field of nuclear power	The gap between experts and the public caused by the complexity of nuclear technology, Invisible and long-term radioactive contamination
Economy	*8. Economic fluctuation*	Oil shock in 1970s
	9. Globalization of nuclear power and equipment market	Export of reactors to the UAE in 2009 deal, Export of research reactors to Jordan in 2010 and the transfer of the research reactors to Jordan in 2017
	10. Resource crisis	Energy security crisis, Weaponizing energy resources, Energy mix policy
	11. Uncertainty of nuclear industry	Economic feasibility of building nuclear power plants, A demand for public guarantees from private nuclear industry, Operators demanding rational, appropriate regulation based on economic feasibility of nuclear industry
	12. Development of nuclear industry	Expansion of nuclear power and equipment market, Construction of new nuclear power plants, Support of nuclear export, Uses of radiation and radioactive material in industry
	13. Electricity industry structure	High level of dependence of energy on overseas, Low energy efficiency, Distorted electricity pricing, Unstable supply and pricing of fossil fuels due to political and social turmoil in Middle East countries
Ecology	*14. Environmental crisis*	International pressure on reducing greenhouse gas emissions, The problem of fine dust pollution
Politics	*15. Moon Jae-in administration's nuclear-free policy*	The permanent shutdown of the Kori unit 1 reactor, Scrapping all plans to build more nuclear power plants, The prohibition of lifespan extension of ageing reactors, The review of spent fuel management, Enhancing seismic design criteria
	16. Political leadership and a sociopolitical approach to safety	For nuclear operating countries, different stances on nuclear energy policy: (1) gradual closure of reactors and investment in new and renewable energy; (2) suspension of nuclear energy policy; (3) operating nuclear power plants continuously, For countries embarking on the use of nuclear power, different

		stances on nuclear energy policy: (1) deciding to introduce nuclear power plants as planned; (2) changing their plans
	17. Nuclear safety & security plan	Establishment of Nuclear Safety and Security Commission (NSSC) and strengthening its independence, Revision of requirements and ordinance for nuclear safety, Nuclear security and nuclear nonproliferation, Establishing effective infrastructure for nuclear safety: (1) strengthening international cooperative research; (2) technical support for regulatory competence, Transparency and disclosure of nuclear safety information, Siting for Geological Disposal Facilities (GDF), Management of nuclear knowledge and safety competence, Computer security regulation, Budgetary control by nuclear safety regulation fund, Development of severe accident management guidelines, Human Resources Development in the field of nuclear safety and security
	18. Decision-making structure	The decision of nuclear energy policy subject to a president and technocrat especially during a dictatorial regime, The establishment of a state commission formed to gauge public opinion on the construction of the Shin-Kori unit 5 and Shin-Kori unit 6 reactors

5. Conclusion

Considering the current situations, the uncertainty and complexity involved in nuclear safety and regulatory environments are expected to increase. In particular, the Moon Jae-in administration is advocating nuclear-free policy while gathering public opinions on whether we should build the new reactors. On the other hand, the lessons learned from the Fukushima accident in 2011 has still been affecting the formation and implementation of nuclear energy policy, which will also lead to the formation and implementation of regulation of nuclear material and nuclear facilities. The afore-mentioned situations indicate that the nuclear energy policy, which can be referred to as science and technology, is closely connected with the society. Hence, social science research can benefit nuclear energy policy in a situation where there is an increase in uncertainty and complexity in decisions related to nuclear energy policy.

This study focuses on scenario planning, which could be a useful, appropriate social science method to prepare the uncertain future. Since it is an ongoing study and it has been conducted without the help of expert external consultants so far, there might be some limitations of this study; concerning the nature of scenario team participants, some scenarios are developed by an individual or combination of some key individuals from within the organization, while others are undertaken by expert external consultants [6]. However, since it is the ongoing study, it could be possible to develop study more while proceeding with the remaining procedures of scenario planning. Also, we could find the meaning of studying scenario planning as a "tool" for resolving uncertain and complex problems in the future.

REFERENCES

[1] Ju, Seongdon, A Study on the Change of the Nuclear Policy in Korea: Focusing on Historical Institution and Actor, Unpublished doctoral dissertation, Graduate School of Catholic University, Seoul, 2010.

[2] Kim, Myeongja, Nuclear Dilemma: The Future of Nuclear Renaissance, ScienceBooks, 2011.

[3] Lee, Yeongjong, Introduction to Scenario Planning Method through Postal Business Case, Postal Information Review, Vol. 2009, No. 3, 2009.

[4] Nuclear Safety and Security Commission, The 2nd Comprehensive National Nuclear Safety Plan, 2016

[5] Ministry of Science and ICT, Ministry of Trade, Industry and Energy, Ministry of Foreign Affairs, The 5th Comprehensive Nuclear Energy Promotion Plan, 2017.

[6] Bradfield, R., Wright, G., Burt, G., Cairns, G., & Van Der Heijden, K, The Origins and Evolution of Scenario Techniques in Long Range Business Planning, Futures, Vol.37, No.8, 2005.