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Analysis of the Social Acceptance in Electric Power Facility Siting

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Analysis of the Social Acceptance in Electric Power Facility Siting

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Abstract

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Long-term sustainable energy development needs to meet diverse conflicting concerns, such as ensuring affordability, minimizing environmental impacts, surmounting technical limitations, etc. Recently, both international and domestic changes of circumstances related to energy policy, such as increasing interest in greenhouse gas emission and social acceptance toward electric power facility siting, emphasize on the importance of incorporating environmental and social aspect of the electricity into the energy planning. Moreover, un-quantified subjective measures from the public regarding energy issues are becoming more important, so a policy maker should consider not only the technical and physical aspects but also the public's preference regarding certain energy issues.

Many energy issues are accompanied by social conflicts, such as local opposition toward electricity facility siting. This social acceptance problem has a critical impact on

the implementation of electricity planning. For example, if the construction of new power plant is delayed due to the strong local opposition, there will be the threat to the reliable energy supply and capital loss. In this regard, understanding the public's preference and the social acceptance regarding electric power facility siting has a significant policy implication for planning and implementing the socially appropriate energy policy measures.

A widely accepted definition of the social cost is the sum of the private cost and the external cost, and the external cost can be categorized into the environmental external cost and the non-environmental external cost. The private cost is the cost that a producer's measure in the market for his profit maximization, while the external cost is the cost that a producer doesn't count in his cost function, and society should take responsible for. The cost incurred by the local opposition can be regarded as the social cost of electricity, since it is not counted in the producer's cost. However, the majority of previous studies have only focused on the environmental external cost, and there are limited studies related to the cost of social acceptance for incorporating this into the social cost framework. Therefore, it is required to analyze the social acceptance regarding electric power facility siting quantitatively.

The purpose of this study is to estimate the cost of social acceptance regarding electric power facility siting. In order to analyze the public's preference for electric power facility siting and estimate it with a monetized term, the choice experience method is applied. From the modeling perspective, it is required to reflect the public's logical tree of decision making, the implicit relationship between energy sources, and the heterogeneity of preference for diverse impacts of electricity. In this regard, hierarchical bayesian mixed nested logit (HBNL) model is applied, which can reflect the individual's heterogeneity and cope with the restriction of the IIA assumption of multinomial logit. Considering the social acceptance problem in economic viewpoint, the empirical model is divided into the two different models: the General Public Model and the Local Residence Model. In addition, in order to reflect the real choice situation that people may consider not only the combination of each attributes but also the name of energy sources, different model specifications are proposed: the model with alternative specific constant (ASC) and without ASC (model 1). The ASC is treated differently in two sub-models such that one includes the category of energy sources; fossil fuel, nuclear, and renewable energy (model 2), and the other includes the specific name of energy sources; coal, gas, nuclear, wind, photovoltaic, and biomass (model 3).

The result of the empirical study applied by HBNL shows that this model is well-behaved in describing the public's preference regarding electric power facility siting of the specific energy sources. Based on the difference of result of relative preference order in the general public and the local residence, it is found that nuclear energy has strong 'not in my back yard (NIMBY)' phenomenon. In terms of heterogeneity, nuclear energy also shows the highest value of standard deviation, which refers to the strong heterogeneous preference among public for nuclear energy. The result of the social acceptance cost in electric power facility siting shows that nuclear energy has highest

value, while renewable energy shows relative low amount of the social acceptance cost.

In conclusion, this dissertation can provide the useful information for understanding the public's preference and social acceptance regarding electric power facility siting for different energy sources. Especially in the case that each stakeholder is sharply opposed to each other due to the different preference for energy sources, this result can be utilized for stakeholders to reach on the consensus and make a socially optimal decision in the energy planning. In addition, the quantitative and monetized value of the public's subjective risk can be utilized for deciding on the proper level of compensation to the local residents near the location of a power plant siting. Additionally, it is also concluded that HBNL model that has not been empirically applied yet can properly describe the public's preference regarding energy issues and can be applied to another related energy issues in the future.

Keywords: Social cost of electricity, Sustainability, Social acceptance, Hierarchical Bayesian Mixed Nested Logit Model

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Chapter 1. Introduction

1.1 Research Background

Adequate and affordable energy supplies are a key factor to economic development. In line with the increasing global energy demand from emerging economies and rapidly growing developing countries, the energy sector has undergone a significant change due to several driving forces both internationally and domestically. Internationally, the global regulation of greenhouse gas (GHG) emission has strengthened in accordance with the adoption of the Kyoto Protocol in 1997. Accordingly, the domestic burden of CO_2 emission reduction has intensified. Furthermore, the continuing high oil prices and the deepening of the energy nationalism have appeared as a major threat in terms of securing a reliable energy supply. Domestically, the continuous instability of the electric power supply and recent issues related to nuclear power, such as the counterfeit of authentication documents of componentry, has amplified the social concerns regarding energy issues. In particular, the expansion of energy facilities has been facing strong local opposition so that a reliable energy supply cannot be guaranteed in the near future. Consequently, the importance of the environmental and social aspects of energy policy is increasing, and there is a need to reflect these issues in energy planning.

The electric power sector enters the spotlight as one of fastest growing energy sources in final energy consumption in Korea over last 30 years, and electricity accounts for approximately 20% of final energy consumption as of 2011. Electric power sector is also regarded as main causes of increased CO_2 emission in Korea, so that the role of electricity in energy mix as well as in GHG emission reduction becomes critical. An electric power system is a type of utility that supports a nation's economy and the public's quality of life. Its characteristics are: (1) once decided, it cannot be changed over a significant amount of time, more than 20 years, and the decision leads to changes in the industry structure; (2) as a public good, the benefits and costs caused by the decision lie with the general public; and (3) social, economic, and technical values affect the energy decision, so electricity planning involves a high degree of uncertainty. In this manner, some label an electric power system as a socio-technical system into which the technical aspects, market dynamics, industrial structure, and social values are organically integrated (Geels, 2002; Geels et al., 2004).

The decision on the electric power system depends fundamentally on the choice of the energy source. In the case of fossil or nuclear fuel, which is called a centralized electricity generation system, a large-scale power plant should be installed near the seashore, and a long-distance transmission and distribution (T&D) line is required to transmit the electricity to the end-users in cities. On the other hand, renewable energy, such as wind and photovoltaic (PV), only requires a regional distribution line, so it is referred to as a distributed generated power system. Therefore, the choice of the energy source determines the shape of the whole electric power system, and this decision should consider diverse uncertainties along with a long-term view in terms of social benefit maximization.

The electric power system produces electricity that contributes to the public's benefit, but it also exerts negative impacts on the environment, such as the pollution of air, water, and soil (Sundqvist, 2002). In addition, it affects the society in terms of diverse risks, such as severe accident risk and human health damage, which the society has to shoulder. These negative impacts are called externalities. When an externality exists, the production level does not reach the socially optimal level, so that market failure and social welfare loss occurs since Pareto efficiency cannot be achieved.

A widely accepted definition of the social cost is the sum of the private cost and the external cost (IEA, 2005). The private cost is a producer's cost of providing goods or services in the market for his profit maximization. Meanwhile, the external cost is the cost that a producer does not count in his cost function and imputes it to the society, such as a third party or the future generation. Since now, the fundamental criterion to decide on the national electricity mix is the private cost. Although the electricity generation incurs external cost related to environmental damage and social risk, these are not included in the current valuation system. The energy decision based only on the private cost leads to several problems in terms of accomplishing socially appropriate energy mix. Firstly, private cost-based valuation of energy technologies is favorable to traditional energy sources, such as coal and nuclear (base-load energy sources), because they show a relatively low private cost due to the economy of scale. Accordingly, it functions as the fundamental basis of the unrealistically low level of electricity price. An unreasonably low price of electricity causes a distortion of the energy market in terms of the production and consumption of energy. For example, the demand for electricity can be increased at a dramatically fast speed, including the switching demand from other primary energy sources, such as oil, to the electricity. Electricity is somewhat inefficient compared with other primary energy sources, since it is accompanied with the efficiency loss during the conversion of energy type. Therefore, too much uses of electricity come with the inefficiency of energy production and consumption. Secondly, an unrealistically low price of electricity causes relatively weak competitiveness of renewable energy, so the time of market entry of renewables can be delayed. Even though renewable energy is accompanied by various social benefits, they are ignored in the current valuation mechanism, so renewable energy falls behind in the competition with traditional energy.

Profit-maximizing producers have no incentive to internalize the external cost, so policy makers need to identify and evaluate these external costs to internalize them into the cost function through diverse policy measures such as taxes or subsidies. In the 1980's, as the public became aware of the negative impacts of electricity, such as the devastation of the environment, policy makers started to include environmental issues in the energy policy (Pohekar and Ramachandran, 2004). Accordingly, the studies have been emerged which explicitly attempt to assess the external costs and internalize them into the social cost estimation in the electric power sector.

Although the definition of social cost seems to be clear according to the above, it is necessary to define the scope of externalities. The definition of externalities can differ depending on the range of society that is affected by the negative impact of electricity, whether the scope of the analysis is set to focus on the local community or expanded to the whole nation, whether it focuses on the current generation or includes future generations, and whether it focuses on environmental impacts or includes diverse risks that the society should endure implicitly.

Endeavors have been made to define the components of the external cost of electricity. According to the IEA (1995), the external cost can be categorized as the environmental external cost and the non-environmental external cost. Many European studies following the ExnterE (External costs of Energy) project have tried to define impact categories of air pollutants (e.g. human health, agricultural products, building corrosion, etc.) from electric power plants. In other words, European studies have focused on the assessment and valuation of the environmental external cost. Recently, the importance of the non-environmental external cost has been increasing. For example, the Japanese electricity generation cost verification committee calculated the social cost of electricity incorporating the cost of the severe accidence which can be interpreted as the realization of the hidden cost of energy. In spite of these efforts to clarify the diverse impacts of electricity, there is no global consensus on the components of the external cost.

In this regard, the concept of sustainability can be utilized to review the components of the social cost of electricity. It is commonly accepted that sustainability consists of three pillars, which are the economic, environmental, and social aspects (Jefferson, 2006). These three aspects of sustainability are the criteria for evaluating an electric power system from the long-term perspective. Comparing the social cost framework with the three dimensions of sustainability, the non-environmental external cost can be regarded as the social dimension of sustainability.

According to Alcorn (2003), social acceptance has been a key part of the social dimension of sustainability. The concept of social acceptance is widely covered by interdisciplinary sectors, such as economics, psychology, public administration, with the names NIMBY (Not In My Back Yard) and LULU (Locally Unwanted Land Use) (Popper, 1985), dealing with diverse objectives such as electricity facilities, waste disposal facilities, and nuclear and renewable facilities. Social acceptance is related to individual's subjective and psychological valuation regarding certain issues rather than objective damage or risk in scientific terms. In Korean context, there have been many social acceptance problems in the form of the local community's opposition to new energy facility construction such as fossil fuel electricity generation, nuclear facilities, electricity transmission towers, etc. These local oppositions have a critical impact on the implementation of electricity planning such as the threat to the reliable energy supply and capital loss due to the delay in the planned schedule of construction. Especially in the situation in which the need for individuals' quality of life is intensifying, it is expected that the role of social acceptance in electricity policy planning will become increasingly critical. In this regard, understanding the public's preference for and social acceptance of electricity facility siting has significant policy implications for planning and implementing socially appropriate energy policy measures (Ferreira et al., 2010;

Bronfman et al., 2012).

Considering the importance of social acceptance in the energy sector, a policy maker should consider not only the technical and physical aspects but also the public's preference regarding a certain energy issue in energy planning. In addition, several studies have explicitly mentioned that the cost incurred by the social acceptance problem is a component of internalization in the electricity cost (Kunruther, 1986; Himmelberger et al., 1991; Flynn et al., 1992). However, most previous studies have not included the cost of social acceptance in the evaluation of energy alternatives. In this regard, there is a need to estimate the cost of social acceptance related to electricity generation facility siting as an important factor in the social cost of electricity

1.2 Research Objectives

With increasing interest in environmental and social aspect of electricity, the discussion of social cost of electricity is widely taking place internationally. Considering the social cost as the sum of the private cost and the external cost, there have been endeavors to explicitly define the component of external costs and assess them for internalization. The external cost can be categorized as the environmental external cost and the non-environmental external cost. Many of previous studies have been focused on the assessment of the environmental external cost, and there is limited number of studies which tried to investigate the non-environmental external costs.

By reviewing previous literature, this study will try to investigate the missing components from the non-environmental external cost. With the consideration of three pillars of sustainability, the non-environmental external cost can be comparable with the social dimension of sustainability. The social dimension of sustainability is difficult to define, and the use of its practical application on social cost discussion is limited. Among different viewpoints toward the social dimension of sustainability, this study focuses on the social acceptance of electric power facility siting.

The social acceptance of electric power facility siting has the critical impact on the implementation of electricity planning. In addition, several studies have explicitly mentioned that the cost incurred by the social acceptance problem can be regarded as a component of the external cost. Therefore, the purpose of this study is to estimate the cost of social acceptance in electric power facility siting. With the increasing importance of social acceptance in energy planning and the necessity of incorporating these costs in the social cost of electricity, this study attempts to estimate the social acceptance cost as a unit cost of electricity such as Korean Won (KRW) per kWh.

In this study, the social acceptance cost is approached by the economic viewpoint regarding a location conflict of electric power facility siting between the local residence and the general public. Since the main cause of the social acceptance problem can be regarded as the regional inequality between benefits and costs of the general public and the local residence, this study proposes two different empirical models such that the general public's perspective dealing with the preference of people who lives long-distance from the location of a power plant and the local community's perspective dealing with people who lives nearby the location of a power plant.

In order to estimate the cost of social acceptance, the choice experiment (CE) is used. Recently, the choice experiment and conjoint analysis approach has become popular in energy economics (Johnson and Desvousges, 1997; Johnson et al., 1998; Telser, 2007). Studies on preference or its valuation in the field of energy and the environment have mainly been conducted through contingent valuation method (CVM). The advantage of the CE compared with the CVM is that it enables the researcher to estimate the preference and value of each attribute. This possibility to understand each person's preference regarding each attribute in the social acceptance problem can provide meaningful implications for public policy or utility suppliers. Among the different CE approaches, this study employed the hierarchical bayesian mixed nested logit model (HBNL), which reflects individuals' heterogeneity and copes with the limitation of independence of irrelevant alternatives (IIA) assumption in multinomial logit model. Recently, the hierarchical bayes (HB) model has received the great attention among choice analysis researchers, but the majority of them have used the HB multinomial logit model (Allenby and Rossi, 2002). Furthermore, it is hard to find studies that apply the HB structure in the nested logit model.

Throughout the empirical analysis, this study aims to investigate the following research questions.

Q1. Which factors are considered as important one in the acceptance of electric power facility siting by public?

In order to investigate which factors are regarded as important one in social acceptance of electric power facility by public, relative importance (RI) will be discussed. RI is calculated based on the estimation result of parameters in two empirical models.

Q2. How does the relative preference order among energy sources look like? And is it changed in general public model and local residence model?

People may consider not only the combination of levels of the attributes but also the name of energy sources when they face on the situation of acceptance of the electric power facility siting. Therefore, this study proposed the different model specifications regarding the alternative specific constant (ASC) as the name of energy sources. The ASCs is treated differently in the two sub-models. The estimation result of ASC indicates the overall preference of the alternatives so that the comparison of ASCs can provide the information of the relative preference order among energy sources. The difference of the relative preference order among energy sources in the two empirical models can also explain the NIMBY phenomenon.

Q3. How does preference heterogeneity toward energy sources and diverse impact from electric power facility siting look like?

HBNL model allows having a different distribution assumption for each parameter so that the preference heterogeneity can be reflected in the model. In addition, based on the estimation result of the standard deviation of each estimates, the magnitude of preference heterogeneity will be discussed.

Q4. What is the source of such heterogeneity?

As well as the distribution assumption for each attribute, HBNL model also allows investigating the individual parameters. The estimation results of individual parameters for each attribute will be used in the multivariate regression analysis for investigating the source of heterogeneity. In multivariate regression analysis, socio-economic characteristics will be used as independent variables so that source of heterogeneity can be discussed by the socio-economic characteristics

Additionally, this study will discuss of the empirical power of HBNL model since it has not been empirically applied yet. The estimation results of two different social acceptance models will be compared with the results of public's attitudinal survey so that it can be discussed whether this model can well-behaved in describing the public's preference.

1.3 Research Outline

This research consists of five chapters, which are organized as follows. Chapter 2 reviews the previous research related to the social cost of electricity. In detail, firstly, the theoretical background of the social cost is reviewed, and then the previous studies that estimate the external cost and social cost of electricity are reviewed. Based on the review of the previous studies, the cost component of the social cost is discussed. In chapter 3, the methodology that is applied in this study is reviewed. This is one of the discrete choice families, so the characteristics of the methodology will be discussed in terms of the evolution of discrete choice modeling. Chapter 4 proposes the empirical model for estimating the cost of social acceptance and the estimated result is discussed. Finally, Chapter 5 summarizes the content of the current study and states the policy implications and limitations of this research.

Chapter 2. Previous Literature

2.1 The Social Cost of Electricity

2.1.1 The Concept of Social Cost

Economics is the study of the allocation of the resources available to society in a way that maximizes social well-being (Goodland and Ledec, 1987). The traditional research objective in economics is the production activity of goods or services and the circulation of income within a social-economic system. In microeconomics, the negative impacts related to the environment, energy, or resource are treated as an externality or a public good, which is regarded as being outside of socio-economic system. The concept of the social cost or external cost was introduced into the economic literature by the neo-classical economists. Since Marshall first introduced the concept of external economies (Marshall, 1890), neo-classical economists have analyzed the social cost by utilizing the concept of externalities.

Neo-classical economists have approached externalities as market failures and suggested the 'internalization of externality' solution to achieve socially optimal resource allocation. In other words, their approaches are based on the assessment and valuation of the external cost, which is not reflected in the market price into monetary terms. This is called as 'monetary-market approach', because the un-priced externalities are expressed as monetary term that is transformed from the public's utility, and this information is reflected in energy policy to use environment efficiently by the market institution or government.

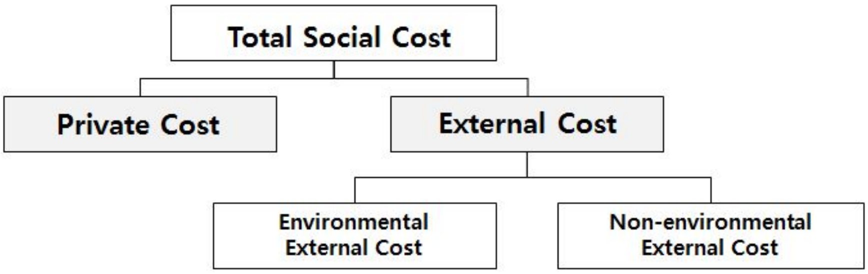

Figure 1. The concept of the total social cost

Source: IEA (1995)

In order to solve the problem of inefficiency due to an external cost, there are two possible approaches: one is based on the market mechanism and the other is based on government intervention. Coase (1960) demonstrated that external cost can be internalized by bargaining between polluters and the affected agents under certain circumstances. In other words, under specific conditions, such as low transaction costs and full information, the market failure can be fixed within the market mechanism. However, in most cases, some kind of government intervention is required because a large number of parties are involved (Sundqvist, 2002). Another approach emphasizes the role of the government in solving this market failure and internalizing the external cost. This is the use of so-called Pigovian taxes (Pigou, 1924), which implies that a tax which is set to be equal to the marginal external cost can provide the incentive for producers to internalize it for un-priced goods and services related to the environment. This has been acknowledged as a fundamentally theoretical ground of government intervention regarding diverse environmental problems or public goods. Because public goods, such as environmental services, do not have a market in which to trade, the government conducts a cost–benefit analysis to supply the optimal level of public goods for the society. To conduct the cost–benefit analysis, the components of the cost or benefit should be assessed as monetized terms.

In order to assess the external cost as a monetary term, the impact of the externality should be assessed and this impact should be transformed into a monetary term. There are two fundamental methodological approaches which are used for the valuation of external impacts in the energy sector: one is the abatement cost approach and the other is the damage cost approach (Sundqvist, 2002). The abatement cost approach uses the costs of controlling the damage or meeting regulations as an implicit value of the external cost. Its concept is the internalization of such cost that the producer should pay for reducing the damage to meet the social requirement. There is a disadvantage of this approach in that it could under-estimate the social cost since producers only need to satisfy the social regulation even when they know the true abatement cost.

The damage cost approach is a method for measuring the economic damage arising from negative impacts regarded as externalities. The bottom-up damage cost approach is the consumer-oriented method, which traces the pollutants during the electricity generation in terms of their quantity and their impact on the environment. It utilizes a damage function or impact pathway to analyze the influences of pollutants regarding diverse impact categories such as human health damages, harmful effects for crops, and drops of property values. This method requires technology-specific data and utilizes them with a dose-response function so that the site-specific result can be analyzed.

The abatement cost approach does not need a monetizing process since it is directly linked to the private cost. However, damage cost approach requires the process of monetizing external impacts of pollution, such as the direct method (e.g. contingent valuation, choice experiment) or the indirect method (e.g. hedonic pricing, replacement cost). Environmental economics are focusing on the theoretical and methodological improvement for assessment of environmental externalities. This also underlies the neo-classical paradigm in microeconomics. With neo-classical assumptions, there is a Pareto-optimal market equilibrium in all markets whereby the supply and demand are equal and no economic subject is able to improve its own situation without deteriorating the situation of another.

The concept of the social cost depends on the definition of the private cost and the external cost. The concept of the private cost and its practical uses seems to be clear. However, in case of the external cost, the scope and length of society that is affected by the externality should be defined. With respect to the scope of society, it is problematic whether the externality is analyzed focusing on the local community, the nation, or the globe. Some externalities only affect to the current generation, but the other externalities can affect to the future generation. Similarly, some externalities could be beneficial in short term, but it could be loss in long term. Sometimes the externality occurred during the electricity generation stage and could be revealed immediately, but there are many cases that damages are not revealed for a long period of the time. Moreover, even people in the same boundary of society can be affected differently by the same impact such that some events can be harmful to one group of people while same event can be beneficial to the other group of people. The benefit and cost are evaluated by people so that the valuation of the externality can be different based on the heterogeneous preference on certain impacts of the electricity by different groups of people. Furthermore, the social cost sometimes includes the opportunity cost which has different value by regions and groups of people. Therefore, defining, assessing, and valuating the social cost of electricity need intensive efforts both quantitatively and qualitatively. In following section, the previous studies which estimate the social cost of electricity are reviewed.

2.1.2 Social Cost Estimation Research

In the early 1980s, studies that explicitly tried to assess the value of externalities of electricity began to emerge (e.g., Schuman and Cavanagh, 1982). These represented the endeavor to estimate the social cost of electricity by the valuation of externalities and their internalization. During the 1990s, a large number of the externality assessment studies had been conducted, largely due to the increased attention from policy makers in

Europe (EC, 1995; EC, 1999), and in the U.S (e.g., Rowe et al., 1995). The results of many of these externality assessment studies have been utilized as inputs into the social cost estimation research for different energy sources and comparison of the relative economics between them. They have also been utilized in diverse modeling works and have served as vehicles in developing advanced methodology in the environment and energy field (Krewitt, 2002).

The social cost estimation studies can be categorized into primary research and benefit transfer research (Burtraw et al., 2012). A primary study refers to site-specific research with own scientific, engineering data. Accordingly, it requires the data gathering by long-term monitoring. A benefit transfer study adapts technical, environmental, or economic data gathering from a primary study in certain resource and policy contexts and utilizes the data to the transfer site. In a primary study, the damage function approach is performed with data which is unique to the study. Compared with primary study, a benefit transfer study would require fewer elements of the damage function which is unique to the study. Benefit transfer studies are usually performed due to lack of the necessary time, money, and expertise to conduct a primary study.

Among many studies, ExternE is widely acknowledged as the 'gold standard' of externality assessment research in energy sector (Krewitt 2002). Beginning in 1991 with the participation of 12 EU countries and the US Department of Energy (DOE), the ExternE project aimed to develop a systematic approach to the valuation of external costs over a wide range of different fuel cycles. ExternE identified the impact of air pollutants with monetized terms in European countries, considering human health, agricultural products, building corrosion, etc. It analyzed the impact of CO_2, SO_2, NOx, and PM (particles) following an impact pathway approach, which used the dose-response function to analyze the local impact according to the distance from the facility. The ExternE project updated its methodology in 2005. ExternE (2005) computed the monetary external damages associated with human health, crops, ecosystems, climate change, and materials. Regarding climate change, avoidance costs were used and defined as the shadow price for reaching the Kyoto targets.

According to Sundqvist (2004), who reviewed 38 previous studies related to electricity externalities, the dominant methodology used to assess externalities is the bottom-up approach. He explained that the main reason for this is that the ExternE project (EC, 1999) has largely served as a vehicle in the development of methodology in externality assessment studies (Sundqvist, 2004). The methodology and the results of external cost estimation in ExternE have been widely utilized in many benefit transfer studies.

Since the ExternE project was firstly conducted in the middle of 90s, several follow-up studies have been developed in Europe using a similar methodology funded by EC. Examples are European Sustainable Electricity (EUSUSTEL, 2007), New Energy Externalities Developments for Sustainability (NEEDS, 2009), and Cost Assessment of Sustainable energy Systems (CASES, 2010). These studies utilized the method and results of the ExternE project. While EUSUSTEL and NEEDS analyzed the social cost of electricity in EU countries, CASES involved results from four non-EU countries such as China, India, Turkey, and Brazil. In addition to these researches, a substantial body of academic literatures uses the benefit transfer techniques for estimating the damages within electricity fuel cycle, and a large amount of them has used the result of ExternE estimates.

Bigano et al. (2000) used the ExternE estimates in a comparative analysis of different energy sources by using external costs to regulate in the Belgian electricity sector. For emissions related damages, the authors borrowed the values for SO_2, NO_x, and PM from ExternE estimates. For non-emissions related damages, the authors also borrowed the values from the result of the ExternE project. Banzhaf et al. (2004) conducted the analysis using equilibrium model for the U.S. electricity sector. They used an integrated assessment model to estimate the changes in SO_2 and NO_x emissions and their health damages. Then, they calculated the efficient level of emissions fees. Muller and Mendelsohn (2009) applied the similar method with more detailed geographic information.

Thanh and Lefevre (2000) estimated the risk of health damages for SO_2 and PM_{10} emissions from four different power plants such as lignite, oil, natural gas, and coal in Thailand. The damage from air pollutants was estimated in Bangkok City according to four impact categories related to health damage such as premature mortality, respiratory and cardiac hospital admissions, and duration of acute respiratory symptoms. Holland and Watkiss (2002) analyzed the external cost of air pollutants. They estimated the external costs per the unit of air pollutants such as SO_2, NO_x, VOC_x, and PM by utilizing the method of ExternE project. This study added VOCs in target pollutants comparing with ExternE project and analyzed the social cost differently by towns and cities based on the population size. Rafaj and Kypreos (2007) used the global energy system model to examine the impacts of the external costs of electric power generation. The authors borrowed values for the costs of pollutants per kWh from ExternE and then scaled them to five global regions by population density. Population densities were classified with high and medium level, and changes in populations over time were not considered. In a similar way, Klaassen and Riahi (2007) examined the global impacts of a policy if all environmental damages from power plants are internalized. The values for NO_x, SO_2, and PM were also borrowed from ExternE on the basis of USD per kWh and adjusted by the population density.

In the Korean context, Kim and Kang (2008) used the average CO_2 emission permit price from 2008 to 2012, 25 EUR/tCO2, according to the analysis of McKinsey and Cambridge Econometrics, to estimate the CO_2 emission cost. They estimated the CO_2 emission cost per energy sources by multiplying the CO_2 emission quantity of each energy sources with the CO_2 emission permit price (31,828 KRW/tCO_2). Then, they collected the environmental pollution cost per unit of each energy sources from previous research to propose the social cost of energy sources. Kang et al. (2011) estimated the environmental pollution cost according to energy use in Korea. They used the pollution cost per air pollution substance unit estimated by the European Union. Because Korea and the EU have different social economic situations, such as the price level, the income level, the 2010 exchange rate was used for the benefit transfer to take this into consideration. This study used the weight of a city with a population of 500,000 for PM and SO_2 to estimate the environmental pollution cost. It estimated the social cost of air pollution by multiplying the air pollution substance emission in Korea with the estimation result of pollution cost of the ExternE project. These studies largely utilized the method and values of the ExternE project and its benefit transfer studies. The scope of externalities, therefore, is based on environmental externality, which used the impact of each pollutant, such as SO_2, NO_x, PM, etc.

Roth and Ambs (2004) tried to estimate the social cost of electricity by using a levelized cost of electricity (LCOE) for 14 different generation technologies in the United States. They approach to the scope of social cost as all stages of the fuel cycle. The externalities covered in the analysis included environmental externalities such as air pollution damage and non-environmental external costs, such as energy security, transmission and distribution costs.

2.1.3 The Components of Social Cost of Electricity in Practice

As previously mentioned, the social cost can be divided into the private cost and the external cost. Based on the studies that were reviewed in the previous chapter, the detailed components of each cost category that are practically used will be reviewed.

2.1.3.1 Private Cost

By definition, the private cost indicates a producer's or supplier's cost of providing specific goods or services. This cost is incurred from input materials, production activity, and delivery of the goods, so it is mainly used as a basis for the price in the market. For electricity, diverse energy sources have different production activities, so the private cost for each energy source can be defined differently.

The most common method of calculating the private cost of electricity generation seems to be the general levelized cost of electricity (LCOE) methodology. It is a discounted cash flow (DCF) approach, and the expected electricity output is converted into annual payments by using net present values. The LCOE methodology can be used in assessing the cost structure of various generation options, analyzing the various generation options available to policy makers and investors, and accordingly identifying the least cost option among alternative generation investments (OECD, 2010).

The cost components of the LCOE consist of the capital cost, fuel costs, and operation and management (O&M) cost. The capital cost means the total investment cost for the construction of electricity generation and related facilities. The fuel cost is the cost incurred by securing and using energy sources for electricity generation. Unlike conventional energy sources, renewable energy sources do not require a fuel cost, except for bio-mass. In the case of nuclear energy, the component of the fuel cost is different from that of other conventional energy sources. The fuel cost of nuclear power is called the fuel cycle cost, since the fuel for nuclear (e.g., uranium) should be controlled even after being used for electricity generation. However, the detailed cost component for the fuel cycle cost of nuclear power is defined differently by country and policy. In the case of Korea, the cost incurred after electricity generation is classified as radioactive waste management cost and added to the O&M cost. The O&M cost is the total cost incurred during the operation of electricity generation facility, except for the fuel cost. As mentioned, the O&M cost of nuclear energy contains the radioactive waste management cost which includes the cost for decommissioning the electricity generation facility, waste disposal, and various insurance costs. Social cost estimation studies have used this LCOE framework as a private cost term (e.g., EUSUSTEL, 2007; NEEDS, 2008; CASES, 2010), and derived the total social cost as a sum of the external costs that are estimated by each study.

2.1.3.2 External Cost

External costs occur when the production or consumption decisions of one agent have a negative impact on the production or consumption opportunities of another agent (Baumol and Oates, 1988). Unlike the conceptual agreement for the definition of external cost, it is difficult to define all the agreed components of the external cost in practice. Sundqvist (2002) reviewed the results from 63 externality studies and compared the results of the estimation, as shown in Figure 2. He attempted to determine the reason behind the disparity across different studies, and the main findings were (a) the use of different technologies; (b) the difference in site characteristics; and (c) the difference in scope of the externalities. He also explained that the welfare economics literature provides a relatively straightforward definition of the concept of externalities, but the choice of relevant externality components tend to differ among different valuation studies (Sundqvist, 2002).

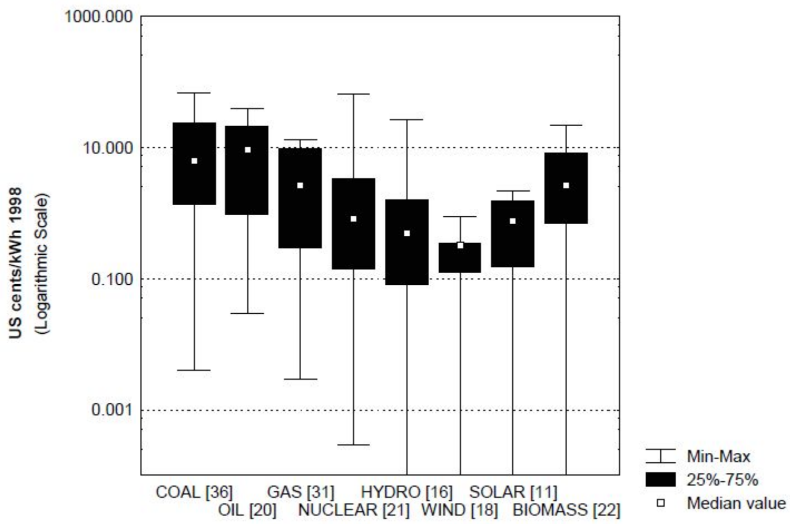

Figure 2. The range of external cost estimates from previous studies

Source: Sundqvist (2002)

As shown in Figure 1, externalities can be categorized into environmental and non-environmental externalities, and accordingly such externalities can cause costs such that the external cost can also be categorized into the environmental external cost and non-environmental external cost. The environmental external cost has been widely studied since the ExternE project in 1995, so the ambiguity of cost components seems to be small. According to Owen (2004), the environmental externalities of energy production can be divided into two broad cost categories which distinguish the emissions of pollutants with local impacts and with global impacts: firstly, the costs of local impact include the human health damage and the environmental damage by emissions of pollutants; second, the costs resulting from the climate change are attributable to GHG emissions. This definition is to a certain extent directly comparable with the impact category in the damage cost approach of ExternE project such that the impact category of ExternE is the human health impact, environmental impact due to air pollutants, and GHG abatement cost (EC, 1999).

However, in the case of the non-environmental external cost, it is difficult to find a general consensus on which components should be considered in externality assessment. In this regard, some of the recent externality studies in terms of the components of the external cost should be closely reviewed. For example, in the ExternE updates (2005), the amenity losses from noise, the visibility and transmission lines, and major accidents in non-nuclear fuel chains were considered as non-environmental external costs. In the case of CASES (2010), the cost of energy security was considered as a non-environmental external cost. Roth and Ambs (2004) used energy security, the depletion of the world's finite resources, and T&D costs as non-environmental external costs, while they mentioned that there are unquantified externalities that impact on employment patterns and fiscal effects.

In the case of nuclear energy, the OECD/NEA (2003) categorized the components of the external cost into radioactive waste disposal, decommissioning of the nuclear reactor, health and environmental damage resulting from normal operation, and damage due to accidents. However, in the case of Korea, several components of these are already internalized, such as radioactive waste disposal, decommissioning of the nuclear reactor, etc.

2.2 Sustainable Energy Development

Sustainable development has been widely discussed and debated within government and non-government institutions. The concept of "sustainable development" has been focused on the political debates since the World Commission on Environment and Development (WCED), also known as the Brundtland Commission, released a report on "Our Common Future" in 1987. The commission defined "sustainable development" as *"… development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (WCED, 1987)*."* Accordingly, sustainable development means the mode of human development in which resource use aims to human needs while preserving the environment so that these needs can be met not only in the present, but also for future generation (IAEA, 2005). Sustainability concepts are mostly known by a three pillar model representing the economic, environmental and social dimensions of sustainability. This approach was suggested as a mean for reducing arbitrariness of the sustainability concept in the Brundtland Commission such that they constructed the basis for quantitative assessment.

Among the various attempts to define the concept of sustainability and its practical uses, many researchers have tried to develop the sustainability indicator sets for its practical use. This endeavor lies behind the multi-criteria decision analysis (MCDA) method which is a fundamental decision-making tool for ecological economists. They did not agree with monetized valuation and insisted that a variety of criteria should be integrated into the evaluation of energy policy decisions. The MCDA could provide for policy makers the possibility to address diverse issues, such as land use, human health, and reliability of the system rather than only focusing on the environmental external cost (Hobbs, 1995). In addition, it allowed to explicitly integrating the social dimension of the decision making process (Ferreira et al., 2010).

Developing evaluation criteria and reliably measure of sustainability is a prerequisite for deciding the best alternative, informing design-makers of the performances of the energy alternatives and monitoring the impacts on the society and environment. Therefore, appropriate sustainability indicators should be selected for measuring performance of energy options in terms of the diverse impacts in the defined dimensions within the scope of the analysis. The sustainability indicators are useful to provide decision makers and public with the comprehensive information regarding the diverse dimension of impacts with integrated form. Since the publication of the Brundtland Report in 1987, various international institutions have been developing sustainability indicator sets to measure the degree of sustainable development. The concept of relative sustainability of energy technologies or energy life cycle enables to decide most appropriate energy options in the society, however the uniquely confirmed criteria or indicators for assessing sustainability is not exist. In following section, the examples of sustainability indicators are reviewed.

2.2.1 Sustainability Indicators

Many international organizations and government institutions have been proposed the sustainability indicators and assessment criteria in energy sector. For example, the OECD/NEA (2002) proposed a set of sustainability indicators for the nuclear energy sector. The indicator sets were designed to assess the nuclear energy and its fuel cycle and summarized in Table 1. Although this indicator set is proposed for nuclear energy, the criteria can be used for comparing the competing energy options such as renewable, fossil fuel associated their energy life cycle.

Table 1. The lists of sustainability indicator proposed by OECD/NEA (2002)

Dimension	Indicators	Units
Economic	Share of nuclear energy in total primary energy consumption	%
	Total nuclear energy generation	TWh
	Nuclear generation per capita	TWh/capita
	Average availability factor of nuclear units	%
	Marginal production cost	USD mill./kWh

Environmental	Natural uranium consumption	tU/year
	Land requirements	km^2
	Radioactivity released to the atmosphere by nuclear energy facilities	Bq/year
	Volume of solid waste	km^2/year
	Share of solid waste in interim storage	%
Social	Employment in the sector	Person/year
	Manpower cost in the sector	USD/year
	Number of days of work lost by accidents on nuclear sites or professional illnesses	Days/year
	Work related fatalities in the nuclear energy sector	Number/year
	Dose to workers	Sv/year
	Fatalities in the public due to nuclear energy activities	Number/year
	Number of accidents in nuclear facilities	Number/year

Source: OECD/NEA (2002)

International Committee on Nuclear Energy (ILK) proposed the set of criteria and indicators for evaluating sustainability of different energy sources. The list has originally been established by the Paul Scherrer Institute (PSI) within its Comprehensive Assessment of Energy System (GaBE) Project for the assessment of sustainability of electricity supply technologies including nuclear power generation in a case study for Germany. This indicator set is summarized in Table 2.

Table 2. Indicator set proposed by International Committee on Nuclear Energy

Dimension	Impact Area	Indicators	Unit/kWh

Environmental	Resource requirements	Exhaustible energy carrier	kWh
		Copper ore	kg
		Bauxite	kg
		Iron ore	kg
	Climate effects	Greenhouse potential	kg CO2 equivalent
	Acidification /Eutrophication	Acidification Eutrophication	kg CO2 equivalent
	Waste	Residential and production	kg
		Construction	kg
		Hazardous	kg
		Heat releasing	m^3
		Non-hear releasing	m^3
Social	Work opportunity	Direct employment	Workers
	Income generation	Added value	€
	Health effects	Public effects Occupational effects	YOLL
Economical	Cost	Private cost	€
		Public cost	€
		Total societal cost	€

Source: OECD/NEA (2002)

The Institut für Energiewirtschaft und Rationelle Energieanwendung (IER) of Stuttgart University assessed the sustainable development of energy technologies and supply chains for the state of Baden-Württemberg in Germany. The set of criteria and indicators used in the full analysis of the candidate technologies for the future electricity supply in Switzerland along with the basic set of used weights. Proposed indicator set is presented in Table 3.

Table 3. Indicator set applied in IER

Dimension	Impact categories	Indicators
Economy	Financial Requirements	Production costs (Rp/kWh) Investment (power plant. SFr/kW) Fuel price increase sensitivity (Increase of Production costs due to doubling of fuel costs)
	Resources	Short-medium term potential (Generation potential GWh/year) Availability (load factors) Geo-political factors (estimation) Long-term sustainability (years) Peak load response (relative scale)
Health & Environment	Human Health Impacts	Mortality (Rp/kWh) Morbidity (Rp/kWh)
		Loss of crop (Rp/kWh)
		Impact on materials (Rp/kWh)
	Non Pollutants' Effects	Land use (m^2 /kWh)
		Greenhouse gases (gCO2-equiv/kWh)
	Wastes	Volume (m^3 /kWh)
	Severe Accidents	Fatalities (Fatalities/kWh)
Social Aspects		Employment (jobs per unit of energy)
		Proliferation risks (yes or not)
		Local disturbance (estimation per unit of energy)
		Critical waste confinement time (years)
		Risk aversion (maximum fatalities per accident)

Source: Hirschberg et al. (2000)

PSI updated its sustainable electricity indicators in 2004. The set of indicators reflects only current technologies. For example, expansion potential, a critical attribute when considering realistic options for the future, has not been considered within the present evaluation, centered on the current electricity supply in Germany. The final set of sustainability indicator proposed by PSI is presented in Table 4.

Table 4. Criteria and indicators employed in Paul Scherrer Institute (PSI)

Dimension	Impact Area	Indicators	Unit
Economy	Financial Requirements	Production cost	€/kWh
		Fuel price increase sensitivity	Factor
		Availability (load factor)	%
	Resources	Geo-political factors	Relative scale
		Long-term sustainability: Energetic	Years
		Long-term sustainability: Non-energetic	kg/GWh
		Peak load response	Relative scale
Environment	Global Warming	CO_2 equivalents	tons/GWh
	Regional Environmental Impact	Change in Unprotected Ecosystem Area	km^2/GWh
	Non-Pollutant Effects	Land use	m^2/GWh
	Severe Accidents	Fatalities	Fatalities/GWh
	Total Waste	Total weight	tons/GWh

Social	Employment	Technology-specific job opportunities	Person-years /GWh
	Proliferation	Potential	Relative scale
	Human Health Impacts	Mortality (reduced life-expectancy)	YOLL/GWh
	Local Disturbance	Noise, visual amenity	Relative scale
	Critical Waste Confinement	Necessary confinement time	Thousand years
	Risk Aversion	Maximum credible number of fatalities per accident	Max fatalities /accident

Source: Hirschberg et al. (2004)

As reviewed above, sustainability indicators are categorized into the economic, environmental, and social dimensions. These general rules for a sustainable energy supply system are not directly applicable when it comes to the comparison and assessment of energy technologies. Therefore, the assessment has to be based on comparative measures of the various sustainability aspects on a functional unit basis of electricity (e.g., kWh). The relative sustainability of energy technologies is basically determined by the overall consumption of resources including environmental resources on a functional unit basis. One useful measure of the overall resource consumption is the total social cost per unit of electricity. These include the private cost as well as the external cost of an energy chain to provide an energy service. Therefore, the concept of relative sustainability of energy technology and the goal of sustainability indicators provide the basis for the sustainable energy development such that it can be achieved at the lowest total social cost. In this regard, the three pillars of sustainability and related indicators can be a useful guidance for identifying the missing components of the social cost of electricity.

2.2.2 Social Dimension of Sustainability

According to Colantonio (2009), during the 1990's, new social concerns emerged due to diverse factors, such as demographic change, social mixing and cohesion, health and safety, social capital, well-being, happiness and quality of life, etc. The social dimension of sustainability has been recognized as a fundamental dimension of sustainable development, but only few works actually referred to the social aspects of electricity planning (Ribeiro et al., 2011). Carrera et al. (2010) mentioned that it is difficult to find coherent theory in social dimension of sustainability so that the measurement of social impact is clearly defined. Vallance et al. (2011) also argued that the social dimension of sustainability is in somewhat chaotic, contradictory and confusing by reviewing the literature which refers "social sustainability".

As a reason for this, Benaim et al. (2008) pointed out that in economics, the environmental perspective can be easily observed in the energy cycle, but the social aspects are highly intangible. They also argued that environmental issues can affect the whole planet, so they demand global response such as reduction of GHG emission to meet the target of Kyoto Protocol. However, no parallel concept exists in the social aspect of sustainability. Harris et al. (2001) explained the main cause of this as the social aspects in the Brundtland Report being set to be too narrow, so most of the sustainable development discussions have been focused only on environmental sustainability. Similarly, Assefa and Frostell (2007) mentioned that the difficulty of measuring and quantifying the social dimension of sustainability arises from the need to identify an objective definition of social sustainability.

Although there is a consensus that the social dimension of sustainability and the social aspect of electricity planning have been weakly investigated, some studies approach this as a concept of social acceptance. Assefa and Frostell (2007) explained that it is impossible to reach consensus on all the factors in social sustainability, but social acceptance has been a key part of many investigations (Alcorn, 2003). In order for a technical system to be regarded as socially sustainable, it should at least satisfy wider social acceptance. In this matter, they considered the social sustainability dimension approached from an angle of social acceptance. Wang et al. (2009) mentioned that social acceptability is the expression of the public's opinions related to the energy systems by the local population from the consumer point of view. Similarly, Wolsink (2007) emphasized the need to take into consideration the public attitude toward the implementation of energy planning, not only at a general level but also at the local project level and stressed the importance of including the public's preference in the decision-making process.

2.3 Social Acceptance in Electric Power Facility Siting

2.3.1 Social Acceptance in Energy Planning

Wang et al. (2009) pointed out that social acceptance is extremely important since the opinion of the public or specific groups of people may heavily influence the amount of time required to implement and complete an energy project. Social acceptance is often shown as an expression of intensified opposition to the facility, so that it is accompanied by the delaying of the energy projects (Morell and Magorian, 1982; O'Hare et al., 1983). Cavallaro and Ciraolo (2005) explained that public acceptance of a project may not be sufficient to ensure its viability, but represents a contribution to its success. Bronfman et al. (2012) also referred to social acceptability as a determinant factor in the failure or success of the government decisions about which electricity generation sources will satisfy the growing demand for energy. In this regard, social acceptability has been employed to analyze the feasibilities of the construction of diverse energy power plants (Cavallaro et al., 2005; Liposcak et al., 2006; Chatzimouratidis et al., 2008).

Social acceptance is often discussed in the economic literature in relation to the facility siting problem, which is accompanied by local opposition, location conflict, or host community compensation. From the economic point of view, the root cause of the social acceptance problem of electricity facility siting comes from the geographical inequality of the benefits and costs of the electricity facility (Sandman, 1986; Kunreuther and Easterling, 1996). Generally, the benefits from the construction of unwanted public facilities are distributed over the entire country, while negative impacts are concentrated on the local residents in the surrounding area (Armour, 1991; Mors et al., 2012). These local burdens can take various forms, such as harm in the form of economic losses, impacts on human health, decrements to the quality of life, and degradation of the physical environment (e.g., Gregory et al., 1991; Schively, 2007).

The perceived imbalance between local burdens and national benefits tends to create emotion of inequity and unfairness within the local public. Economic psychology studies have shown that in decisions-making concerning risk, probable outcomes are valued less than certain ones (Kahneman and Tversky, 1979), thus residents host communities value the existing local quality of health, property values and environmental endowment over the uncertain situation where the host the proposed LULU development. If a facility, such as the power plants, waste disposal facility, and transmission towers, is expected to cause damage to the environment or to health facilities, psychological concerns of the local residents rise. This ultimately causes an increase in the psychological perceived cost of the local people and results in stronger opposition from the people of the local community (Jung, 2010). This opposition creates lengthy and expensive siting procedures, which in turn increase the private and social costs of providing electricity facilities (Cavallaro and Ciraolo, 2005).

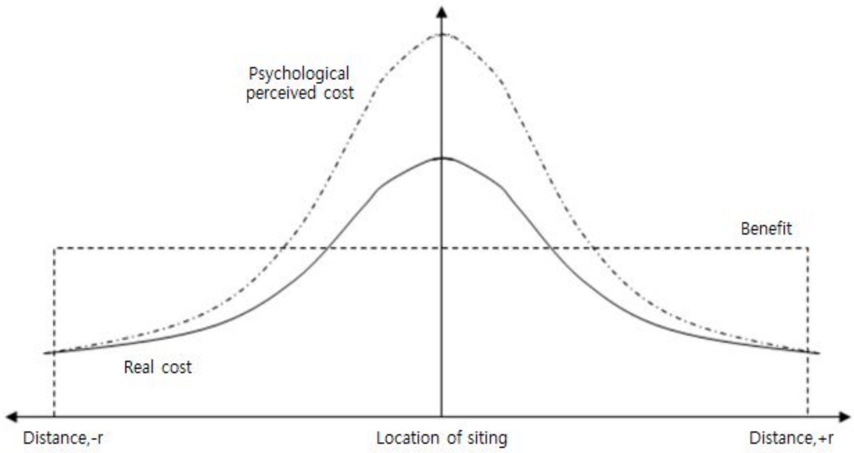

Figure 3. Social conflict regarding facility siting

Source: Jung (2010)

According to Mors et al. (2012), host community compensation may be used as a strategy to resolve this imbalance. In this regard, the compensation for host community can be defined as an equity adjustment for correcting imbalances between regional benefits and local burdens associated with the siting of new facilities (Himmelberger et al., 1991). Kunreuther and Easterling (1996) explained that compensation can provide a solution to siting problem at least theoretically. Compensation involves the making of payments to those people who are negatively affected by the facility. Therefore, compensation should be set at a level that at least offsets the burdens experienced by the host community (Kunreuther and Easterling, 1996).

Flynn et al. (1992) insisted that federal government of the United States, Department of Energy, and the nuclear developers had not understood the root cause of failure of radioactive waste disposal facility by only emphasizing on technique, schedule and cost, and the public concern led to the failure of the policy over 30 years. Therefore, the cost incurred by social conflict regarding energy facility issues can be considered as the major hidden cost, which is the objective to be internalized. To estimate the truer social cost, the assessment and valuation of social acceptance cost is required.

From the economic standpoint, compensation helps internalize the full social and environmental costs associated with unwanted facilities, thereby achieving a more socially desirable mix of facility locations and sizes than would be the case when the local community shoulders the adverse impacts without offsets (Kunreuther and Kleindorfer, 1986). Himmelberger et al. (1991) also emphasized the role of compensation as internalization tool in economic perspective.

2.3.2 Public Attitude toward Electric Power Facility Siting

The major objective of previous studies can be categorized as conducting the research on the major factors affecting social acceptance and the valuation of social acceptance. These studies are widely focused on different locally hazardous facilities, such as electricity generation facilities, waste disposal facilities, or nuclear related facilities. Recently, many studies have recognized the social acceptance problem for renewable energy, since its penetration rate is behind the expected level.

One major research area related to the social acceptance is the investigation of the major factors of local acceptance of potentially hazardous facilities. Based on previous research, this study considers many factors that could affect the local acceptance of a potentially hazardous facility. These factors include the perception of risk, scientific knowledge, perceived effect on the economy, trust, participation, political attitudes, demographic characteristics, etc.

Dear (1977) noted that the main determinant of public's attitude towards the siting of new facilities is the distance of the facility from an individual's residential area. Lindell and Earle (1983) examined public perceptions of risk associated with different industrial facilities and found that the people who have higher perceived risk show the higher the minimum acceptable distance. Furuseth and O'Callaghan (1991), and Frey and Oberholzer-Gee (1996) reported that perceived risk is particularly associated with the level of public's trust in developers and utility companies. Tanaka (2004) asserted that individuals' risk attitude and trust in government and energy companies are correlated with the acceptability of nuclear power plants. Krosnick et al. (2000) and Bannon et al. (2007) found out that consumers' attitude towards global warming affects their preferences for energy alternatives.

Some research has focused on the NIMBY phenomenon and its relationship with individuals' characteristics. Wright (1993) found that NIMBY attitude and local opposition for a hazardous waste facility were positively related to knowledge about the facility. Regarding NIMBY phenomenon, Warren et al. (2005) insisted the different perspective with other studies such that residents living closer to facility siting location could have more positive views than those living further away, which has been described as an ‘inverse NIMBY syndrome.’

Regarding as a clean alternative energy, renewable energy is enforced by many advanced countries. However, the penetration rate of renewable energy is not as great as its enforcement. Accordingly, many studies on the social acceptance of energy facilities have focused on renewable energy sector.

There is research that has tried to investigate the public preference for renewable energy sources focusing on their environmental impacts (Roe et al., 2001; Alvarez-Farizo and Hanley, 2002; Bergmann et al., 2006; Champ and Bishop, 2006; Kim, 2007; Longo et al., 2008; Solomon and Johnson, 2009). Scarpa and Willis (2010) investigated the determinants of household preference on micro-generation technologies for commercial use, such as heat pumps, pellet stoves, and micro-wind. Many previous studies pointed out that there has been widespread local opposition towards renewable energy developments, particularly wind and biomass (Toke, 2005; Upham and Shackley, 2005; Warren et al., 2005), .

Some researchers have investigated the public preference and the WTP for renewable energy sources focusing on the security of energy supply (Hartman et al., 1991; Woo et al., 1991; Beenstock et al., 1998; Doane et al., 1988; Goett et al., 2000; Baarsma et al., 2005; Layton and Moeltner, 2005; Asif and Muneer, 2007; de Nooij et al., 2007). Hanley and Nevin (1999) used a contingent valuation method to estimate people’s willingness to pay for biomass and hydropower. Bergmann et al. (2006) and Bergmann et al. (2008)

applied the choice experiment method to quantify people's preferences regarding the social and environmental impacts of hydro and wind power as well as biomass production, and then they focused on differences in preferences between rural and urban citizens.

While a large number of studies have focused on renewable energy, some studies have tried to analyze wider scope of energy resources, including fossil fuel, nuclear, and renewables. Greenberg (2009) ascertained that the public preferences for different energy sources for electrical generation have been widely reported during the last 20 years worldwide, and there are many economic studies that have specifically estimated willingness to pay for the types of energy. Bolsen and Cook (2008) gauged public attitudes about the local construction of new nuclear power plants.

The heterogeneity of preferences for energy sources has been studied, and these studies also largely deal with renewable energy. In order to study the heterogeneity, the discrete choice model has been often used. Bergmann et al. (2008) examined the heterogeneity of preferences for renewable energy using a choice experiment. They used the random parameter logit model to reflect the heterogeneity of preference for the parameter of the model that is the attribute of the renewable energy policy. Their research concerned the difference between each individual and the group in urban and rural areas. The difference in preference between the two groups was explained such that rural communities would be directly affected by many of these investments, such as the visual effects of wind farm construction in upland areas. Longo et al. (2008) also used the conditional logit model to investigate the heterogeneity of the WTP for electricity. They assessed the preferences of respondents for a policy for the promotion of renewable energy. Birol et al. (2006) employed a choice experiment to estimate the values of changes in several ecological, social and economic functions that the Cheimaditida wetland provides to the Greek public. In order to account for the heterogeneity in the preferences, a conditional logit model, a random parameter logit model, a random parameter logit model with interactions, and a latent class model were used. Wilson and Dowlatabadi (2007) explained that, in the energy and environmental sector, many of market failures are related with individual decision making and are pervasive facets of human behavior. They mentioned that the heterogeneity of preferences within population is one of main causes for this. Laitner et al. (2000) emphasized the preference heterogeneity in policy such that the poor characterization of heterogeneous preferences could be a reason why macroeconomic models can fail to capture the energy efficiency gap. Wilson and Dowlatabadi (2007) provided empirical evidence for the importance of heterogeneity of preferences and tastes in investment decisions in energy-efficient systems. They showed the potential biases that can be caused by ignoring heterogeneity and dealing with a uniform utility function for individuals.

2.4 Limitation of Previous Approaches and Research Motivation

As previously reviewed, externality assessment studies have mainly focused on the environmental external cost. Although a few studies have tried to include non-environmental external costs, such as energy security, it seems not to be a widely accepted component of internalization. Meanwhile, social acceptance has received a great deal of attention in energy planning. As discussed, compensation can be a solving mechanism for social acceptance related to energy facility siting. In addition, several studies have explicitly mentioned that the cost incurred by the social acceptance problem is a component of internalization in the electricity cost (Kunruther, 1986; Himmelberger et al., 1991; Flynn et al., 1992). Accordingly, there is a need to estimate the cost of social acceptance related to electricity generation facility siting.

Within the literature related to social acceptance, there are studies to estimate the economic value of facility siting, such as waste disposal siting, nuclear facilities, or renewables. The majority of previous studies related to social acceptance have focused on a specific type of energy facility, such as nuclear or wind. Studies that cover a wider range of energy sources simultaneously are lacking. Moreover, there are no studies that compare the social acceptance of different types of energy sources in terms of monetized value. From the policy maker's point of view, the energy mix or portfolio is an important issue. In other words, a comparison between different energy sources is required both qualitatively and quantitatively. In the situation in which there is social conflict on energy facility siting, regardless of what the energy sources are, an understanding and comparison of the social acceptance of a wider range of energy sources are critical. In this regard, a study that investigates the public's preferences for fossil fuel, nuclear, or renewable energy as a whole and compares them in monetized unit values is required.

Social acceptance is related to individuals' psychological issues and subjective valuation regarding certain issues rather than objective damage or risk in scientific terms. Therefore, individuals' heterogeneity or diversity in terms of valuation should be considered along with their heterogeneity or diversity in the value that they place on the issues. Accordingly, an economic model that makes it possible to reflect the heterogeneity of preference for energy sources and facility siting should be considered.

Considering the social acceptance of energy facility siting, it is intuitively understandable that the impacts of electricity facilities can be categorized as direct or indirect impacts on individuals. From the economic perspective, the social acceptance problem is due to the geographical inequality between the benefit that all the public enjoys and the cost that the local community endures. Consequently, the model should contain the concept of distance from the facility. In addition, Sagoff (1988) claimed that individuals essentially have at least two different preference orderings, private preferences and public preferences. The private preferences reflect only their own well-being as consumers of private goods, while the public preferences reflect moral values relating to what persons as citizens believe is right and just for the society as a whole. In their roles as citizens, people may express a rights-based belief system, which denies the principle of utilitarianism and instead recognizes the priority of the right over the good (Spash, 1997). Sundqvist et al. (2002) mentioned that this moral position of individuals is widely observed in many energy and environmental issues. Following this point of view, this study approaches the social acceptance of electricity facility siting in two different ways. Firstly, the general public's perspective will be considered, named the 'General Public Model.' From the point of view of society as a whole in a country, it can be measured by people's preference for or opposition to each form of power equipment and power source. In this respect, various studies have been conducted for each energy source, such as the analysis of people's preference for renewable energy, the determination of consumers' risk level of nuclear power, avoidance level of fossil fuels, etc. Secondly, the impact of an electricity facility that more directly affects the individual is considered. This kind of conflict is more practical and occurs in the region around the power plant location, such as the NIMBY phenomenon.

Aggregating all the necessary requirements to analyze the social acceptance of electricity facilities, this study applies the hierarchical bayesian mixed nested logit (HBNL) model. This methodology can cope with the restriction of the IIA assumption of multinomial logit and reflect individuals' heterogeneity, as well as a hypothetical decision tree that shows 'accept' of or 'opposition' to electricity facility siting. Academic research applying this methodology is difficult to find, to the author's best knowledge. Therefore, the result of this study can also contribute to the verification of the modeling power of the HBNL model.

Chapter 3. Methodology: Hierarchical Bayesian Mixed Nested Logit Model

This chapter explains the empirical model for analyzing the social acceptance of electric power facility siting. In order to reflect the hypothetical decision tree of the people and public's preference heterogeneity for certain attributes, the hierarchical bayesian mixed nested logit (HBNL) model is applied. This methodology is based on the mixed nested logit model but constructed with hierarchical bayes structure in order to make individual level draw of the parameters. The nixed nested logit model is a one of mixed GEV model which is proposed by Hess et al. (2005). However, the application of hierarchical bayes structure for mixed nested logit model is hardly found in previous research. Therefore, in this chapter, the structure and characteristics of HBNL model will be explained in the context of the purpose of this study. This chapter, firstly, discuss the limitation of multinomial logit model, which is regarded as the basis of the discrete choice model, in order to emphasize on the advantage of nested logit model. Secondly, the closed form of nested logit model will be explained in the context of the social acceptance of the electric power facility siting. Thirdly, the random coefficient model for nested logit structure for reflecting the preference heterogeneity will be discussed, and hierarchical bayes model for constituting individual level heterogeneity will be followed.

3.1 Discrete Choice Models for Coping with the Limitation of MNL

The discrete choice model is one of the most useful methods for analyzing consumer preference. Discrete choice models are based on random utility theory. It is assumed that each respondent faces a choice amongst J alternatives in each of choice situations and chooses the alternative that provides the highest utility (Huber and Train, 2001).

According to the Train (2003), the easiest and most widely used discrete choice model is logit. Among different logit models, multinomial logit (MNL) model is applied when decision-makers choose one alternative among J alternatives. In the utility function, the stochastic part is assumed to have an independently and identically distributed (IID) type-I extreme value distribution. The benefit of MNL is that it has the simple closed form of choice probability. Although the MNL model has the advantage which has a simple closed form of choice probability, it cannot adequately reflect consumer heterogeneity, and also has an unrealistic IIA assumption (Train, 2003). The evolution of discrete choice model is the process of coping with the limitation of MNL by developing the specification of model and underlying assumptions.

According to Hess et al. (2005), two main streams of model specification in discrete choice model can be categorized as the models concerned with the correlation between alternatives in the unobserved component in utility function and models concerned with allowing for tastes heterogeneity across decision-makers.

An appropriate treatment of the correlation structure is critical when a model is used for forecasting of market shares. In this regard, MNL model has the limitation. The unrealistic substitution patterns of the MNL model can cause the misleading of demand forecast if some correlation exists between the alternatives. The representative model for relaxing the correlation structure of MNL is generalized extreme value (GEV) model. The most widely used model in the GEV family is nested logit. This model has been applied by many researchers in a variety of field such as energy, transportation, housing, telecommunications, etc (e.g., Ben-Akiva, 1974; Train, 1986; Train el al. 1987; Forinash and Koppelman, 1993; Lee, 1999). Its advantage is the relatively simple functional form compared to other types of GEV models. The probit model can also solve this problem. The probit model is derived with the assumption of jointly normal distribution among unobserved components of utility function. It was firstly derived by Thurstone (1927) for a binary probit model and Marschak (1960) translated the terminology of psychological stimuli into economic terms as utility. Hausman and Wise (1978) and Daganzo (1979) elucidated the generalized specification for representing diverse aspects of choice behavior of consumers.

With respect to considering taste heterogeneity of consumers, the MNL model also has a limitation. In order to reflect the taste variation, many researches applied the interaction terms in the model specification (Kim et al., 2006; Ahn et al., 2006; Lee and Cho, 2009). The interaction term between the socio-demographic characteristics and attributes of the alternatives can explain the effect of attributes on utility differently by the socio-demographic characteristics. In modeling perspective for easiness of interpretation, it is preferable to use socio-demographic characteristics for explaining the taste variation of consumers (Hess et al., 2005). However, it involved the inherent randomness due to the non-quantifiable variation in limited number of data. If such heterogeneity is not explicitly reflected in the model, researchers can discard valuable information regarding heterogeneity in choice behavior as well as the risk of false conclusion (c.f. Hensher and Greene, 2003; Hess and Polak, 2004).

The mixed multinomial logit model can reflect the random taste variation by imposing a distribution on parameters which assume random coefficient of coefficient. The mixed MNL model has advantages such that: it allows assuming the distribution of each coefficient of variables, based on the ex-ante assumption for the impact of certain attributes on consumers (Train, 2003). In mixed MNL model, each coefficient can have different assumption of distribution such as normal, log-normal, or censored normal distribution. Therefore, it is possible to analyze more realistically by applying specific distribution according to a researcher’s hypothesis.

Hess et al. (2005) pointed out that the modeling works for reflecting correlation among unobservable components among alternatives and the taste heterogeneity among respondents have usually been treated in separate ways. In this regard, Hess et al. (2005) proposed mixed GEV model which can reflect both the correlation among unobservable component in utility function and taste heterogeneity explicitly. It is the integration of GEV-style choice probabilities over the distribution of taste coefficients (c.f. Chernew et al., 2001; Bhat and Guo, 2004).

3.2 Hierarchical Bayesian Mixed Nested Logit Model

3.2.1 Closed Form of Nested Logit Model

In order to reflect the hypothetical decision tree of the people, this study employed nested structure of discrete choice model. The nested logit model is useful for modeling the two stages of decision-making by people. At the first stage, people may decide the ‘accept’ or ‘opposition’ of the facility siting. If one choose the ‘accept’ at the first stage, then people may state their preference for one option among the possible alternatives. This nested structure can be specified within nested logit model specification. Therefore, in this section, the closed form of choice probability in the nested logit model will be discussed. The notification of the closed form of the nested logit model is followed by Train’s work (Train, 2003).

Based on random utility theory, the utility of an individual n by obtaining alternative j in a choice set of C_n can be defined as follows:

$$U_{nj} = V_{nj}(x_j) + \varepsilon_{nj} = \alpha + \beta_n x_j + \varepsilon_{nj} \text{ .} \cdots\cdots \text{Eq. (1)}$$

U_{nj} is the respondent’s utility by obtaining alternative j, and it can be divided into two parts: the deterministic utility V_{nj}, and the stochastic term ε_{nj}. The deterministic utility affected by the attributes of the alternatives, x_j, is a component that can be observed by the researcher. In order to set the stochastic term as mean zero, certain constant can be included. It is called as alternative specific constant (ASC) which refers to the average effect of the alternative to the utility.

Each respondent chooses an alternative that provides the highest utility to them. In this case, the choice probability that a consumer chooses alternative j is defined by Eq. (2):

$$\begin{aligned} P_{ni} &= \text{Prob}(U_{ni} > U_{nj} \ \forall j \neq i) \\ &= \text{Prob}(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \ \forall j \neq i) \\ &= \text{Prob}(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj} \ \forall j \neq i) \end{aligned} \quad \text{Eq. (2)}$$

Unlike the MNL model, the set of alternatives j in the nested logit model is partitioned into K nests, denoted as B_1, B_2,…, B_K. Therefore, the stochastic term ε_{nj} is different from that of MNL, which assumes the independent and identically distributed Gumbel (type-I extreme value) distribution. In the nested logit model, ε_{nj} is correlated with ε_{nm}, for any two alternatives j and m in the same nest. For any two alternatives in the different nests, however, the unobserved portion of utility is still uncorrelated such that $Cov\left(\varepsilon_{nj}, \varepsilon_{nm}\right) = 0$, for any $j \in B_k$ and $m \in B_l$ with $l \neq k$.

The stochastic part shows GEV-type cumulative distribution, which is presented as:

$$\exp\left(-\sum_{k=1}^{K}\left(\sum_{j \in B_k} e^{-\varepsilon_{ni}/\lambda_k}\right)^{\lambda_k}\right) . \quad \text{Eq. (3)}$$

, where λ_k is a measure of the degree of independence in unobserved utility among the alternatives in nest k.

λ_k can differ over nests, reflecting the different correlations among the unobserved factors within each nest. A higher value of λ_k indicates higher independence. When λ_k has a value of 1, there is complete independence within nest k. In this case, the nested logit model becomes the standard logit model. If $0 \le \lambda_k \le 1$, the model is consistent with utility-maximizing behavior for all the possible values of the explanatory variables. In case of $\lambda_k > 1$, the model can be consistent with utility maximizing behavior for a certain range of the explanatory variables but not for all the values. If $\lambda_k < 0$, however, the model is not consistent with utility maximization.

The choice probability for alternative $i \in B_k$ is calculated as Eq. (4).

$$P_{ni} = \frac{e^{V_{ni}/\lambda_k}\left(\sum_{j \in B_k} e^{V_{nj}/\lambda_k}\right)^{\lambda_k - 1}}{\sum_{l=1}^{K}\left(\sum_{j \in B_l} e^{V_{nj}/\lambda_l}\right)^{\lambda_l}} \quad \text{Eq. (4)}$$

As previously mentioned, this study employed the logical tree of decision making regarding the electric power facility siting. In this regard, the choice probability of nested logit model as shown in Eq.(4) can be decomposed by two probabilities such that such that $P_{ni} = P_{ni|B_k} P_{nB_k}$. $P_{ni|B_k}$ indicates the conditional probability of choosing alternative *i*, given that an alternative in nest B_k is chosen. P_{nB_k} refers to the marginal probability of choosing an alternative in nest B_k .

According to the decision tree of the nested logit model, the choice probability for each component can be decomposed as follows;

$$P_{nB_k} = \frac{e^{\lambda_k I_{nk}}}{\sum_{l=1}^{K} e^{\lambda_l I_{nl}}} \quad \cdots\cdots \text{Eq. (5)}$$

$$P_{ni|B_k} = \frac{e^{V_{ni}/\lambda_k}}{\sum_{j \in B_k} e^{V_{nj}/\lambda_k}} \quad \cdots\cdots \text{Eq. (6)}$$

, where $I_{nk} = \ln \sum_{j \in B_k} e^{V_{nj}/\lambda_k}$.

By flowing the decomposition of the choice probability, P_{nB_k} can be regarded as the choice probability at the stage 1, which is 'accept' or 'opposition.' Accordingly, $P_{ni|B_k}$ indicates the choice probability of the alternative i give nest, which is 'accept.' In this study, the empirical model is constructed as the one that has no ASC (model 1), and the one that has the specific types of energy sources such as fossil fuel, nuclear, and renewable as the ASCs (model 2), and the one that has the ASCs as the name of specific energy sources such as coal, gas, nuclear, wind, PV, and biomass (model 3). Figure 4 presents this decision tree and nested structure of the empirical model.

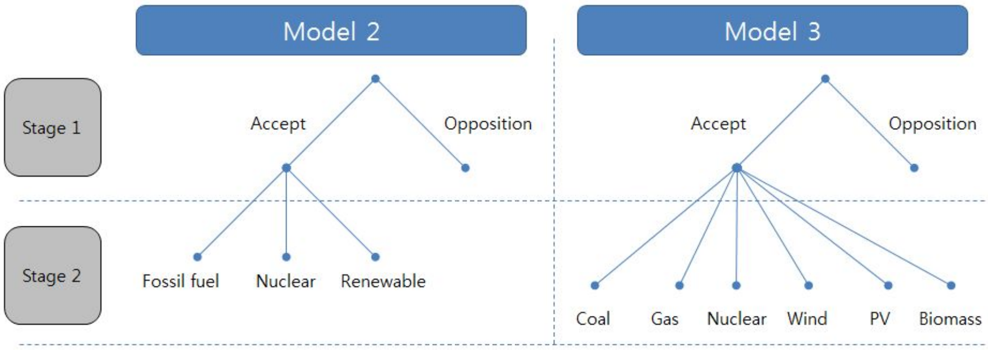

Figure 4. Decision tree of the empirical model (Model 2, Model 3)

3.2.2 Mixed Nested Logit Model

The traditional nested logit model can reflect the inter correlation structure by relaxing the IID assumption of MNL. However, it cannot represent the random taste variation. In order to reflect the heterogeneity, the random coefficient model is applied to the nested logit model. Similar to the mixed logit and probit models, the mixed nested logit model allows random coefficients, of which the distribution in the population is estimated. Mixed nested logit is a mixture of the nested logit function evaluated at different β with $f(\beta)$ as the mixing distribution.

The choice probability of the mixed nested logit model is the integrals of standard nested logit probabilities over a density of parameters as follows:

$$P_{ni} = \int L_{ni}(\beta) f(\beta) d\beta \text{ ······························· Eq. (7)}$$

,where $L_{ni}(\beta) = \dfrac{e^{V_{ni}/\lambda_k}\left(\sum_{j \in B_k} e^{V_{nj}/\lambda_k}\right)^{\lambda_k - 1}}{\sum_{l=1}^{K}\left(\sum_{j \in B_l} e^{V_{nj}/\lambda_l}\right)^{\lambda_l}}$ which is the nested logit probability evaluated at parameters β.

If the utility is linear in β, the choice probability is simply expressed as Eq. (8).

$$P_{ni} = \int \left(\frac{e^{V_{ni}/\lambda_k}\left(\sum_{j \in B_k} e^{V_{nj}/\lambda_k}\right)^{\lambda_k - 1}}{\sum_{l=1}^{K}\left(\sum_{j \in B_l} e^{V_{nj}/\lambda_l}\right)^{\lambda_l}} \right) f(\beta) d\beta \text{ ······················ Eq. (8)}$$

When $f(\beta)$ is assumed to be a continuous random variable that has a specific distribution, then the mean and variance of β and λ_k should be estimated, which are denoted as θ in $P_{ni} = \int L_{ni}(\beta) f(\beta) d\beta$.

In the same way as for the mixed logit model, $f(\beta)$ can be a specific distribution such as lognormal, uniform, triangular, gamma, etc, and β refers to the tastes of individual decision makers (Train and Sonnier, 2005).

As previously discussed, Lahiri and Gao (2002) pointed out that maximizing the likelihood function for the nested logits is often difficult numerically, and the mixed model will compound the difficulty as well. Train (2003) suggested that hierarchical bayes estimation could prove particularly useful in this situation, since it does not involve maximizing the likelihood function. In the following section, this study will discuss the hierarchical bayesian approach to estimating this mixed nested logit model.

3.2.3 Hierarchical Bayes Structure for Mixed Nested Logit Model

The hierarchical bayes (HB) model is a hierarchical model analyzed using bayesian methods. Dong (2007) explained that the HB method has advantages such that it provides individual-level parameters so that inferences of the parameters can be easily acquired. According to Allenby and Rossi (2006), the hierarchical model has two levels; at the higher level, individual's part worth is described by multivariate normal distribution characterized by a vector of means and a matrix of covariance; at the lower level, given an individual's part worth, the choice probability for particular alternative is calculated under the model specification such as multinomial logit or nested logit. In short, the advantage of the HB model compared with the traditional discrete choice model is that it is possible to investigate the individual part worth values to assess the heterogeneity among consumers.

Following the approach developed by Allenby (1997) and generalized by Train (2001), the hierarchical model will be explained. As previously mentioned, an individual's part worth at the higher level is described by multivariate normal distribution. Let β be assumed to have the covariates $\mathbf{Z}_n$ such that it shows as Eq. (9):

$$\beta_n = \Gamma \mathbf{Z}_n + \xi_n, \qquad \xi_n \sim MVN\left(0, \Sigma\right) \quad \text{Eq. (9)}$$

, where Γ is the matrix of coefficients that relates β_n to the value of $\mathbf{Z}_n$. $\mathbf{Z}_n$ is the vector of covariates that account for observed heterogeneity, and ξ_n is an unobserved heterogeneity component that is assumed to be the multivariate normal distribution (Allenby and Ginter, 1995). The covariates can include respondent demographics.

This hierarchical model structure is estimated by bayesian method. Bayes's theorem, as shown in Eq. (10), serves as the basis of the bayesian estimation procedure.

$$P(\theta|Y) = \frac{P(Y) \times P(Y|\theta)}{P(Y)} \quad \text{Eq. (10)}$$

, where Y and θ represent the observed data and the parameters to be estimated, respectively. $P(\theta)$ is the assumed distribution of unknown parameters, also called the prior distribution; $P(Y|\theta)$ is the likelihood function that indicates the distribution of the data conditional on the parameters; and $P(\theta|Y)$ is the updated prior distribution by the likelihood, also called the posterior distribution. Because $P(Y)$ is made a constant so as to make the posterior a probability distribution, Eq. (11) is written simply as

$$P(\theta|Y) \propto P(Y) \times P(Y|\theta)\,. \cdots\cdots \text{Eq. (11)}$$

In order to estimate the parameter, bayesian estimation procedure that applied Markov chain Monte Carlo (MCMC) Gibbs sampler can be used. According to Choi (2009), this consists of the three steps as shown in Eq. (12):

$$\begin{array}{l} \Gamma|\Sigma,\beta_n \\ \Sigma|\beta_n,\Gamma\,. \\ \beta_n|\Gamma,\Sigma \end{array} \qquad \cdots\cdots \text{Eq. (12)}$$

The prior distributions of Γ and $\Sigma|$ are assumed to be normal and inverse-Wishart distributions, respectively. Their conditional distributions can be denoted as follows:

$$\Gamma|\Sigma,\beta_n,Z \quad \forall n = \gamma|\Sigma,\beta,Z \quad \forall n \quad Normal(\gamma^*,S) \cdots\cdots \text{Eq. (13)}$$

,where $\beta = (\beta_1^{'},\beta_2^{'},\ldots,\beta_n^{'},\ldots,\beta_N^{'})^{'}$, $\gamma^* = S(Z^{*'}(I \otimes \Sigma^{-1})\beta)$, $S = (Z^{*'}(I \otimes \Sigma^{-1})Z^*)^{-1}$, $Z^* = (Z_{l=1} \otimes I, Z_{l=2} \otimes I, \ldots, Z_{l=n} \otimes I)$, and

$$\Sigma \left| \beta_n, \Gamma \quad \forall n \quad InvertWishart\left(K + N, (KI + N\overline{S})/(K + N) \right) \right. \text{......................Eq. (14)}$$

, where $\overline{S} = (1/N)\sum_{n}(\beta_n - \Gamma\mathbf{z}_n)(\beta_n - \Gamma\mathbf{z}_n)'$ and K represents the number of random variables.

Chapter 4. Empirical Analysis

4.1 The Structure of Empirical Analysis

In this chapter, an empirical analysis of electricity generation facility siting in Korea is conducted by applying the HB mixed nested logit model. Since Korea's electricity demand is growing faster than that of any other country, it is essential to construct new power plants in order to meet the demand for electricity. Nowadays in Korea, however, there are a variety of conflicts related to social acceptance in connection with the power plant issue. This study estimates the cost of social acceptance of energy sources that would demonstrate an important role in the future energy power mix.

Since the main cause of the social acceptance problem is the perceived imbalance of mostly local burdens versus mostly regional or national benefits, modeling needs to be undertaken of the difference in the two groups of people who live near the facility siting area and people who live far away (Sandman, 1986). Furthermore, following the claim of Sagoff (1988) that the preference can be distinguished as public preference and private preference, this study sets two different empirical models: first, the 'General Public Model,' which represents the psychological cost of the consumer once the power source in the country's total energy mix increases by the construction of one unit electricity generation facility; second, the 'Local Residence Model,' which means the cost of psychological risks, once the facility is located near the residence of the consumer. In accordance with the conceptual construction of these two models, each model has different attributes in the empirical study.

From the modeling perspective, the HB mixed nested logit model is applied. In reality, the logical structure of thought regarding energy facility siting seems to consist of two stages: the first stage, which decides the ‘acceptance of’ or ‘opposition toward’ the facility; and the second stage, which involves deciding on or showing a preference for one option among the possible alternatives. In this regard, the nested structure is more appropriate to describe the real choice situation.

Regarding the real choice situation, it seems that people will consider the name of energy sources, rather than the combination of the attributes. Accordingly, the empirical model is constructed as one that has unlabeled alternatives and no alternative specific constant (ASC), named Model 1, and another that has labeled alternatives with ASCs in the empirical mode. In order to figure out the effect of specific types of energy sources, the ASC model is divided into different levels such that one contains the type of energy source, for instance fossil fuel, nuclear, and renewable (Model 2), and another one contains six different energy sources: coal, gas, nuclear, wind, PV, and biomass (Model 3). This approach is applied to both the General Public Model and the Local Residence Model. To gain stated preference data, a conjoint survey was conducted of 1,000 people nationwide. The details are presented in the next section.

4.2 Survey Design and Data Collection

In order to analyze the social acceptance of electricity facility siting for different energy sources, the conjoint analysis method is applied. Conjoint analysis is widely used in various fields, including marketing (Green and Srinivasan, 1990; DeSarbo et al., 1995), transportation (Hensher and Greene, 2001) and environmental studies (Hanley et al., 1998; Layton and Brown, 2000). In conjoint analysis, hypothetical situations are presented to respondents in order to generate stated preference data for products or services that are generally not available in the market. The general procedure for conjoint analysis is as follows: firstly, the important attributes are determined and appropriate levels for each attribute are concluded; secondly, by using the attributes and their levels, a hypothetical alternative set is developed from the combination by applying the full factorial design method; and lastly, the conjoint survey is conducted to collect the data. In each choice task, the respondent compares the alternatives and chooses the one that provides the highest utility (Bennett and Blamey, 2001).

4.2.1 Attributes and Levels in the Conjoint Survey

The social acceptance in this study represents the public's valuation of the social impacts of an electricity facility. In addition, these impacts can be regarded as the major causes of social conflict if the acceptor's value and the planner's value are different. In this regard, the attributes in the choice experiment are derived through the review of the previous literature related to social acceptance and the social dimension of the sustainability indicator. As previously mentioned, there is a lack of research on choice experiments that deal with diverse energy sources related to the social acceptance problem. The majority of studies set the attributes as certain energy specific impacts, such as a visual impact and noise for wind, heat and water for coal, etc. Therefore, the studies related to the social dimension of sustainability indicators are also reviewed.

Since this study includes a variety of energy sources instead of setting a narrow scope, the selection of appropriate levels is important. While some energy sources have a very small impact, other energy sources can have a great impact. For example, GHG emission is mostly a result of the use of fossil fuel. However, renewable and nuclear energy show relatively small amounts of GHG emission. Consequently, it is conducive to set the absolute level of each attribute for different energy sources; then, a realistic and feasible range of levels can be concluded.

4.2.1.1 General Public Model

In the General Public Model, the social acceptance indicates that the public's psychological value if a certain power plant is increased one unit among the national energy mix. Therefore, the presence of long distance power plants affects the entire of country, rather than influencing each individual directly. Therefore, the attributes in the general public model are constructed as the impact on the entire country.

The first attribute in general public model is 'new job creation', denoted as employment. The construction of a new power plant requires a large amount of new manpower from the construction stage and during its operation and management stage. This attribute has been used in many previous studies. In order to set the appropriate levels for each energy source, comprehensive data on the employment effect of each energy source is required. However, it seems that there is no global consensus, the exact number of impacts has not been clearly concluded, and there is a difference due to site-specific impacts. Wei et al. (2010) reviewed the 15 previous studies related to the employment impact of energy technologies and suggested a range of employment impacts for each energy source. The general trend is that renewable energy shows a higher employment impact compared with fossil fuel and nuclear energy. Though there are different views on biomass, it makes sense that biomass needs more people when we consider the operation of fuel production.

The second attribute in the conjoint model is 'greenhouse gas (GHG) emission.' The electricity sector is responsible for a large amount of domestic GHG emissions, so the operation of new electricity generation facility causes additional GHG emission. Because the alternatives are set by comparing them with no-accept option, the amount of GHG emission from each energy source can be a guideline to set the appropriate levels. Based on the IAEA (2006) and KEPCO (2010), the GHG emission per unit of electricity generation (kWh) is considered.

Thirdly, 'land occupation' is used as an attribute. The construction and operation of an electricity facility requires a large extent of land. The land occupation in this research includes the long-term land occupation for the electricity generation facility and forest damages. Hirschberg et al. (2004) and Evans et al. (2009) showed the amount of land occupation for each energy source of electricity. Shin et al. (2014) also mentioned the size of land occupation for renewable energy.

In terms of a reliable energy supply, this study considers 'the duration of annual electricity outage' as the fourth attribute. It is arguable which indicator is appropriate to measure the reliability of the electricity supply. The Presidential Council for Future & Vision (2012) suggested the capacity factor and electricity system stability as a measure of a reliable electricity supply. However, this is not a good measure for the general public to understand the concept of electricity reliability. Therefore, we alternatively consider the duration of electricity outage in a year, denoted as the supply limit, which has been used in several social acceptance studies on renewable energy (e.g., Longo et al., 2008; Shin et al., 2014). These previous studies mentioned that the large portion of renewable energy in the energy mix causes the increasing probability of power outage due to the intermittent characteristic of renewable energy. The base level of this attribute is set as the current annual outage duration, and the duration of electricity outage for each energy options is assumed, based on the capacity factor of each energy sources.

The last attribute is 'the monthly electricity bill,' and it is used as a cash vehicle to measure the marginal willingness to pay (MWTP) for other attributes. It is assumed that each energy option will produce one TWh in a year and estimated the reasonable impact of the final electricity price to consumers, based on the unit cost of electricity generation for each energy sources. The levels are presented as the absolute changes as well as the percentage changes from the hypothetical average monthly electricity bill, 50,000 KRW (Korean Won). It is assumed that renewable energy will increase the monthly electricity bill due to its high unit generation cost, and base load sources such as coal and nuclear will reduce the bill. The final set of attributes in general public mode is presented in Table 5.

Table 5. Definition of the attributes in the General Public Model

Attributes	Definitions	Unit of attributes
Employment	The number of new jobs resulting from a new facility construction and operation	Person/year·TWh
GHG emission	The amount of increasing CO2 emission, generated by the new electricity facility	ton CO_2 eq./TWh
Land occupation	Required size of land occupation for producing a unit of electricity	km^2/TWh
Supply limit	The degree of reliable electricity by the measure of the annual electricity outage duration per household	Minute/year
Electricity bill	Monthly electricity bill	10,000KRW/month

Presenting a realistic level of alternatives is important, since it affects to the result of people's preference and accordingly to the MWTP for each attributes. Conventionally, the levels of attributes are independent of the different alternatives in conjoint analysis. In this study, however, several attributes are clearly dependent on the characteristics of the alternatives; for example, GHG emission is absolutely high for fossil fuel and low for renewable and nuclear energy. With the generic conjoint design, the alternatives in the model including alternative names are unrealistic and thus may cause the distortion of respondents' concentration on survey process. To cope with this problem, the alternative-specific design (ASD) method is applied to the models which include ASC variables.

According to Carson and Louviere (2011), ASD enables the attributes' parameters to be specified to be the same for some, but not all effects. ASD is discussed in the choice experiment design literature accompanied by labeled choice experiment (Louviere et al., 2000; Hensher et al., 2005). The practical uses of ASD can be found in some recent literature. Kosenius and Olikainen (2012) studied the social acceptance of renewable energy by choice experiment. They considered different renewable options, such as wind, biomass (crop, wood), and hydro, with the attributes of local diversity, GHG emission, local job creation, and a change in the electricity bill. As the authors claimed, renewable energy has different levels of impact regarding the attributes considered. Therefore, the level of each attribute is set to be different for each alternative, except for the price term. Jung et al. (2012) also used ASD in their studies on car options. They considered gasoline, hybrid, and electricity vehicle as alternatives with the attributes of the price of the car, fuel cost, and availability of fueling or charging stations. The levels of these attributes were set to be different for each alternative. Both studies constructed the coefficient of attributes as fixed for different alternatives. Following the theories and previous literature related to ASD, this study attempts to set the different levels for each energy alternatives. In the case of the unlabeled choice experiment (model 1), there is no need to consider ASD. Table 6 shows the levels of each attribute for the alternatives.

Table 6. The levels of the attributes in the General Public Model

Attributes (Units)	Levels of attributes in the empirical model		
	Model 1	Model 2	Model 3
Employment (person/ year·TWh)	1,000 /2,000 /3,000	Fossil: 1000/2000/3000 Nuclear: 1000/2000/3000 Renewable: 2000/2500/3000	Coal, Gas: 1000/1500/2000 Nuclear: 1000/1500/2000 Wind, PV, Bio: 2000/2500/3000
GHG emission (ton CO_2 eq./ TWh)	100 /500 /900	Fossil: 500/700/900 Nuclear: 10/30/50 Renewable: 10/50/100	Coal: 800/900/1000 Gas: 400/500/600 Nuclear: 10/30/50 Wind, PV, Bio: 10/50/100
Land occupation (km^2/TWh)	10 /50 /80	Fossil: 5/7/10 Nuclear: 5/7/10 Renewable: 50/70/90	Coal, Gas: 5/7/10 Nuclear: 5/7/10 Wind, PV, Bio: 50/70/90
Supply limit (minutes/year)	30 /60 /90	Fossil: 10/15/20 Nuclear: 10/15/20 Renewable: 40/50/60	Coal, Gas: 10/15/20 Nuclear: 10/15/20 Wind, PV, Bio: 40/50/60

Electricity bill (10,000KRW/ month)	4.8 /5.2 /5.5	All: 4.8/5.2/5.5	Coal: 4.7/4.8/4.9 Gas: 5.1/5.2/5.3 Nuclear: 4.7/4.8/4.9 Wind, PV, Bio: 5.2/5.4/5.6

Following the specification of the attributes and levels, the choice tasks were formed by combining the levels following the experimental design procedure. By using the full factorial design, the final choice set was constructed. The tasks were blocked into six blocks of three choice tasks, and the blocks were divided into two types. The sample of respondents was divided into two groups such that one group would have the first type of choice block and the other group would have a different choice task.

4.2.1.2 Local Residence Model

Unlike the general public model, in the local residence model it is assumed that the electricity generation facility will be sited near to the area where the respondents currently live. A hypothetical situation is provided such that the facility will be sited within 5km from their living location. The area of 5km is the official area of government support under the law for improving the social acceptance of electricity sector. Accordingly, it is expected that the respondents will consider the more direct effect from an electricity generation facility in their choice situation. Therefore, in terms of modeling the choice experiment for the social acceptance in the local residence model, the attributes should be closely related to the direct impact that the households should endure. According to Jung (2000), the main factors of social acceptance for LULU facilities can be categorized into economic factors, individuals' psychological factors and the political legitimacy that covers the democratic decision-making process, the outer hierarchy. Following his study, the attributes in the local residence model are selected as psychological risk (risk to the environment, health, and quality of life), economic factor (compensation), and political legitimacy itself.

The first attribute in the local residence model is 'local environmental damage.' The siting of an electricity generation facility and its operation cause diverse forms of local environmental damage since electricity generation facilities produce many pollutants, including SOx, NOx, etc. These pollutants cause acidification and eutrophication, which affect the local environment, and such damage leads to diverse ill effects, such as deterioration of the local biodiversity. As a measure of local environmental damage, Hirschberg et al. (2004) suggested the indicator of changes in the unprotected ecosystem area that is in the regional environmental impact area and reported its impact for each energy source. Following this study, the attribute of local environmental damage is defined as the range of the area affected by acidification and eutrophication due to the pollutants from each electricity generation facility.

Another critical impact is 'human health damage,' and this is the second attribute in this model. In European studies, the estimation of the human health impact has largely been conducted based on the bottom-up approach of ExternE project (EC, 1995). Various studies have dealt with this concept as years of life lost (YOLL) per unit of electricity generation. Hirschberg et al. (2004) also reported the human health impact of each energy sources in terms of YOLL per GWh. Taking into consideration other previous studies dealing with the human health impact, this study adopts the levels of this attribute as shown in Table 7.

Local residences near to an electricity generation facility may experience diverse forms of inconvenience due to its operation. The major factors of the inconvenience are vibration and noise for fossil fuel, noise and visual amenity for wind and PV, etc. These are directly related to the quality of life for the local residences; therefore they should be considered as an important attribute in this model. Hirschberg et al. (2004) also mentioned local disturbance as one of the sustainability indicators, referring to noise and visual amenity, presenting a relative scale between one and fifteen. Following their study, this study sets three levels of inconvenience, named ‘quality of life’ in the attribute, as high, medium, and low.

The electricity generation facility siting process is mostly accompanied by conflict between the subject of business, such as the local government or utility companies, and the local community. Therefore, it is important to follow a democratic process of decision making and thus secure political legitimacy. The importance of the legitimacy of decision making is widely mentioned in diverse academic areas, such as public administration, psychology, and economics (Mazmanian and Sabatier, 1989). Regarding the importance, the ‘legitimacy of decision making’ is set as the fourth attribute in this model.

With respect to the cash vehicle, this study considers the amount of compensation, since compensation works as a social acceptance mechanism that compensates for the diverse damage to the local residence due to the siting and operating of electricity generation facilities. There is the arguable issue of the payment vehicle regarding whether willingness to pay (WTP) or willingness to accept (WTA) is a more suitable measure of environmental valuation. Willig (1976) proved that the difference between WTP and WTA in the price change is the function of the elasticity of income, and in a reasonable range there is no great difference between WTP and WTA. However, Hanemann (1986) showed that the difference between WTP and WTA is the function not only of income elasticity but also of elasticity of substitution. In his conclusion, it can be interpreted that WTP and WTA can differ according to the characteristics of goods. The general consensus on this issue is that WTP is a more appropriate measure of the valuation of environmental goods. Although this discussion is still arguable in the economic context, various studies still use compensation as a cash vehicle; especially, the studies dealing with NIMBY or LULU widely use compensation as a cash vehicle (c.f. Sergio and Vito, 2012). With regard to the mechanism of compensation in the social acceptance problem, this study adopts ‘compensation’ as the cash vehicle.

Table 7 shows the attributes and their levels in the local residence model. Since the absolute magnitudes of attributes for the considered energy resources are not significantly different, the generic conjoint design method is applied in local residence model, unlike the ASD of general public model.

Table 7. The attributes and their levels in the Local Residence Model

Attributes	Definitions	Levels of attributes (Units)
Environmental damage	The range of the area affected by acidification and eutrophication due to the pollutants from each electricity generation facility.	10/20/30 (km^2/TWh)
Health damage	The reduction of health condition due to the pollutants from electricity generation facility operation.in terms of YOLL and converted into dying persons.	5/10/15 (Person /mil.people·TWh)
Quality of life (disamenity)	The degree of disamenity in daily life due to noise, vibration, visual impact, etc.	High/Medium/Low
Legitimacy of decision making	Transparency, fairness, and the participation of the local community or residents in the facility siting process	Yes/No
Compensation	The amount of compensation for diverse forms of damages and drop of property rights (Rum-sum payment at the stage of decision-making)	500/700/900 (mil. KRW)

4.2.2 Data Collection

4.2.2.1 Survey Procedure

The conjoint survey was conducted in May 2013 by a professional survey firm. The survey was implemented using face-to-face interview with members of 1,000 households aged from 20 to 65. The sample was randomly drawn nationwide proportionally to the population characteristics. To assure the quality of responses, survey supervisors conducted phone verifications with a random selection of 777 respondents among the total 1,000 samples after completing the survey. For verification of the quality of survey, supervisors of the survey asked the respondents whether the investigator conducted the survey using the proper process, and they requested some missing items to mitigate the non-response problem. They also asked several questions using survey questionnaires to verify the consistency of the responses. Table 8 shows descriptive statistics of the analyzed samples in this study.

Table 8. Descriptive statistics of the survey respondents

Categories		Statistics
Gender	Male	509 (50.9%)
	Female	491 (49.1%)
Age	20–29	31 (3.1%)
	30–39	232 (23.2%)
	40–49	394 (39.4%)
	50–59	269 (26.9%)
	60 above	74 (7.4%)
Residence Area	*Seven metropolitan areas*	
	Seoul	236 (23.6%)
	Busan	82 (8.2%)
	Daegu	54 (5.4%)
	Incheon	57 (5.7%)
	Gwangju	33 (3.3%)
	Deajeon	34 (3.4%)

	Ulsan	20 (2.0%)
	Five provinces excluding metropolitan areas	
	Gyeonggi–province	231 (23.1%)
	Gangwon–province	27 (2.7%)
	Chungcheong–province	54 (5.4%)
	Jeolla–province	59 (5.9%)
	Gyeongsang–province	113 (11.3%)
	Middle school or less	46 (4.6%)
Education	High school	34 (3.4%)
	College or more	527 (52.7%)

4.2.2.2 Questionnaires

In the conjoint survey, background information regarding the social impact of electricity was presented. The background information should be closely related to the attributes of the model such that each attribute is described along with the definition and range of its levels. It was also emphasized to the respondents that they needed to judge using the presented attributes rather than only focusing on the name of the energy sources.

In the choice question, a dual response method was applied because, when the no-choice option is selected, no information is obtained on the relative attractiveness of the available alternatives. With the dual response method, firstly, the respondents chose their preferred option among the presented alternatives in a forced choice task. To obtain more information, the respondents made a rank-ordered choice among the given alternatives. In the next question, an opt-out option was provided by asking whether s/he would actually accept the most preferred option in the alternatives to the first question. Brazell et al.

(2006) pointed out that researchers can employ the dual response approach, taking advantage of the increased power of estimation, without concern for systematically biasing the resulting parameter estimates by enforcing the respondents to pay attention to the choice task compared with presenting the opt-out option at the same time.

In addition to conjoint questions, questions on the respondents' general attitude toward electric energy sources were posed. The questionnaires were based on diverse previous literatures and mostly the MIT/Harvard Energy Survey 2008, and they included the knowledge, perceived cost, perceived environmental harm, perceived health risk, and trust in the local government, etc. The results of these questions will be discussed in the empirical result section. The socio-economic characteristics of the respondents are also collected in terms of sex, age, education years, household income, and current monthly electricity bill.

4.3 Empirical Results

In this section, the empirical results are discussed. Public's general attitude on the electricity resources and energy facility siting issues will be presented first, and then the estimation results of social acceptance models with HB nested logit model will be discussed. Finally, the cost of social acceptance will be calculated based on the theory of social conflict regarding the electricity facility siting.

4.3.1 Public's Attitude toward Energy Resources and Energy Facility Siting

For six different energy sources, such as coal, gas, nuclear, wind, PV, and biomass, the public's general attitude and perceptions were asked to respondents. The questions consisted of the previous knowledge, perceived cost, perceived risk in terms of environment health, and the trust in the government for the six different energy sources. These attitudinal variables were measured using 5 point likert scales; as 1 for representing the most negative one and 5 for representing the most positive one.

Previous knowledge about energy resources

Question: *How well do you know each energy sources?*

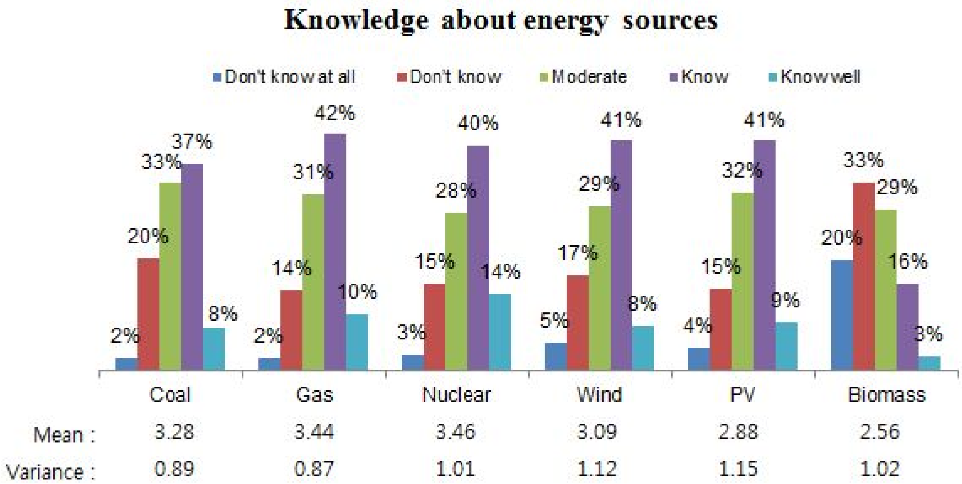

Figure 5. Public's attitude toward knowledge about energy sources

Respondents are inclined to know traditional energy sources such as coal, gas, and nuclear power better than renewable energy sources. Among six energy sources, people have the more knowledge about nuclear power than others, while respondents have the most lack of knowledge about biomass.

Perceived cost of each electricity sources

Question: *What do you think about generation cost of each energy sources?*

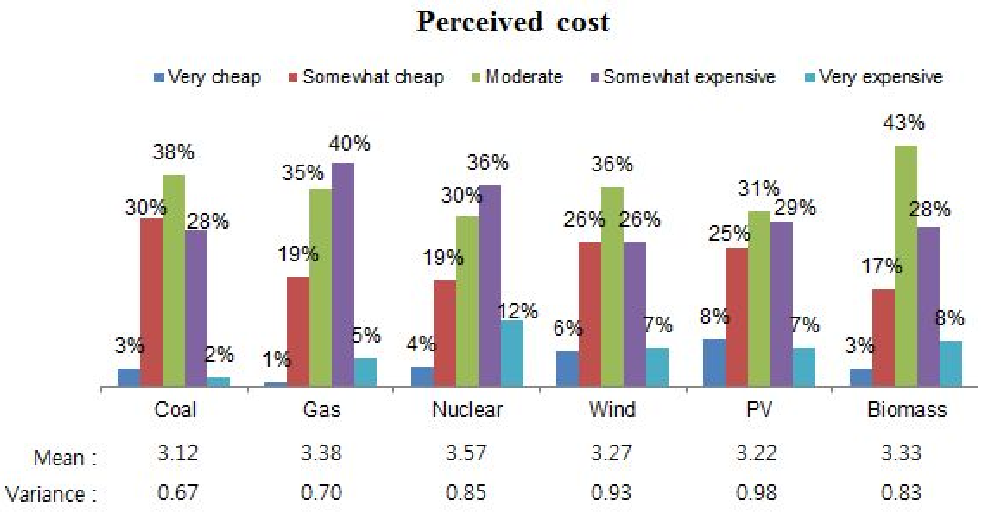

Figure 6. Public's attitude toward perceived cost

Among six energy sources, respondents perceive that the nuclear energy is the most expensive energy source. This result is opposite with the current private cost data that is the nuclear energy is the cheapest energy source. Therefore, it is found that public's perceived cost for nuclear energy is different with the realized market value. Another base-load energy source, coal, is regarded as the cheapest energy source from public as consistent with the private cost data. Among three renewable energies, respondents think that biomass is the most expensive energy source, followed by wind and PV. Regarding the private cost of renewable energy, PV is the most expensive energy source due to the large portion of the capital cost. However, it is shown that people do not recognize this since responses from respondents show that PV is the cheapest energy among renewables. The high portion of response 'moderate' to biomass seems to reflect the lack of knowledge of biomass in Figure 5.

Perceived environmental harm

Question: *How do you think of the environmental harm of each energy source?*

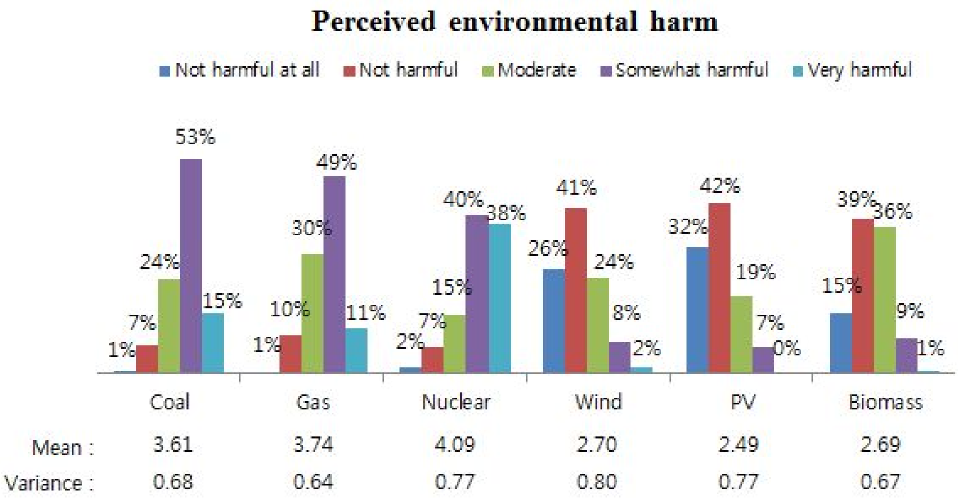

Figure 7. Public's attitude toward perceived environmental harm

According to the result of perceived environmental harm of each energy source, the traditional energy sources are more harmful to environment than renewable energy sources. Among six energy sources, respondents regard nuclear energy as the most harmful energy source to environment. This result is opposite with the result of previous externality assessment studies that showed the nuclear energy have the least environmental external cost. Therefore, the disparity between public's perceived risk and scientific data is found by this result. It should be noted that gas is regarded as more harmful energy source to environment than coal, which is also opposite result with previous externality studies. Among renewable energies, respondents regard that PV is the least environmentally harmful energy source. Biomass shows high portion of response 'moderate', which also may reflect the lack of knowledge on biomass.

Perceived risk of health and safeness

Question: *How do you think about each energy source regarding the negative impact on health and safeness?*

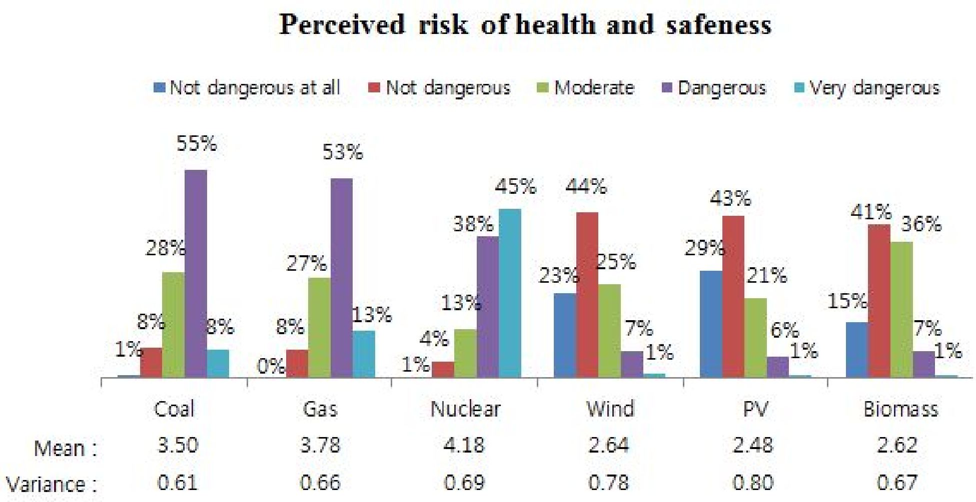

Figure 8. Public's attitude toward perceived risk of health and safeness

According to responses, respondents think that renewable energy is relatively not dangerous to their health and safeness compared with the traditional energy sources. Among six energy sources, nuclear power is regarded as the most dangerous energy sources to their safety and health. This result may reflect the public's concerns about the severe accident risk. This is also found in case of gas, which seems to have large amount of damage if severe accident occurs. The portion of response 'moderate' in biomass shows relatively high consistently with other results, and it can be regarded as the lack of knowledge on biomass.

Trust in appropriate assessment for energy technology

Question: *Do you think that government assesses usefulness and dangerousness of each energy sources appropriately?*

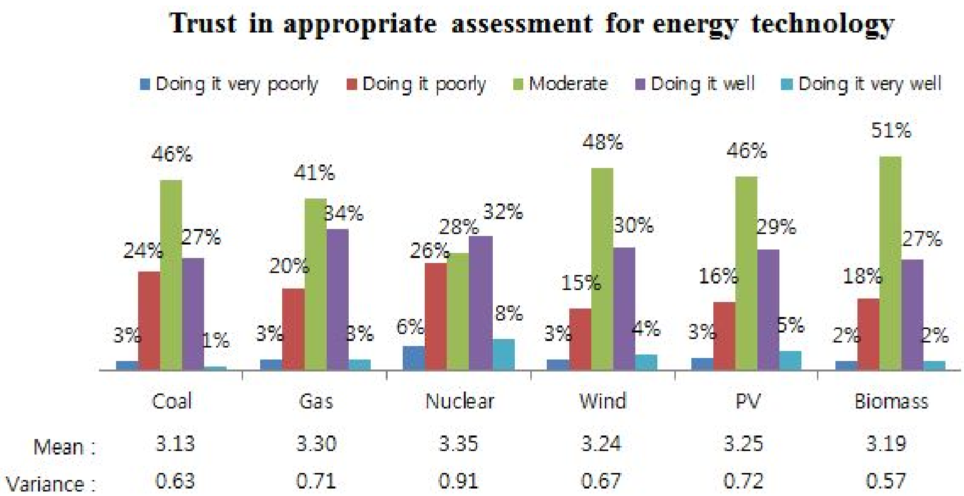

Figure 9. Public's attitude toward trust in proper assessment for energy technology

Generally, the response of ‘moderate’ takes a high proportion of answers in most energy sources, but in the case of nuclear power, its portion is relatively low. If the mean of responses is considered to analyze public’s attitude toward trust in appropriate assessment, respondents seem to regard that nuclear energy is most appropriately assessed energy source. However, the proportion of negative and positive answers except for the response ‘moderate’ shows the highest proportion for both directions in that 32% of responses are negative, and 40% of responses are positive. In addition, the response toward nuclear energy shows the highest variance indicating that the public’s opinion of trust in appropriate assessment of usefulness and dangerousness is heterogeneous more than other energy sources.

Political legitimacy in facility siting process

Question: *Do you think that power plant siting is processed fairy and democratically?*

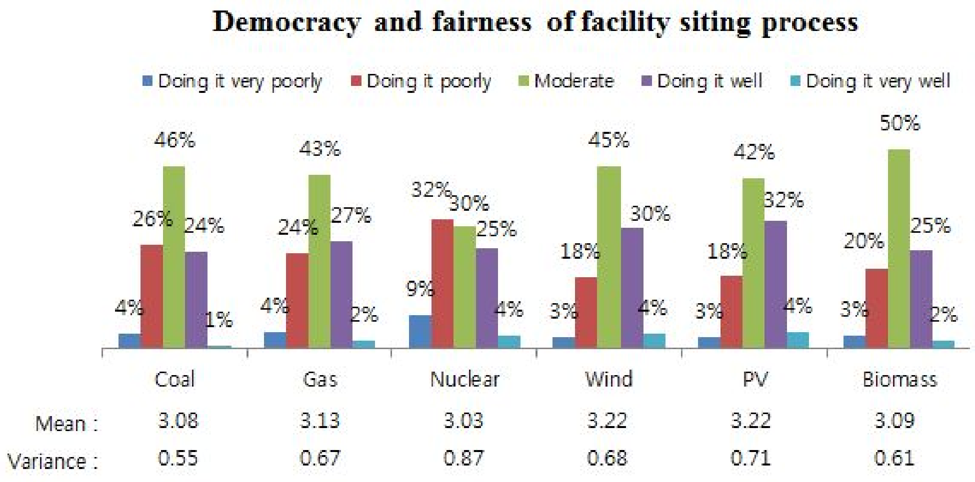

Figure 10. Public’s attitude toward democracy and fairness of facility siting process

For most of energy sources, the proportion of response ‘moderate’ is relatively high except for nuclear energy. Comparing the traditional energy sources with renewable energy, the facility siting process for renewable energy is regarded as more fairly and democratically processed than traditional energies. Among six energy sources, respondents regard that the democracy and fairness of facility siting process is most poorly secured for nuclear energy.

Preference for energy sources in energy mix

Question: *Do you think whether a proportion of the each energy sources in energy mix should be increasing or decreasing to meet increasing energy demand?*

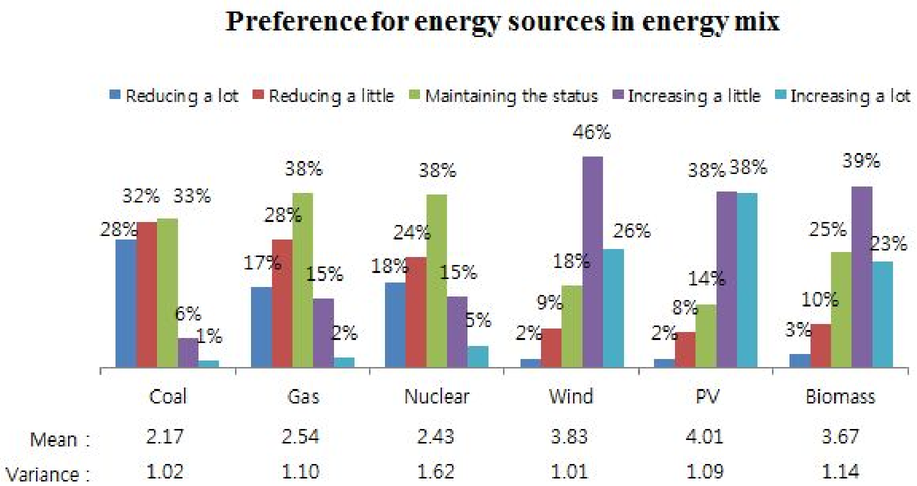

Figure 11. Public’s attitude toward preference for energy sources in energy mix

Based on the responses of the preference for the energy sources in energy mix, respondents think that renewable energy should be increasing, while fossil fuel and nuclear energy should be decreasing in energy mix. According to the results of mean of responses among the traditional energy sources, it seems that relative preference order among energy sources is gas, nuclear, and coal in descending order. However, if the response 'maintaining the status' is excluded, the relative preference order among the traditional energy sources is nuclear, gas, and coal in descending order. It shows that publics think fossil fuel should be decreasing more than nuclear energy. The variance of response indicates the preference heterogeneity on the energy sources, and nuclear energy shows the highest variance. Among renewable energy, the relative preference order is shown as PV, wind, and biomass in ascending order.

Attitude toward new facility siting nearby residential area

Question: *What do you think about power plant siting nearby your residential area?*

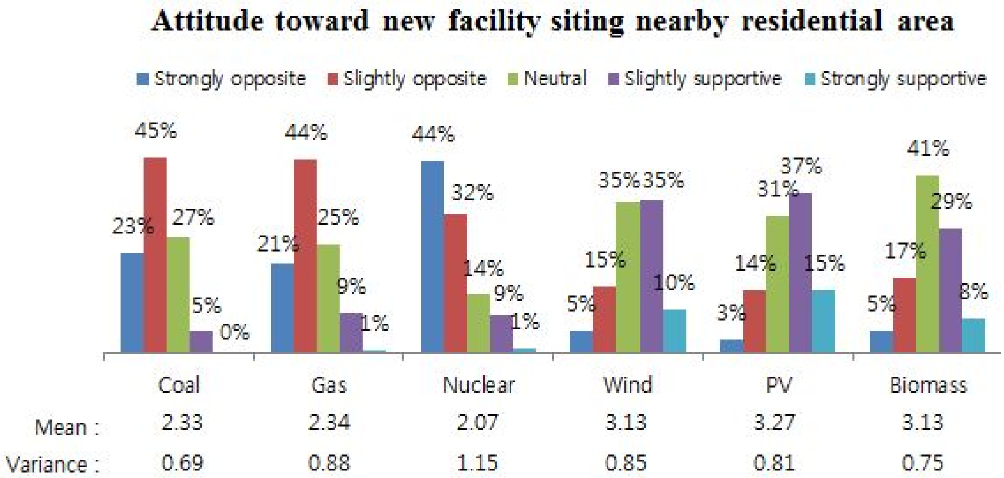

Figure 12. Public's attitude toward new facility siting nearby residential area

Generally, respondents show stronger opposition for power plant siting of the traditional energy sources near to their residential area than renewable energy. Among the traditional energy sources, publics are strongly opposite for nuclear energy, followed by fossil fuel such as coal and gas. This result is different with the result of public's preference on energy sources in energy mix such that the public prefers nuclear energy in energy mix to fossil fuel but prefers fossil fuel to nuclear if it is located near to their residential area. Therefore, it is found that NIMBY phenomenon appears for nuclear energy since the public prefers nuclear in energy mix but shows stronger opposition if nuclear facility is located near to their residential location. With regard to the preference heterogeneity on energy sources, the responses for nuclear have the highest variance. Among renewable energy, respondents are stronger supportive to PV than wind and biomass. Excluding the response 'neutral', respondents prefer wind to biomass. Therefore, relative preference order among renewable energy is appeared as PV, wind, and biomass in ascending order. This is consistent with the case of public's preference in energy mix.

4.3.2 Estimation of Social Acceptance Model for Electricity Facility Siting

4.3.2.1 Empirical Model

In this study, social acceptance is estimated by the HB nested logit model. The nested logit (NL) model introduces two stages. In the upper level of the model, the choice between the branches ‘accept’ and ‘opposition’ is made, and in the lower level follows the choice between the presented alternatives. The idea of the NL model is to model the correlation between groups of similar alternatives, that is, by assumption that the accepted alternatives have more in common than opposition of energy facility siting. This solves the restriction of the simple multinomial logit model which assumes that the respondents perceive all the alternatives in one choice task similarly (IIA assumption).

The coefficients of the alternative specific constant (ASC) refer to the average effect of the alternative to utility, which is not considered in the selected attributes. Due to the limitation of setting numbers of attributes, the ASC can be interpreted as the average effect of the characteristics of energy sources, which is not included in the attributes. As previously mentioned, the empirical model is divided into three different models: model 1 has the unlabeled alternatives, model 2 has the labeled alternatives named as fossil fuel, nuclear, and renewable, and model 3 has the labeled alternatives named as coal, gas, nuclear, wind, PV, and biomass. For the upper-level specification, five covariates are used: sex, age, year of education, household income, and attitude toward risk. These will be used for analyzing individuals’ heterogeneity regarding the coefficient in the utility model.

Considering the choice situation, the opt-out options has a single alternative. For this reason, the parameter of inclusive value, λ_O, set to 1 for normalization. The parameter of inclusive value refers to the similarity or independence among alternatives in the same nest. Since the option ‘opposition’ has a single alternative, it is completely independent and eventually equivalent of multinomial logit model in the nest 2 (binomial choice situation) The stated preference data were collected by the conjoint survey and were used to estimate the coefficients in the model by using the RSGHB package in the R program. Among 20,000 iterations, the initial 10,000 iterations were discarded as burn-in draws for convergence, and 10^{th} of the remaining 10,000 iterations were retained to calculate the mean and the standard deviation of the parameters.

Since this package and all the other programs are not allowed to have upper-level specification (inclusion of covariates in the model), additional multivariate logit regression with the unit changed as a percentage change in parameters for each respondent and his or her socio-demographic characteristics. The multivariate regression also used the R package and was estimated following the bayesian approach.

4.3.2.2 The Estimation Results in the General Public Model

The HB mixed nested logit model allows researchers to reflect the distribution assumption for the random parameters. Therefore, the appropriate distribution should be assumed to conduct a more realistic analysis. Generally, the parameters in the random coefficient model are assumed to have a normal distribution. However, for some parameters, the attributes of which are certain to show one-sided directions, the estimates can be assumed to have a lognormal distribution, so that they constantly have specific positive or negative signs (Train and Sonnier, 2005). Thus, this study assumes a lognormal distribution for the parameters of variables such as GHG emission (-), supply limit (-), and electricity bill (-), while the other parameters, new employment and land occupation are assumed to have a normal distribution. With respect to the ASCs, the parameters are assumed to have a normal distribution since the preference regarding each energy source cannot be assumed ex-ante. The empirical results will be presented in the order of model 1, model 2, and model 3.

Model 1

For the model 1 in general public model, Eq. (15) shows the utility of respondent n in choosing an alternative j:

$$\begin{aligned} U_{nj} = {} & \beta_{n,Emp} X_{Emp} + \beta_{n,GHG} X_{GHG} + \beta_{n,Land} X_{Land} + \beta_{n,Supply} X_{Supply} \\ & + \beta_{n,Bill} X_{Bill} + \varepsilon_{nj} \end{aligned} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\text{Eq. (15)}$$

, where $\varepsilon_{nj} \sim Generalized\ extreme\ value\ distribution$.

The variables of X_{Emp}, X_{GHG}, X_{Land}, X_{Supply}, and X_{Bill} indicate the attributes of employment, GHG emission, land occupation, supply limit, and monthly electricity bill, respectively.

In order to investigate which attributes are more important when people consider the acceptance of energy sources, the relative importance (RI) of each attribute is calculated.

RI indicates people's perceived importance of certain attributes compared to other attributes. The RI of i attribute is calculated as follows:

$$RI_i = \frac{\hat{\beta}_i \times (Max_{Level_i} - Min_{Level_i})}{\sum_{i=1}^{J} \hat{\beta}_i \times (Max_{Level_i} - Min_{Level_i})} \quad \text{Eq. (16)}$$

, where $\hat{\beta}_i$ indicates the estimate of attribute i and $(Max_{Level_i} - Min_{Level_i})$ means the difference between the maximum and the minimum levels of attribute i.

In order to estimate the economic value of each attribute, the marginal willingness to pay (MWTP) is also calculated for each variable. The MWTP can be calculated as Eq. (17). In this study, the price variable indicates the variable of the monthly electricity bill. The estimation result of model 1 is presented in Table 9.

$$MWTP_{x_{jt}} = -\left[\left(\partial U_{nj} / \partial x_{jt}\right) / \left(\partial U_{nj} / \partial x_{j,price}\right)\right] = -\beta_t / \beta_{j,price} \quad \text{Eq. (17)}$$

Table 9. The estimation results of model 1 in General Public Model

Variables	Assumed distribution	Mean of estimate	Standard deviation of estimate	Relative importance of estimate	Mean of MWTP (10,000KRW/each unit)
β_{Emp}	Normal	1.9658***	0.4546***	3.31%	0.4295

β_{GHG}	Log-normal	-6.5937***	0.4515***	44.44%	-1.4408
β_{Land}	Normal	-1.8133***	0.3432***	10.69%	-0.3962
β_{Supply}	Log-normal	-2.8812***	0.4462***	14.56%	-0.6296
β_{Bill}	Log-normal	-4.5765***	0.3731***	26.99%	
λ_A	Fixed	1.0133	0.2900		
λ_O	(Set to 1 for normalization)				

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

The estimated result of the parameters of the attributes shows a statistically significant and expected sign for all the parameters. The variables of GHG emission, land occupation, supply limit, and electricity bill are all regarded as damage to people, so that the negative sign is deduced, while new job creation shows a positive sign since it is regarded as a positive impact on society. In terms of relative importance, people regard the GHG emission as the most important factor, followed by the electricity bill, supply limit, land occupation, and new employment.

This result indicates the subjective weight the public places on each impact of an electric power facility. Since people regard each impact differently, the government or utility suppliers should consider them to improve social acceptance when planning electric power facility siting. In other words, the government or utility providers should control the impacts to different degrees by regulation or technology development in order to enhance social acceptance.

The estimated mean of estimates can be transferred to a monetized term by using the mean of MWTP from Eq. (18). The results can be interpreted as the approximate amount of people's physiological risk for each impact of electric power in monetary terms. As shown in 6^{th} row in Table 9, a household is willing to pay KRW 4.295 thousand for new job creation of 10,000 people per TWh, and it can be interpreted as the economic benefit of marginal improvement of such an attribute. A negative sign of MWTP indicates that a household is willing to pay a certain amount of money to avoid the unit increment of each attribute, so it can be interpreted as the cost that is measured by the monetary term. The results of MWTP to avoid the unit increment are KRW 14.408 thousand for increasing GHG emission by a million tons of CO_2−equivalents, KRW 3.962 thousand for increasing damaged land areas by 100 km^2 per TWh, and KRW 6.296 thousand for increasing electricity outages by 100 minutes a year.

The statistical significance of the standard deviation of an estimate is regarded as the indication of preference heterogeneity (Bergmann et al., 2008). According to the result of the standard deviation of estimates, people have more heterogeneous preference for new employment, GHG emission, supply limit, electricity bill, and land occupation.

In order to analyze the source of heterogeneity, multivariate regression analysis was conducted. Since the HB structure allows each individual's utility function to be included, the mean of estimates for each variable can be regarded as the dependent variables. Therefore, they can be analyzed by each respondent's characteristics as an independent variable, named as covariates. Multivariate regression can be presented as the n^{th}

respondent's coefficient of the kth attribute is assumed to be a function of the covariates of nth respondent as shown in Eq. (18).

$$\begin{aligned}\beta_{n,k} &= \Gamma_{Sex,k}Z_{n,Sex} + \Gamma_{Age,k}Z_{n,Age} + \Gamma_{Edu,k}Z_{n,Edu} + \Gamma_{Hinc,k}Z_{n,Hinc} + \Gamma_{AttRisk,k}Z_{n,AttRisk} \\ &+ \Gamma_{Fsize,k}Z_{n,Fsize} + \Gamma_{Ebill,k}Z_{n,Ebill} + \delta_n\end{aligned} \qquad \text{Eq. (18)}$$

,where $\delta_n \quad N(0,\Sigma_\beta)$.

The covariates of $Z_{n,Sex}$, $Z_{n,Age}$, $Z_{n,Edu}$, $Z_{n,Hinc}$, $Z_{n,AttRisk}$, $Z_{n,Fsize}$, and $Z_{n,Ebill}$ indicate the nth respondents' socio-economic characteristics such as sex, age, education, house income, risk attitude, family size, and electricity bill, respectively. The definition and statistics of covariates in multivariate regression analysis is shown in Table 10.

Table 10. The definition and statistics of covariates in the heterogeneity analysis

Variables	Sex	Mean	Standard Deviation
Sex	Sex of the respondent (1: men, 0: women)	0.509	0.5
Age	Age of the respondent in years	45.87	8.94
Education	Education level of the respondent in years	13.76	2.4
House income	Monthly household income of the respondent (in KRW 10,000)	414.55	201.52
Risk attitude	Respondent's attitude toward risk (1: very risk averse, and 5: very risk-taking)	3.15	0.81

Family size	Number of persons in respondent's household	3.49	1.03
Electricity bill	Monthly electricity bill (in KRW 10,000)	5.23	2.33

In Eq. (18), the estimates of each variable are drawn for each respondent so that a total of 1,000 estimates are used for the multivariate regression. Due to the difference in scale for each variable, the percentage change for each parameter is used as input data. The estimation results of the parameters can be interpreted as the effect of covariates on the marginal utility of variables in the utility function, that is, Eq. (15). Table 11 shows the results of the multivariate regression analysis for analyzing the source of heterogeneity among respondents.

Table 11. The results of heterogeneity analysis in model 1 in General Public Model

Variables	Covariates						
	Sex	Age	Edu	H_inc	AttRisk	F_Size	E_Bill
β_{Emp}	0.0006	-0.0011	-0.0041	0.0024	0.0020	-0.0005	0.0010
β_{GHG}	0.0009	-0.0014**	-0.0110	0.0066	-0.0124	0.0054	-0.0144**
β_{Land}	0.0004	0.0049	0.0029	-0.0005	0.0019*	-0.0005	-0.0029**
β_{Supply}	-0.0005	0.0049	0.0045	0.0046*	0.0012	0.0009	-0.0022
β_{Bill}	0.0009*	0.0186	0.0035	0.0028	-0.0065	0.0083*	-0.0130***

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

Among the results of the multivariate regression analysis, several factors are statistically significant. Therefore, the interpretation of the result will focus on these factors. In terms of each respondent's characteristics, the covariate of sex shows statistical significance with a positive sign for the parameter of the electricity bill. This implies that men are less sensitive to an increment in their electricity bill than women. With the result of the covariate of age, which shows a negative sign for GHG emission, it is found that older people are more sensitive to an increment in GHG emission. In other words, the coefficient of the variable GHG emission for older people shows a higher magnitude with a negative sign than for younger people, and it implies that a unit change in GHG emission has a stronger negative effect on utility for older people. Similarly, respondents who have a higher household income are less sensitive to the supply limit, and people who are reluctant to take a risk are less sensitive to land occupation. Respondents who have a larger family size are less sensitive to the electricity bill, so that households with a small family size are more sensitive to an increase in their electricity bill. Regarding households with a higher level of electricity consumption, they are more sensitive to GHG emission, land occupation, and increases in their electricity bill.

These results can be utilized to understand the source of heterogeneity in the estimates of variables in the utility function according to the individuals' characteristics. The information of more sensitive groups of people in relation to specific parameters' marginal utility can give an idea to the policy planner for setting a communication strategy to improve the social acceptance of a certain project.

Model 2

As mentioned, model 2 includes the ASC of three different energy types. For the model 2 in the general public model, Eq. (19) shows the utility function of respondent n in choosing an alternative j:

$$\begin{aligned} U_{\mathrm{n,j\_Accept}} &= \alpha sc_{\mathrm{n,j}} + \beta_{n,Emp}X_{Emp} + \beta_{n,GHG}X_{GHG} + \beta_{n,Land}X_{Land} + \beta_{n,Supply}X_{Supply} + \beta_{n,Bill}X_{Bill} + \varepsilon_{nj} \\ U_{\mathrm{n,j\_Opposite}} &= \beta_{n,Emp}X_{Emp} + \beta_{n,GHG}X_{GHG} + \beta_{n,Land}X_{Land} + \beta_{n,Supply}X_{Supply} + \beta_{n,Bill}X_{Bill} + \varepsilon_{nj} \end{aligned} \quad \text{Eq. (19)}$$

, where $\varepsilon_{nj} \sim \textit{Generalized extreme value distribution}$ and the alternative j includes fossil fuel, nuclear, and renewable energy.

In terms of specification, the ASCs are included for the three alternatives of fossil fuel, nuclear, and renewable energy in the 'accept' nest. The utility function for the 'opposition' nest does not have ASC since it is differentiated by the other three equations of the accept nest. Table 12 shows the estimated result of model 2 in general public model.

Table 12. The estimation results of model 2 in General Public Model

Variables	Assumed distribution	Mean of estimate	Standard deviation of estimate	Relative importance	Mean MWTP (10,000KRW/each

				of estimate	unit)
$\alpha sc_{\text{Fossil}}$	Normal	0.0502***	0.4847***	1.56%	0.0293
$\alpha sc_{\text{Nuclear}}$	Normal	0.5258***	0.5312***	16.34%	0.3070
$\alpha sc_{\text{Renewable}}$	Normal	0.7137***	0.3808***	22.18%	0.4167
β_{Emp}	Normal	0.0841	0.4326***	0.52%	0.0491
β_{GHG}	Log-normal	-0.8201***	0.4513***	22.68%	-0.4788
β_{Land}	Normal	-0.0764	0.4266***	2.02%	-0.0446
β_{Supply}	Log-normal	-2.0714***	0.9429***	32.19%	-1.2093
β_{Bill}	Log-normal	-1.7128***	0.7340***	42.59%	
λ_A	Fixed	0.5069	0.0272		
λ_O	(Set to 1 for normalization)				

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

The estimation result of the IV parameter shows a value between 0 and 1, implying that the nested structure can be properly applied in this model. Considering the estimation results of each attribute, the sign of the attributes is the same as the expected one. However, the variables of employment and land occupation are not statistically significant, which means that they are statistically not different from zero. With respect to the relative importance, the supply limit is regarded as the most important factor in the social acceptance of an electric power facility when respondents face the choice situation of energy selection including the type of energy source, followed by the electricity bill and GHG emission.

In model 2, ASCs are incorporated to investigate the choice behavior of the respondents when they consider the type of energy source. The estimation result of ASCs refers to the average effect of the unobserved term in the utility function. This means the effect of the alternative itself on utility if all the attributes have the same value, and it implies the relative preference order among the alternatives. Therefore, the relative order among the alternatives is important rather than the absolute value of ASCs.

The estimation result shows that people prefer renewable energy to nuclear and fossil fuel. Regarding the relative preference order between nuclear and fossil fuel, it is shown that people prefer nuclear to fossil fuel. The results of the standard deviation for all the parameters are statistically significant, and this confirms the preference heterogeneity for each attribute. The result shows that the preference for the supply limit is highly heterogeneous compared with the other attributes. Regarding the heterogeneity of the preference for the ASCs, nuclear energy shows the highest standard deviation, followed by fossil and renewable energy.

The result of MWTP shows that a household is willing to pay KRW 0.293 thousand, KRW 3.07 thousand, and KRW 4.167 thousand for fossil fuel, nuclear, and renewable energy, respectively. The results of MWTP to avoid the unit increment are KRW 4.788 thousand for increasing the GHG emission by a million tons of CO_2−equivalents, and

KRW 12.093 thousand for increasing the electricity outages by 100 minutes a year.

Regarding the heterogeneity of marginal utility of the each parameter is analyzed by multivariate regression. Compared with Eq. (19), ASCs are additionally considered in the model as Eq. (20). Table 13 shows the estimation results.

$$\begin{aligned} ASC_{n,j} &= \Gamma_{Sex,k}Z_{n,Sex} + \Gamma_{Age,k}Z_{n,Age} + \Gamma_{Edu,k}Z_{n,Edu} + \Gamma_{Hinc,k}Z_{n,Hinc} + \Gamma_{AttRisk,k}Z_{n,AttRisk} \\ &\quad + \Gamma_{Fsize,k}Z_{n,Fsize} + \Gamma_{Ebill,k}Z_{n,Ebill} + \delta_n \\ \beta_{n,k} &= \Gamma_{Sex,k}Z_{n,Sex} + \Gamma_{Age,k}Z_{n,Age} + \Gamma_{Edu,k}Z_{n,Edu} + \Gamma_{Hinc,k}Z_{n,Hinc} + \Gamma_{AttRisk,k}Z_{n,AttRisk} \\ &\quad + \Gamma_{Fsize,k}Z_{n,Fsize} + \Gamma_{Ebill,k}Z_{n,Ebill} + \delta_n \end{aligned} \qquad \text{Eq. (20)}$$

,where $\delta_n \quad N(0,\Sigma_\beta)$.

Table 13. The results of heterogeneity analysis in model 2 in General Public Model

Variables	Covariates						
	Sex	Age	Edu	H_inc	AttRisk	F_Size	E_Bill
$\alpha sc_{\text{Fossil}}$	0.0589***	-0.0159	-0.0904	0.0372	-0.1736	0.0845	-0.0541
$\alpha sc_{\text{Nuclear}}$	-0.0021	-0.0180	0.0076	0.0068	0.0066	-0.0065	-0.0022
$\alpha sc_{\text{Renewable}}$	-0.0015	0.0150	0.0198	-0.0063	0.0046	0.0078*	0.0016
β_{Emp}	-0.0186	0.0037	0.0092*	0.0586	-0.0341	0.0476	-0.0298
β_{GHG}	-0.0014	0.0020	-0.0010	0.0036	0.0054	-0.0046	-0.0048*
β_{Land}	0.0086	0.0574	0.0484	0.0167	-0.0284	-0.0121	-0.0328

β_{Supply}	-0.0003	-0.0086*	-0.0081	-0.0014	-0.0048	0.0036	0.0058***
β_{Bill}	0.0006**	0.0016	0.0008*	-0.0018	0.0107	0.0025	0.0019

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

The estimation result of the multivariate regression analysis shows that women are more sensitive to the increasing electricity bill, older people are more sensitive to the supply limit, and people who have a higher education level show less sensitivity to the electricity bill. Households with a higher level of electricity consumption are more sensitive to GHG emission, and households that use less electricity are more sensitive to the supply limit. Since this study used the percentage changes in each variable as the input data, the absolute amount of the estimation for specific parameters can be compared. In terms of the supply limit, a 1 percentage change in age has a greater impact on the marginal utility of the electricity bill compared with electricity consumption.

Model 3

Utility function for model 3 in the general public model is same as model 2 as shown in Eq. (20), except for the number of alternatives. Model 3 incorporated the ASCs as six different energy sources: coal, gas, nuclear, wind, PV, and biomass in 'accept' nest. Similar to the utility function in model 2, the 'opposition' nest does not includes the ASC. The estimation results of model 3 in the general public model are presented in Table 14.

Table 14. The estimation results of model 3 in General Public Model

Variables	Assumed distribution	Mean of estimate	Standard deviation of estimate	Relative importance of estimate	Mean MWTP (10,000KRW/each unit)
αsc_{Coal}	Normal	-0.7079***	0.5600***	14.83%	-0.4834
αsc_{Gas}	Normal	-0.7644***	0.4904***	16.02%	-0.5219
$\alpha sc_{Nuclear}$	Normal	-0.6676***	0.7649***	13.99%	-0.4558
αsc_{Wind}	Normal	-0.3945***	0.6461***	8.27%	-0.2694
αsc_{PV}	Normal	0.9488***	0.4400***	19.88%	0.6478
$\alpha sc_{Biomass}$	Normal	-0.6584***	0.6743***	13.80%	-0.4496
β_{Emp}	Normal	0.2324**	0.7371***	0.97%	0.1587
β_{GHG}	Log-normal	-1.1607	0.5875***	24.08%	-0.7925
β_{Land}	Normal	-1.4377***	0.5859***	25.61%	-0.9817
β_{Supply}	Log-normal	-2.0738***	1.9475***	21.73%	-1.4161
β_{Bill}	Log-normal	-1.4645*	1.0144***	27.62%	
λ_A	Fixed	0.1731	0.1865		
λ_O	(Set to 1 for normalization)				

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

The sign of the estimation result for each attribute is as expected. However, the parameter of GHG emission is not statistically significant. With respect to the relative importance, the supply limit is regarded as the most important factor in the social acceptance of an electric power facility, followed by the electricity bill, land occupation, and employment. Regarding the estimation result of ASCs, the relative preference order among energy sources is PV > wind > biomass > nuclear > coal > gas. This result seems consistent with the result of the ASC in model 2 such that the relative preference order shows renewable > nuclear > fossil fuel. The relative order among ASCs in model 3 consistently follows the result of model 2. The results of the standard deviation for all the parameters are statistically significant, confirming the preference heterogeneity for each attribute. The results show that the preference for the supply limit is highly heterogeneous, and this is followed by the electricity bill, employment, and land occupation. Among the ASCs, nuclear energy has the highest value of standard deviation, which implies strong heterogeneity of the preference for nuclear energy. The result of MWTP shows that a household is willing to pay KRW 1.587 thousand for new job creation by 10,000 people per TWh. The results of MWTP to avoid the unit increment are KRW 9.817 thousand for increasing damaged land areas by 100 km^2 per TWh and KRW 14.161 thousand for increasing the electricity outages by 100 minutes a year.

Regarding the heterogeneity of marginal utility, each parameter is analyzed by multivariate regression. The estimation results are presented in Table 15.

Table 15. The results of heterogeneity analysis in model 3 in General Public Model

Variables	Covariates						
	Sex	Age	Edu	H_inc	AttRisk	F_Size	E_Bill
αsc_{Coal}	0.0032	0.0037	-0.0110	0.0045	0.0007	-0.0042	-0.0126
αsc_{Gas}	0.0021	-0.0041*	0.0157	-0.0007	0.0040	0.0110	-0.0056
$\alpha sc_{Nuclear}$	-0.0041	-0.0311	-0.0196	-0.0043	-0.0128	-0.0026	0.0093
αsc_{Wind}	0.0048	0.0048	-0.0209*	0.0132	-0.0015	0.0160	0.0053
αsc_{PV}	0.0006	0.0073	0.0158	0.0009	0.0069	0.0014	-0.0023
$\alpha sc_{Biomass}$	-0.0005	0.00001*	-0.0159	-0.0035	0.0004	0.0084	-0.0095
β_{Emp}	-0.0091	0.0020	0.0287**	0.0030	-0.0009	0.0041	-0.0124
β_{GHG}	-0.0001	0.0028	0.0141	0.0033	0.0043	-0.0045	-0.0023
β_{Land}	0.0003	-0.0035	-0.0100*	0.0020	-0.0071	-0.0055	-0.0001
β_{Supply}	-0.0063	-0.0033	-0.0099	-0.0078	0.0026	-0.0185*	-0.0035
β_{Bill}	0.0054**	-0.0064***	-0.0025	-0.0009	-0.0032	0.0110	-0.0020

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

The estimation result of the multivariate regression analysis shows that women and older people are more sensitive to an increase in their electricity bill. People who have a higher education level show more sensitivity to employment and land occupation, and people in a small family show more sensitivity to the supply limit.

The Result of ASCs in Model 2 and Model 3

According to Louviere and Woodworth (1983) and Oppewal and Timmermans (1993), the probability for a dummy variable might be interpreted as an indicator of the overall preference for products/services. Therefore, the relative order of ASCs can be interpreted as people's generic preference for energy sources.

In model 2 and model 3, the estimation results of ASCs show that people regard renewable energy as the most preferred energy source. The relative preference between nuclear and fossil fuel seems to be more arguable. In this study, general attitudinal questions were also asked, and the question regarding the preference for the energy mix is relevant to this discussion.

According to the result of the preference for energy sources in the energy mix, as shown in Figure 11, people tend to think that fossil fuel should be decreased in the energy mix compared with nuclear power. The estimation results of ASCs in model 2 and model 3 consistently address the same message as this result. Therefore, it can be concluded that this model can explain the real behavior of people's preference for energy sources. In terms of preference heterogeneity, the standard deviation for nuclear energy shows the highest value consistently, and this implies strong heterogeneity of the public's preference for nuclear energy.

4.3.2.3 The Estimation Results in Local Residence Model

In the local residence model, a log-normal distribution is assumed for the parameters of variables, such as health damage risk (-), quality of life, such as inconvenience (-), and compensation (+). In the case of health damage risk and quality of life, they can be regarded as a direct impact on individuals so that they are assumed to be negative log-normal distribution. Compensation can be regarded as additional income, and it is assumed that a rational individual will prefer to have a higher level of compensation. Therefore, the variable of compensation is assumed to have a positive log-normal distribution. Local environmental damage and legitimacy of decision making are assumed to have a normal distribution. The public's preference for environmental quality is difficult to assume ex ante. In the case of legitimacy of decision making, some people may prefer one-direction notification from the government since it can be regarded as a faster way of making decisions. The empirical analysis for each model in the Local Residence Model will be discussed in this section.

Model 1

For model 1 in the local residence model, Eq. (21) shows the utility of respondent n in choosing an alternative j:

$$U_{nj} = \beta_{n,Env} X_{Env} + \beta_{n,Health} X_{Health} + \beta_{n,QoL} X_{QoL} + \beta_{n,Legit} X_{Legit} + \beta_{n,Compen} X_{Compen} + \varepsilon_{nj} \quad \cdots\cdots \text{Eq. (21)}$$

,where $\varepsilon_{nj} \sim Generalized\ extreme\ value\ distribution$.

The variables X_{Env}, X_{Heath}, X_{QoL}, X_{Legit}, and X_{Compen} indicate the attributes local environmental damage, health damage risk, quality of life (inconvenience), legitimacy of decision making, and compensation, respectively. In order to compare the importance of each attribute, RI is calculated in the same way as for the general public model. Unlike the general public model, however, the local residence model uses marginal willingness to accept (MWTA) to compute the monetized value for each attribute. The notation of MWTA is identical to that of MWTP except for the sign of the equation if the income distribution holds as fixed. The estimation result of model 1 is presented in Table 16.

Table 16. The estimation results of model 1 in Local Residence Model

Variables	Assumed distribution	Mean of estimate	Standard deviation of estimate	Relative importance of estimate	Mean MWTA (mil. KRW/each unit)
β_{Env}	Normal	-0.2305***	0.4505***	0.49%	0.1597
β_{Heath}	Log-normal	-1.3567***	0.5260***	2.90%	0.9400
β_{QoL}	Log-normal	-1.5244***	0.5754***	32.59%	1.0562
β_{Legit}	Normal	0.2162***	0.3810***	2.31%	-0.1498

β_{Compen}	Log-normal	1.4433***	0.5802***	61.71%
λ_A	Fixed	0.5000	0.000	
λ_O	(Set to 1 for normalization)			

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

The estimation result of the IV parameter shows a value between 0 and 1, implying that the nested structure can be properly applied in this model. The estimated result of the parameters of attributes shows a statistically significant and expected sign for all the parameters. In terms of the relative importance, the variables of quality of life, compensation, and health damage are regarded as the important factors to decide the acceptance of an energy facility.

A positive sign of MWTA indicates the minimum amount of money that a household is willing to accept for a unit increment in each attribute. Therefore, it can be regarded as the cost. Meanwhile, a negative sign of MWTA implies that a household is willing to pay a certain amount of money to accept the unit increment in each attribute. Thus, it can be regarded as the economic benefit.

The MWTA is calculated as KRW 0.1597 million for increasing local environmental damage by 100 km^2 per TWh, KRW 0.94 million for increasing health damage risk by 50 people in a billion people per TWh, KRW 1.0562 million for decreasing the quality of life from low to medium and medium to high, and – KRW 0.1498 million for ensuring legitimacy of decision making in electric power facility siting.

The estimation results of the standard deviation for all the parameters are statistically significant. Throughout the results, it is found that the heterogeneity of preference for compensation, quality of life, and health damage is high compared with that for environmental damage and legitimacy.

In order to investigate the source of preference heterogeneity, Eq. (18) is used for the multivariate regression analysis. Unlike the general public model, attributes used in analysis are environmental damage, health damage risk, quality of life, legitimacy of decision-making, and compensation. Table 17 shows the results of the multivariate regression analysis for analyzing the source of heterogeneous preference on the each attribute among the respondents.

Table 17. The results of heterogeneity analysis in model 1 in Local Residence Model

Variables	Covariates						
	Sex	Age	Edu	H_inc	AttRisk	F_Size	E_Bill
β_{Env}	0.0051	-0.0014	-0.0466	0.0402	-0.0380*	0.0260	-0.0249**
β_{Heath}	0.0030	0.0195	0.0005	-0.0013	-0.0086	0.0084*	-0.0024
β_{QoL}	-0.0002	0.0059	0.0079	-0.0090*	-0.0066	-0.0016	-0.0044
β_{Legit}	-0.0181	-0.0525*	-0.0073	0.0065	0.0896***	0.0096	-0.0457
β_{Compen}	0.0008	0.0148	-0.0082**	0.0015	0.0067**	0.0123	-0.0096

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

According to the results that are statistically significant, younger people are more sensitive to the legitimacy of decision making and less educated people are more sensitive to the amount of compensation. The results also show that households with a higher income are more sensitive to the quality of life, small households are more sensitive to health damage, and households that use a large amount of electricity are more sensitive to environmental damage. In addition, people who are reluctant to take a risk are more sensitive to environmental damage, legitimacy of decision making, and the level of compensation.

Model 2

For model 2 in the local residence model, Eq. (22) shows the utility of respondent n in choosing an alternative j:

$$\begin{aligned} U_{\mathrm{n,j\_Accept}} &= \alpha\mathrm{sc}_{\mathrm{n,j}} + \beta_{n,\mathrm{Env}} X_{\mathrm{Env}} + \beta_{n,\mathrm{Health}} X_{\mathrm{Health}} + \beta_{n,\mathrm{QoL}} X_{\mathrm{QoL}} + \beta_{n,\mathrm{Legit}} X_{\mathrm{Legit}} + \beta_{n,\mathrm{Compen}} X_{\mathrm{Compen}} + \varepsilon_{nj} \\ U_{\mathrm{n,j\_Opposite}} &= \beta_{n,\mathrm{Env}} X_{\mathrm{Env}} + \beta_{n,\mathrm{Health}} X_{\mathrm{Health}} + \beta_{n,\mathrm{QoL}} X_{\mathrm{QoL}} + \beta_{n,\mathrm{Legit}} X_{\mathrm{Legit}} + \beta_{n,\mathrm{Compen}} X_{\mathrm{Compen}} + \varepsilon_{nj} \end{aligned} \quad \text{Eq. (22)}$$

, where $\varepsilon_{nj} \sim \textit{Generalized extreme value distribution}$ and the alternative j includes fossil fuel, nuclear, and renewable energy.

In terms of specification, the ASCs are included for the three alternatives as fossil fuel, nuclear, and renewable energy in the ‘accept’ nest. The utility function for the ‘opposition’ nest does not have an ASC since it is differentiated by other three equations of the accept nest. Table 18 shows the estimated result of model 2 in the general public model.

Table 18. The estimation results of model 2 in Local Residence Model

Variables	Assumed distribution	Mean of estimate	Standard deviation of estimate	Relative importance of estimate	Mean MWTA (mil. KRW/each unit)
$\alpha sc_{\text{Fossil}}$	Normal	-0.0857	0.3734***	0.97%	0.0570
$\alpha sc_{\text{Nuclear}}$	Normal	-0.3833***	0.4849***	4.35%	0.2550
$\alpha sc_{\text{Renewable}}$	Normal	0.0192	0.3795***	0.22%	-0.0128
β_{Env}	Normal	-0.9415***	0.3982***	2.14%	0.6264
β_{Heath}	Log-normal	-1.0214**	0.4708***	2.32%	0.6795
β_{QoL}	Log-normal	-1.0441*	0.4645***	23.69%	0.6946
β_{Legit}	Normal	0.3223***	0.4520***	3.66%	-0.2144
β_{Compen}	Log-normal	1.5031***	0.6302***	68.20%	
λ_A	Fixed	0.5000	0.0000		
λ_O	(Set to 1 for normalization)				

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

The estimation result of the IV parameter shows a value between 0 and 1, implying that the nested structure can be properly applied in this model. Considering the estimation results of each attribute, the sign of the attributes is the same as the expected one. However, the estimation results of the ASCs, such as fossil fuel and renewable energy, are not statistically significant. With respect to the relative importance, compensation is regarded as the most important factor in the social acceptance of an electric power facility, followed by the quality of life, health damage, environmental damage, and legitimacy.

Regarding the result of the ASCs, the public's preference order for energy types is renewable, fossil fuel, and nuclear. The result of the ASCs in the General Public Model showed that the relative preference for energy types was renewable, fossil fuel, and nuclear. Interestingly, the order of relative preference among the energy sources has changed.

The results of the standard deviation for all the parameters are statistically significant, and this confirms the preference heterogeneity for each attribute. The result shows that the preference for compensation is highly heterogeneous compared with the other attributes. Regarding the heterogeneity of the preference for the ASCs, nuclear shows the highest standard deviation, followed by renewable and fossil fuel.

The MWTA is calculated as KRW 0.6264 million for increasing the local environmental damage by 100 km^2 per TWh, KRW 0.6795 million for increasing the health damage risk by 50 people in a billion people per TWh, KRW 0.6946 million for decreasing the quality of life from low to medium and medium to high, and – KRW 0.2144 million for ensuring the legitimacy of decision making in electric power facility siting.

Following the Eq. (20), the sources of heterogeneity of marginal utility of each parameter in utility function are analyzed, and Table 19 shows the estimation results.

Table 19. The results of heterogeneity analysis in model 2 in Local Residence Model

Variables	Covariates						
	Sex	Age	Edu	H_inc	AttRisk	F_Size	E_Bill
$\alpha sc_{\text{Fossil}}$	-0.0345***	-0.0645	-0.0903	-0.0756***	-0.0203	-0.0491	-0.0465
$\alpha sc_{\text{Nuclear}}$	-0.0035	0.0702**	0.0961	-0.0382**	-0.0024	0.0146	0.0117
$\alpha sc_{\text{Renewable}}$	-0.2742	1.7679	1.6100	-0.7959	0.0818*	0.2401	0.3729
β_{Env}	-0.0027	0.0027	-0.0135	0.0054	0.0069	0.0057	-0.0132
β_{Heath}	-0.0002	0.0214	-0.0029	0.0105*	0.0085	-0.0047	-0.0039
β_{QoL}	0.0045	-0.0203**	0.0250	-0.0030	0.0011	-0.0121	0.0018
β_{Legit}	-0.0107	0.0383	-0.0471	0.0032	0.0266	0.0634	-0.0063
β_{Compen}	-0.0019	0.0169	0.0277	0.0004	0.0187	-0.0124**	0.0132*

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

The results show that older people are more sensitive to the quality of life and households with a lower income are more sensitive to health damage. In addition, small households are more sensitive to compensation and households that have a lower level of electricity consumption are more sensitive to compensation.

Model 3

Model 3 incorporated the ASCs as six different energy sources: coal, gas, nuclear, wind, PV, and biomass as same as the case of model 3 in the general public model. In addition, the utility function for model 3 in the local residence model is same as Eq. (19) except for the attributes in the model. The estimation results of model 3 in the general public model are presented in Table 20.

Table 20. The estimation results of model 3 in Local Residence Model

Variables	Assumed distribution	Mean of estimate	Standard deviation of estimate	Relative importance of estimate	Mean MWTA (mil. KRW/each unit)
αsc_{Coal}	Normal	0.2824***	0.8787***	0.97%	-0.0470
αsc_{Gas}	Normal	0.4337**	0.8682***	1.49%	-0.0722
$\alpha sc_{Nuclear}$	Normal	-0.7035**	0.9438***	2.42%	0.1170
αsc_{Wind}	Normal	1.6907	0.5653***	5.81%	-0.2813
αsc_{PV}	Normal	1.1285***	0.5986***	3.88%	-0.1878
$\alpha sc_{Biomass}$	Normal	1.6048***	0.5498***	5.51%	-0.2670
β_{Env}	Normal	-2.7709**	0.7379***	1.90%	0.4610

β_{Heath}	Log-normal	-2.1633***	0.4787***	1.49%	0.3599
β_{QoL}	Log-normal	-1.6501**	1.2451***	11.33%	0.2745
β_{Legit}	Normal	0.7899***	0.5872***	2.71%	-0.1314
β_{Compen}	Log-normal	6.0105***	0.3744***	82.56%	
λ_A	Fixed	0.1791	0.2340		
λ_O	(Set to 1 for normalization)				

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

Regarding the estimation results for each attribute, the sign of the attributes is as expected. However, in the estimation results of the ASC, wind is not statistically significant. In terms of the relative importance, people regard legitimacy as the most important factor in deciding energy facility siting, followed by compensation, quality of life, health damage, and environmental damage.

The order of preference for energy sources is wind > biomass > PV > gas > coal > nuclear. From the categorical perspective, renewable is the most preferred option, and fossil fuel is preferred to nuclear. This is consistent with the result of model 2 in the Local Residence Model. However, this preference order is somewhat different from the result in the General Public Model.

The results of the standard deviation for all the parameters are statistically significant, and quality of life shows the highest value, followed by environmental damage, legitimacy, health damage, and compensation. Among the ASCs, nuclear energy shows the highest standard deviation, followed by fossil fuel (coal and gas) and renewables (PV, wind, and biomass).

The MWTA is calculated as KRW 0.4610 million for increasing the local environmental damage by 100 km^2 per TWh, KRW 0.3599 million for increasing the health damage risk by 50 people in a billion people per TWh, KRW 0.2754 million for decreasing the quality of life from low to medium and medium to high, and – KRW 0.1314 million for ensuring the legitimacy of decision making in electric power facility siting.

The heterogeneity of the marginal utility of each parameter is analyzed by multivariate regression. The estimation results are presented in Table 21.

Table 21. The results of heterogeneity analysis in model 3 in Local Residence Model

Variables	Covariates						
	Sex	Age	Edu	H_inc	AttRisk	F_Size	E_Bill
asc_{Coal}	0.0046	-0.0204	-0.0097	0.0079	-0.0105	0.0005	0.0075
asc_{Gas}	0.0006	0.0271	0.0280	0.0003	0.0052	0.0019	-0.0149
$asc_{Nuclear}$	0.0007	0.0056**	0.0297**	-0.0095***	0.0009	0.0038	-0.0019
asc_{Wind}	0.0013	-0.0087	-0.0059*	0.0023	-0.0047	-0.0011	-0.0017
asc_{PV}	-0.0005	0.0214*	0.0165	0.0031	-0.0040	0.0023	-0.0036

$\alpha sc_{Biomass}$	0.0003	-0.0033**	-0.0013	0.0009	0.0023	0.0002	-0.0033
β_{Env}	0.0010**	0.0040**	-0.0057	0.0007	-0.0048	0.0024*	-0.0005
β_{Heath}	0.0034**	0.0099	-0.0104*	0.0041	-0.0050*	-0.0035	-0.0027
β_{QoL}	-0.0016*	-0.0219***	-0.0117*	0.0072	0.0005*	-0.0019	-0.0014
β_{Legit}	-0.0010	-0.0157	-0.0092	-0.0019	-0.0041	-0.0058	0.0044
β_{Compen}	0.0025	0.0196	0.0127	-0.0017	0.0052	-0.0008	-0.0002

***, **, and * imply statistical significance at the 1%, 5%, and 10% levels, respectively

According to the estimation results, women are more sensitive to environmental damage and health damage, and men are more sensitive to the quality of life. In terms of age, younger people are more sensitive to environmental damage, while older people are more sensitive to the quality of life. People who have a higher level of education show greater sensitivity to health damage and quality of life, and people who are reluctant to take a risk are more sensitive to health damage and less sensitive to the quality of life. Households consisting of a small family are more sensitive to environmental damage.

The Result of ASCs in Model 2 and Model 3

In model 2 and model 3, the result shows that people regard renewable energy as the most preferred energy source, and the estimation results of the ASCs show that people regard renewable energy as the most preferred energy source. Unlike the result in the General Public Model, the relative preference between nuclear and fossil fuel shows that people prefer fossil fuel to nuclear when such a facility is sited near to their residential area.

According to this result, it can be assumed that people consider fossil fuel to be the leading source of GHG emission and that it should be decreased in the energy mix from the perspective of public preference. Meanwhile, people think of the direct risk of energy sources in the case of the Local Residence Model. In this manner, people consider nuclear energy as involving more risky technology and try not to accept it in their local residential area.

This result can be checked with the result of the general attitude question as well. Figure 12 shows the attitude toward new facility siting near to the residential area. It implies that people are strongly opposed to nuclear energy, which is consistent with the result of the choice experiment model. This phenomenon is called 'not in my backyard (NIMBY),' and nuclear energy shows a strong NIMBY phenomenon among the energy alternatives. In terms of preference heterogeneity, nuclear energy also shows strong heterogeneity of the public's preference. Through the results of ASCs, it can be concluded that this model can explain the real behavior of people's preference for energy sources.

4.3.2.4 Scenario Analysis

Utilizing the estimation results in a social acceptance model, the cost of social acceptance on the sample level can be expanded to the national level. To expand the estimated mean MWTP for each attribute from the sample, appropriate scenarios are required. In order to set the scenarios, the technical specification of the power plant should be considered. Then, the absolute value for each attribute in the scenario is multiplied by the result of the mean MWTP and MWTA. By using the result of the calculation, the cost of each social acceptance model will be calculated by increasing 1 unit per year and the unit cost of electricity, such as KRW/kWh. In the scenario analysis, six different energy sources are considered: coal, gas, nuclear, wind, PV, and biomass. Therefore, the estimation results of model 3 in the two different models are applied in the scenario analysis.

First, the standard capacity factor is assumed for each energy source. In order to set the standard capacity for the model plant of each energy source, several references are reviewed for coal, gas, and nuclear energy, and the sixth plan for electricity supply and demand is used. In the case of renewable energy, the Japanese electricity generation cost estimation committee's model is considered. The standard capacity for each electricity source is notified to the respondents when conducting the survey as a display card. Based on standard capacity and load factors, the annual amount of electricity generation is calculated. This information is presented in Table 22.

Table 22. The technical specifications of power plants

Variables	Units	Energy alternatives					
		Coal	Gas	Nuclear	Wind	PV	Biomass
Capacity	MW	1000	800	1500	20	10	30
Amount of annual electricity generation	TWh	7.5	6.2	11.3	0.013	0.053	0.223

Source: KEPCO (2010)

The next step is to set the values for each attribute of the social acceptance model for each energy source. The absolute values for each attribute for the different energy sources were reviewed in the process of selecting the levels of the attributes in the conjoint survey. Following the above process, the final set of scenarios for the General Public Model and the Local Residence Model is presented in Table 22.

General Public Model

Regarding the attributes of employment, GHG emission, land occupation, and supply limit, the following levels are considered in the scenario, as shown in Table 23. The scenario is based on the TWh for comparing different energy sources and capacity factors, and it was already considered at the stage of survey design.

Table 23. The scenario for attributes in General Public Model

Variables	Units	Energy alternatives					
		Coal	Gas	Nuclear	Wind	PV	Biomass
New employment	Person/year·TWh	1,000	1,000	1,500	2,000	2,000	3,000
GHG emission	10,000 ton CO_2 eq/TWh	90	50	1	1	10	40
Land occupation	km^2/TWh	10	10	10	70	50	90
Supply Limit	minutes/year	10	20	15	50	60	20

By multiplying the estimated mean MWTP, the cost of social acceptance can be estimated. The result of the social acceptance cost in the General Public Model is presented in Table 24.

Table 24. The social acceptance cost derived from scenario analysis in General Public Model (Unit: 10,000 KRW)

Social acceptance cost	Energy alternatives					
	Coal	Gas	Nuclear	Wind	PV	Biomass
1 facility increasing /household·year	9.06	6.64	6.17	0.08	0.01	0.37

The result shows that the general public's physiological cost for 1 unit of electric power facility siting is KRW 90.6 thousand, KRW 66.4 thousand, KRW 61.7 thousand, KRW 0.08 thousand, KRW 0.01 thousand, and KRW 0.37 thousand for coal, gas, nuclear, wind, PV, and biomass, respectively. The large scale of the electric power facility, such as coal, gas, and nuclear, shows a higher social acceptance cost for the general public. Meanwhile, renewables show a relative smaller social acceptance cost. These results imply that the public is concerned about the diverse negative impacts of traditional energy sources more than renewable energies. In this regard, renewables are the most favorable energy options in terms of the public's perceived cost.

Local Residence Model

The scenario for the attributes in the Local Residence Model is presented in Table 25. The approach to setting the scenario in the Local Residence Model is similar to the case of the General Public Model. However, in the case of legitimacy of decision making, the levels for all the energy sources are set to be 'not included.' The attributes of legitimacy can be controlled by the government or utility companies, so this attribute will be interpreted as a reduction of the social acceptance cost if the legitimacy of decision making is attained. In terms of quality of life, all the energy sources have the level 'medium' except for wind. Because various previous studies have mentioned the negative impact of wind on quality of life, such as noise and visual disamenity, the level of quality of life for wind is set to be high.

Table 25. The scenario for attributes in Local Residence Model

Variables	Units	Energy alternatives					
		Coal	Gas	Nuclear	Wind	PV	Biomass
Environmental damage	km^2/TWh	39	16	1.7	11	2.7	17.8
Health damage	Person /mil.people,TWh	1.44	0.5	0.19	0.12	0.75	0.56
Quality of life	High, Medium, Low	Mid	Mid	Mid	Mid	High	Mid
Legitimacy	Yes/No	No	No	No	No	No	No

By multiplying the estimated mean MWTP, the cost of social acceptance can be estimated. The result of the social acceptance cost in the General Public Model is presented in Table 26.

Table 26. The social acceptance cost derived from scenario analysis in Local Residence Model (Unit: 10,000 KRW)

Social acceptance cost	Legitimacy	Energy alternatives					
		Coal	Gas	Nuclear	Wind	PV	Biomass
1 facility increasing/ household·year	Not Included	561.29	397.49	845.49	3.31	0.58	8.64
	Included	462.73	316.01	696.99	2.61	0.41	5.70

The result shows that the physiological cost of the local residents for 1 unit of electric power facility siting is KRW 5.613 million, KRW 3.975 million, KRW 8.455 million, KRW 0.033 million, KRW 0.006 million, and KRW 0.086 million for coal, gas, nuclear, wind, PV, and biomass, respectively. For the installation of 1 unit of an electric power plant, nuclear shows the highest social acceptance cost, followed by coal and gas. In the case of renewables, a relative smaller social acceptance cost is calculated. If the legitimacy of decision making is attained, the cost of social acceptance is reduced.

4.3.3 Estimation of the Social Acceptance Cost

4.3.3.1 The Cost of Social Acceptance

From the economic point of view, the root cause of social acceptance or local opposition is the inequality between the benefits and the costs of the facility (Sandman, 1986). Generally, the benefits from the installation and operation of disliked public facilities are distributed over the entire country, or evenly distributed across the region, while negative impacts are concentrated on the local community (Armour, 1991). If the facility is expected to cause damage to the environment or to health facilities, such as hazardous power plants, waste treatment plants, and transmission towers, the psychological concerns of local residents rise. This ultimately causes an increase in the psychological perceived cost of people in the local area and results in an expansion of backlash from the people.

By utilizing the concept of the economic theory of social acceptance and the estimation results of the General Public Model and the Local Residence Model, the cost of social acceptance can be calculated. In order to proceed with the social acceptance cost estimation, several assumptions are necessary. Since this study divided the social acceptance model into long-distance general public and nearby local residents, the cost line in Figure 13 can be described as a discrete form.

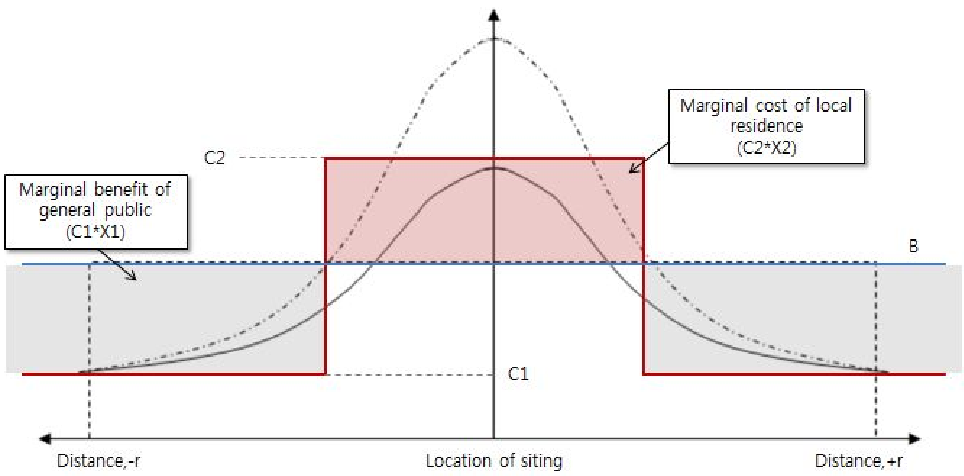

Figure 13. Graphical scheme of calculation of social acceptance cost

This procedure can also be presented as Eq. (23). Because the information on the population density by the distance from the location of facility siting is not included in Figure 13, the marginal cost and benefit should include the number of households.

$$MB_{Public} = MC_{Local}$$
$$(B - C_1) \cdot X_1 = (C_2 - B) \cdot X_2 \quad \cdots\cdots\text{Eq. (23)}$$

, where B refers to evenly distributed benefits per household across the whole country, C_1, C_2 indicate the cost of social acceptance for the general public and local residents, respectively, and X_1, X_2 represent the number of household in the scenario analysis for the general public model and the local residence model, respectively.

Based on the above equation, the benefit that makes the marginal cost of local residents and the marginal benefit of the general public equivalent can be calculated as Eq. (24).

$$B = \frac{C_1 \cdot X_1 + C_2 \cdot X_2}{X_1 + X_2} \quad \cdots\cdots\text{Eq. (24)}$$

Table 27 shows the data for each variable in Eq. (24). For the marginal benefit of the general public and the marginal cost of the local residents, the estimation results of two different empirical models are used. In the case of the number of household in the general public model, '2012 Population and Housing Census' is used. In order to decide on the number of households in the local residence model, the population density is used. According to the above reference, the population density in Korea is approximately 2.5 people/ km^2. Since the supporting area under the regulation is 25 km^2, the number of household in the local residence model is calculated as about 5,100 households.

Table 27. The data used for calculation of the social acceptance cost

Variables	Units	Legitimacy	Energy alternatives					
			Coal	Gas	Nuclear	Wind	PV	Biomass
The result of the general public model for 1 facility increasing/ household·year (C_1)	10,000 KRW		9.06	6.64	6.17	0.08	0.01	0.37
The result of the local residence model for 1 facility increasing/ household·year (C_2)	10,000 KRW	Not Included	561.29	397.49	845.49	3.31	0.58	8.64
		Included	462.73	316.01	696.99	2.61	0.41	5.70
The number of households in the general public model (X_1)	Number of households		20.45 million					
The number of households in the local residence model (X_2)	Number of households		5,100					

Source: 2012 Population and Housing Census (Statistics Korea, 2012)

Since it is assumed that the marginal cost equals the marginal benefit, the cost of social acceptance can be either marginal benefit or marginal cost in Eq. (23). Therefore, the cost of social acceptance can be presented as Eq. (25).

$$SA = (C_2 - B) \cdot X_2 = \left(C_2 - \frac{C_1 \cdot X_1 + C_2 \cdot X_2}{X_1 + X_2} \right) \cdot X_2$$
$$= (B - C_1) \cdot X_1 = \left(\frac{C_1 \cdot X_1 + C_2 \cdot X_2}{X_1 + X_2} - C_1 \right) \cdot X_1 \quad \text{Eq. (25)}$$

Applying the data in Eq. (25), the cost of social acceptance can be calculated as shown in Table 28.

Table 28. The result of social acceptance cost

	Units	Legitimacy	Energy alternatives					
			Coal	Gas	Nuclear	Wind	PV	Biomass
The cost of social acceptance for 1 facility increasing/ household·year	10,000 KRW	Not Included	552.1	390.8	839.1	3.2	0.6	8.2
		Included	453.5	309.3	690.7	2.5	0.4	5.3
The unit cost of social acceptance	KRW/kWh	Not Included	3.76	3.22	3.72	3.10	2.32	1.88
		Included	3.09	2.55	3.07	2.43	1.53	1.22

4.3.3.2 The Validity Test of the Social Acceptance Cost

The cost of social acceptance implies that the public’s psychological perceived cost. This cost is caused by the perceived risk from diverse factors by the public or people who live near the facility siting area. As previously mentioned, the root cause of the social acceptance problem is the regional inequality between benefits and costs from the facility (Sandman, 1986). This problem can be compromised by adequate level of compensation both in financial and non-financial term. In policy planner's point of view, the implementation of a policy without a social acceptance problem is critical. Especially, the importance of smooth implementation of the electric power facility siting is directly linked with the issue of the reliable energy supply in country. In this regard, the government has established the diverse policy tools for improving the social acceptance of energy facility siting. For this purpose, the government has reserved 'Electric power industry basis fund' and employed them for a variety of projects related with electricity or energy sector. 'Electric power industry basis fund' is coming from approximately 3.7% of the electricity price from electricity users. Table 29 shows the lists of projects which used 'Electric power industry basis fund' for three years.

Table 29. The expenditure of projects based on the 'Electric power industry basis fund' (Unit: million KRW)

Classification	2009	2010	2011
Electrical safety management	86,078	92,260	96,011
Demand side management	117,106	143,186	172,704
Electric power supply for a farming and fishing village	117,006	127,318	144,919
Neighboring area support of power plants	154,354	161,565	169,831

Another energy sources support	203,006	6,000	7,603
Policy research on the electric power industry	1,800	2,100	12,027
Technology development	243,540	209,548	
Development of energy convergence original technology	114,475	113,621	406,232
Building the infrastructure of the rnergy research	18,872	16,372	9,478
International collaboration	23,400	23,400	55,728
Energy human resource training	24,580	23,050	25,050
Energy standardization and certification			9,041
Dissemination of new and renewable energy	321,652	513,932	445,000
Low-interest loan	98,023	20,000	20,000
Promoting the exportation of electric power industry	10,000	9,000	14,400
Electric power competitiveness improvement and electricity supply and demand stabilization	7,439	7,439	9,040
Total	**1,541,331**	**1,468,791**	**1,597,064**

Source: Electric Power Public Tasks Evaluation & Planning Center (ETEP)

Note: available at http://www.etep.or.kr/home/busi_info/result/pResultView.jsp

In order to conduct the validity test of the social acceptance cost, the government budget or realized expenditure used for improving the social acceptance in electric power facility siting can be utilized to compare them with the estimation result. Among many projects based on ‘Electric power industry basis fund’, the project directly closed to the social acceptance cost is ‘Neighboring area support of power plants’. The amount of expenditure for this project is approximately 15% of the total amount of ‘Electric power industry basis fund’. According to the Ministry of Strategy and Finance (2012), the average unit price of electricity for a household is 137 KRW/kWh and 3.7% (4.4 KRW/kWh) of the electricity cost is accumulated as the ‘Electric power industry basis fund’. Therefore, this information can be used for the validity test of the estimation result of this study.

The government projects for improving the social acceptance in electric power facility siting are not only the projects based on the ‘Electric power industry basis fund’ but also based on the other capital sources. One is the project based on the utility company and the other one is the project based on ‘Regional resources facilities tax’ from the local government. Table 30 shows the amount of expenditure which is used for different project related to regional support near to power plants for improving the social acceptance in electric power facility siting. From the realized expenditure, the total amount of regional support nearby power plants about twice the ‘Neighboring area support of power plants’ in ‘Electric power industry basis fund’.

Table 30. The total amount of expenditure used for regional support near power plants (Unit: million KRW)

Classification	2009	2010	2011
Projects based on the ‘Electric power industry basis fund’	154,300	161,400	169,800

Projects based on a utility company	50,300	57,000	57,300
Projects based on the 'Regional resources facilities tax'	74,000	72,100	76,300
Total amount of regional support near power plants	278,600	290,500	303,400

Source: Electric Power Public Tasks Evaluation & Planning Center (ETEP)

By utilizing this ratio, the amount of money for using regional support near power plants to improve the social acceptance of electricity facility per unit of electricity is approximately 1.5 KRW/kWh. Since the estimation result of the social acceptance cost ranges from 1.98 KRW/kWh (biomass) to 3.82 KRW/kWh (coal and nuclear), the realized amount of money for using social acceptance is smaller than estimated result. Although this is a rough comparison between the estimated result and the realized expenditure, it is certain that the social acceptance of an electricity facility at the time of the survey was higher than the average of the last three years.

Chapter 5. Conclusion

5.1 Discussion

5.1.1 Summary of the Dissertation

Many energy issues are accompanied by social conflict, so a policy maker should consider not only the technical and physical aspects but also the public's preference regarding certain energy issues. Moreover, un-quantified subjective measures from the public regarding energy issues are becoming more important in energy policy, so the complexity of decision making is increasing. The social acceptance problem, such as local opposition to electricity facility siting, has critical impact on the implementation of electricity planning. Social acceptance is related to individual's subjective valuation of certain issues rather than objective and scientific risk. This subjective valuation naturally leads the heterogeneity of preference toward energy issues.

The purpose of this study was to estimate the cost of social acceptance regarding electricity facility siting. For this purpose, a choice experience method was applied. When people consider the energy sources, there may be a certain relationship between each energy sources. Therefore, among the different discrete choice models, the nested logit model is applied. Since the social acceptance problem is a matter of individual's psychological perceived risk, the model should reflect the public's heterogeneity of preference for energy sources. In this regard, hierarchical bayesian mixed nested logit model (HBNL) was applied to reflect individuals' preference heterogeneity and cope with the restriction of the IIA assumption of the multinomial logit.

Regarding the major cause of the social acceptance problem that is the geographical inequality of benefit and cost by distance from the facility, this study proposed two different approaches: a General public model, and a Local Residence model. The impact of an electricity facility differs between local and wider regions. In this regard, the possible impacts of electricity on the public indirectly at the national level were considered in the general public model, and the direct impacts of an electricity facility were considered as attributes in the model. Regarding the real choice situation in which people may consider not only the combination of levels of attributes but also the name of energy sources, several model specifications were proposed. In model 1, no alternative specific constant (ASC) was included, while model 2 and 3 included ASCs. In model 2, ASCs of fossil fuel, nuclear, and renewable were provided. In model 3, coal, gas, nuclear, wind, PV, and biomass were considered as ASCs.

In the general public model, the order of relative preference for energy sources (ASC) was shown as; renewable > nuclear > fossil fuel in model 2, and PV > wind > biomass > nuclear > coal > gas in model 3. Based on the public's attitude survey result, this is well-behaved in describing the public's preference. In the local residence model, the order of relative preference for ASCs was shown as; renewable > fossil fuel > nuclear in model 2, and wind > biomass > PV > gas > coal > nuclear in model 3. This result is also well-behaved compared with the result of the attitudinal survey. According to the difference of relative preference order in the general public model and the local residence model, nuclear energy shows a strong NIMBY phenomenon such that it is preferred to fossil fuel if the facility is a long-distance from the respondent, but if it is located in their back yard, the opposition intensifies. Based on the result of the standard deviation, the heterogeneity of preference toward each parameter is confirmed. Across all the results among the ASCs, nuclear energy has the highest value of the standard deviation. In other word, the preference on nuclear energy is highly heterogeneous among respondents. The higher heterogeneous in energy issues may be interpreted as the higher possibility to incur social conflict. Based on the result of the general public model and the local residence model, the cost of social acceptance in Korea was estimated. The unit cost of social acceptance is lowest for PV, with 1.98 KRW/kWh, and highest for coal and nuclear, with 3.82 KRW/kWh. Since this result is higher than realized government expenditure for last three years, it can be concluded that the public's concern in terms of the social acceptance of electricity facility siting has increased.

5.1.2 Policy Implication

The estimation result of social acceptance cost in this study implies the public's psychological perceived cost. The social acceptance cost in the general public model can be regarded as representing the public's preference for nation's energy mix. When the government announces an energy plan that includes the long-term energy mix, various entities express the concerns based on their preference or perception. Some focuses on the reliable energy supply and the environmental problem related to the energy, while others show higher concerns about safety matters. These different and heterogeneous interests concerning energy issues constitute the preference for energy resources. Based on these preferences, each entity engages in collective behavior such as striking or expressing their concerns to the media. This eventually works to provide information to the general public, which also forms the public's preference for or perception of energy sources.

The heterogeneity of the preference for the energy mix leads the social conflict, but it is not easy to be compromised. For example, the Korean government tried to reflect the diverse voices from different social groups by constituting private governance in the '2nd National energy basic plan'. However, it has shown that a great deal of time and resources is required for coming to the agreement. Therefore, understanding the public's preference and social acceptance regarding energy mix can have an important role in decision-making on future energy issues. In the Korean context, diverse social conflicts regarding energy facilities occur intensively. For example, the Miryang transmission tower is facing a critical social conflict with strong opposition from local residents, while the reliable electricity supply is also facing a critical and dangerous situation. Therefore, in the case that each stakeholder is sharply opposed to the others due to their different preferences, this result can provide the useful information to be used for reaching social consensus and decision making.

The social acceptance cost in the local residence model can be regarded as representing the public's preference if the electric power facility is siting within 5km near to their residential area. In order to meet the fast growing demand of electricity in Korea, the new construction of electric power facility is necessary, and the local opposition to electric power facility siting is the main obstacle to implement such a policy. In this regard, the estimation result of the local residence model can provide the useful information to understand the public's heterogeneous preference on energy sources and diverse impacts of power plants. Especially, what people think as important factors in electric power facility siting can be understood by the result of RI. In addition, source of heterogeneity is identified by socio-economic characteristics of people so that the policy makers can establish the differentiated communication plans targeting on a specific segment of people according to their different preferences. In addition, the monetized value of the public's subjective risk can be utilized for deciding the proper level of compensation to the local residents near to the location of power plant siting. From the modeling perspective, the local residence model uses 'legitimacy' as an attribute in the conjoint analysis. The result empirically shows that the cost of social acceptance can be reduced when legitimacy of decision making is secured. Additionally, it is also concluded that HBNL model that has not been empirically applied yet can properly describe the public's preference for energy issues and can be applied to other related energy issues in the future.

5.2 Limitation and Further research

In this study, the social acceptance cost is estimated only for an electricity generation facility. If the scope of the research objective is extended to the full energy supply chain, there are additional electricity facilities such as transmission tower and radioactive waste disposal facilities, to be considered. Because these facilities are also regarded as LULU and accompanied by intensified local opposition, the external cost and the cost of social acceptance should be analyzed and incorporated into the cost structure.

Because of the environmental impact and the social acceptance problem, centralized electricity generation facilities, such as coal and nuclear energy cannot be sited near cities, where most of the electricity consumption occurs. Therefore large-scale transmission towers and lines should be installed, unlike renewable energy, which is regarded as a distributed electricity source. Recently, transmission-related costs, such as capital costs and congestion costs, have been increasing rapidly. Moreover, the social acceptance problem is highly intensified regarding transmission towers and nuclear facilities, so the cost of social acceptance seems to be significant. Therefore, when comparing with energy sources for deciding on energy mix, these costs may lead to a decreasing of the relative economics of centralized electricity generation sources.

Nuclear energy produces the spent fuel which will be a burden to both current and future generation. In order to control the spent fuel from nuclear power plants, the radioactive waste disposal facility is required. The spent fuel of nuclear energy should be administrated either by reprocessing it in the form of the high-level radioactive waste or keeping it in storage facility permanently. There is an increasing concern about the radioactive waste disposal facilities in Korea such that its capacity would be saturated in 2016. Therefore, the construction of new radioactive waste disposal facility is the urgent matter in Korea. However, strong local opposition from the local community makes it difficult, and significant amount of external cost will be accompanied. In fact, the cost for these facilities is controversial because it is somewhat intangible for the members of the general public who use electricity. Therefore, the comprehensive analysis of diverse impacts of these facilities on the environment and the society is required for measuring truer social cost of electricity.

From the modeling perspective, this research approaches social acceptance according to the concept of distance from the location of an electricity facility. In the model, however, there are only two segments of people, those within 5 km of the facility and those living at the distance of more than 5km of the facility. Since the economic theory of social acceptance is based on the heterogeneous perceived cost by distance, modeling work that includes the distance as a variable will be more realistic approach. An empirical study incorporating the concept of distance as a continuous variable can be conducted as a further study. In addition, these two models use different cash vehicles: one uses WTP, and the other uses WTA. these two different measures of cash vehicles are incorporated.into the process of the social acceptance cost estimation. However, there is a possibility that WTP and WTA cannot be simultaneously incorporated since WTP is based on the compensating variation and WTA is based on Hicksian equivalent variation. Therefore, the empirical test for the disparity of WTP and WTA in the model of this study can provide useful information for verifying the social acceptance cost, and it will be leaved as the scope of further study. The survey data for these two models were gathered from the same respondents. Accordingly, there may be response effects which means that the responses from two different models may be somewhat correlated, because same person response to different question. In order to cope with this limitation, the respondents can be segmented by different groups so that each response is independent to each other.

The estimation result in this study can be utilized in future research regarding the optimal energy allocation. Since the cost of social acceptance is measured as a monetary term for each energy source, these costs can be valuable input data for deriving the socially optimal energy mix that can achieve social cost minimization with the realistic physical and political constraints.

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Appendix 1: Korean Version of Survey Questionnaires

Part B: Survey questionnaires for General Public Model

Part B. 전력 에너지원에 대한 사회적 수용성 (일반)

※ 조사원은 다음의 내용을 주지시켜 주십시오.

본 설문에서는 전기를 생산하는 데 투입되는 각 에너지원이 사회적으로 미치는 영향에 대한 귀하의 의견을 여쭙고자 합니다. 에너지원이 사회에 미치는 영향은 다음과 같습니다. 국가경제 차원에서 신규 발전소를 건설하고 운영하는 과정에서 ① **새로운 일자리가 창출**되고 실업률이 감소하는 효과가 발생할 수 있습니다. 전력을 생산하는 과정에서 지구온난화에 영향을 미치는 ② **온실가스를 배출**합니다. 각 발전소가 입지하여 전력을 생산 시 많은 ③ **부지가 사용**됩니다. 해당 부지 확보를 위한 산림훼손이 예상되며, 장기간 (약 20~30년간) 동안 오염원에 노출되어 생태계 파괴가 예상됩니다. 전력은 국민의 삶을 영위하는 데 필수적인 요소로서 사회적 안정성을 위해서 ④ **공급 안정성**이 확보되어야 합니다.

이러한 관점에서 각 에너지원들은 그 특징에 따라 서로 다른 영향을 미치게 됩니다. **[보기카드 B - 6개 발전원 특징]**

본 조사에서는 귀하 가구가 각 발전소가 건설됨에 따라 사회적으로 미치는 영향에 따라 소비자가 부담해야할 ⑤ **전기요금의 변화**를 통해 각 에너지원의 사회적 수용성을 조사하려고 합니다. 이제 귀하에게 3개의 질문카드가 제시됩니다. 귀하 가구의 소득은 제한되어 있고 그 소득은 여러 용도로 지출되어야 한다는 사실을 고려하신 후 다음 질문에 신중하게 대답하여 주시기 바랍니다. **특히 답변 시 에너지원 명만 보지 마시고, 제시되어 있는 속성과 그 수준을 동시에 보고 판단해 주시기 바랍니다.**

속성	설명	속성 수준
1. 고용창출 효과	새로운 발전소 건설 및 운영으로 창출되는 일자리 수	(발전소 건설 및 운영기간 동안 창출되는 일자리 수) **- 최소 : 500 명 ~ 최대 : 3000 명**
2. 온실가스 배출	각 발전원별로 신규 발전소 건설/운영 시 발생하는 온실가스 (CO_2) 배출 증가량 (현재의 전력부문 총 탄소배출량은 약 2억 2천만톤이며, 단위 생산 전력 당 약 450 g/kWh임)	(신규 발전소 건설로 인한 온실가스 배출 증가량) **- 최소 : 1 만톤 CO2 eq/TWh*** (10 g/kWh) **- 최대 : 100 만톤 CO2 eq/TWh** (1000 g/kWh) * 한 가구당 월 평균 240 kWh를 사용하며, 1kWh는 일반 선풍기(50W)를 약 20시간 사용하는 정도의 전력양입니다.
3. 토지 점유	각 발전원 별 동일 전력 생산에 필요한 토지점유 면적으로, 산림훼손 및 생태계 파괴가 예상됨 (발전소, 저장설비, 원료확보 등의 면적을 모두 포함)	(1TWh 전력 생산 당 사용 토지 면적) **- 최소: $3km^2$/TWh** (약 100만평, 잠실종합운동장의 약 40배) **- 최대: $90km^2$/TWh** (약 3300만평, 잠실종합운동장의 1350배)
4. 전력 공급 안정성 (연간 정전시간)	지속적이며 안정적으로 전력을 공급할 수 있는 정도. 발전원의 특징에 따른 공급 불확실성의 차이로 정전 발생 가능성이 높아질 수 있음 (연간 가구 당 정전 시간)	(연간 가구 당 정전 시간) **- 최소 : 10 분 내외 / 년** (일년 중 가구 당 약 10분 정도의 정전이 발생) **- 최대 : 60 분 내외 / 년** (일년 중 가구 당 약 60분 정도의 정전이 발생)
5. 전기요금	각 가구당 매월 지출하는 전기요금 액수 (현재 4인가구 기준 월 평균 약 5 만원)	(월 평균 약 5만원 기준으로 지출 전기료) **- 최소 : 4만 8천원** (약 4% 하락, 2천원 절감) **- 최대 : 5만 5천원** (약 10% 증가, 5천원 추가부담)

* 1TWh는 1KWh의 약 10^9 배로, 1200MW 원자력 발전소 1기가 연간 생산하는 전력양의 약 10분의 1 수준입니다.

B1. [컨조인트 카드 제시] 제시된 3개의 질문에 대해 서로 다른 3개의 대안 (발전소)이 제시되어 있습니다. 각 대안의 속성 수준을 보시고 귀하께서 가장 선호하는 발전원 별로 □란에 순위를 적어주시기 바랍니다.

※ 급증하는 전력수요를 충당하기 위해 발전소의 건설은 매우 중요합니다. 정부가 위와 같은 발전소의 증설을 계획하고 있다고 가정했을 때, 귀하께서는 이러한 중요성을 인지한 상태에서 위의 가장 선호하는 발전소의 증설을 수용하시겠습니까? 아니면 수용하지 않고 현재 상태를 유지하시겠습니까? (현재 상태를 유지할 때, 급증하는 전력 수요를 대처하기 어려워 대규모 정전 등의 위험성이 지속될 수 있습니다)

① 위의 대안 중 선호하는 발전소를 건설하여 부족한 국가 전력 공급을 늘린다
② 현재 상태를 유지한다 [전기 사용량을 대폭 (기존 대비 약 30% 정도) 절약하여 전력 수요 증가 방지에 노력한다]

(※면접원은 각 질문별로 대안에 대한 응답자의 선호, 현재상태 유지 질문의 순서로 진행하시기 바랍니다. 응답자가 총 3개 질문에 모두 체크했는지 확인해 주십시오. 면접원은 각 식별번호와 대안순위를 적어주세요)

차례	식별번호	대안 1	대안 2	대안 3
질문 1				
질문 2				
질문 3				

위 선호 대안을 수용	현재 상태 유지 (발전소 증설 반대)
①	②
①	②
①	②

B2. (컨조인트 카드 제시) 제시된 3개의 질문에 대해 서로 다른 3개의 대안 (발전소)이 제시되어 있습니다. 각 대안의 속성 수준을 보시고 귀하께서 가장 선호하는 발전원 별로 □란에 순위를 적어주시기 바랍니다.

※ 급증하는 전력수요를 충당하기 위해 발전소의 건설은 매우 중요합니다. 정부가 위와 같은 발전소의 증설을 계획하고 있다고 가정했을 때, 귀하께서는 이러한 중요성을 인지한 상태에서 위의 가장 선호하는 발전소의 증설을 수용하시겠습니까? 아니면 수용하지 않고 현재 상태를 유지하시겠습니까? (현재 상태를 유지할 때, 급증하는 전력 수요를 대처하기 어려워 대규모 정전 등의 위험성이 지속될 수 있습니다)

① 위의 대안 중 선호하는 발전소를 건설하여 부족한 국가 전력 공급을 늘린다
② 현재 상태를 유지한다 [전기 사용량을 대폭 (기존 대비 약 30% 정도) 절약하여 전력 수요 증가 방지에 노력한다]

(※면접원은 각 질문별로 대안에 대한 응답자의 선호, 현재상태 유지 질문의 순서로 진행하시기 바랍니다. 응답자가 총 3개 질문에 모두 체크했는지 확인해 주십시오. 면접원은 각 식별번호와 대안순위를 적어주세요)

차례	식별번호	화석에너지	원자력에너지	재생에너지
질문 1				
질문 2				
질문 3				

위 선호 대안을 수용	현재 상태 유지 (발전소 증설 반대)
①	②
①	②
①	②

B3. (컨조인트 카드 제시) 제시된 3개의 질문에 대해 서로 다른 6개의 전력 에너지원 (발전소)이 제시되어 있습니다. 각 대안의 속성 수준을 보시고 귀하께서 가장 선호하는 발전원 별로 □란에 순위를 적어주시기 바랍니다.

※ 급증하는 전력수요를 충당하기 위해 발전소의 건설은 매우 중요합니다. 정부가 위와 같은 발전소의 증설을 계획하고 있다고 가정했을 때, 귀하께서는 이러한 중요성을 인지한 상태에서 위의 가장 선호하는 발전소의 증설을 수용하시겠습니까? 아니면 수용하지 않고 현재 상태를 유지하시겠습니까? (현재 상태를 유지할 때, 급증하는 전력 수요를 대처하기 어려워 대규모 정전 등의 위험성이 지속될 수 있습니다)

① 위의 대안 중 선호하는 발전소를 건설하여 부족한 국가 전력 공급을 늘린다
② 현재 상태를 유지한다 [전기 사용량을 대폭 (기존 대비 약 30% 정도) 절약하여 전력 수요 증가 방지에 노력한다]

(※면접원은 각 질문별로 대안에 대한 응답자의 선호, 현재상태 유지 질문의 순서로 진행하시기 바랍니다. 응답자가 총 3개 질문에 모두 체크했는지 확인해 주십시오. 면접원은 각 식별번호와 대안순위를 적어주세요)

차례	식별번호	석탄	가스	원자력	풍력	태양광	바이오매스
질문 1							
질문 2							
질문 3							

위 선호 대안을 수용	현재 상태 유지 (증설 반대)
①	②
①	②
①	②

컨조인트 카드 B1 **일반국민 수용성 [Block 1]**

식별번호 1	대안 1	대안 2	대안 3
고용효과 (명)	1000 명	3000 명	2000 명
온실가스 배출 (만톤 CO_2 eq/TWh)	90 만톤/TWh (900 g/kWh)	10 만톤/TWh (100 g/kWh)	90 만톤/TWh (900 g/kWh)
토지점유 (km^2/TWh)	10 km^2 (300만평) 잠실종합운동장의 130배	10 km^2 (300만평) 잠실종합운동장의 130배	10 km^2 (300만평) 잠실종합운동장의 130배
전력공급 안정성 (가구 당 연간 정전시간: 분/년)	총 30 분 내외/년	총 60 분 내외/년	총 60 분 내외/년
전기요금 변화 (현재 월평균 5만원 기준)	5만 2천원 (4% 상승) (2천원 추가부담)	5만 5천원 (10% 상승) (5천원 추가부담)	5만 5천원 (10% 상승) (5천원 추가부담)
순위 (1,2,3 위)			

컨조인트 카드 B2 **일반국민 수용성 [Block 1]**

식별번호 1	화석에너지	원자력에너지	재생에너지
고용효과 (명)	1000 명	2000 명	2000 명
온실가스 배출 (만톤 CO_2 eq/TWh)	90 만톤/TWh (900 g/kWh)	3 만톤/TWh (30 g/kWh)	5 만톤/TWh (50 g/kWh)
토지점유 (km^2/TWh)	10 km^2 (300만평) 잠실종합운동장의 130배	10 km^2 (300만평) 잠실종합운동장의 130배	70 km^2 (2100만평) 잠실종합운동장의 900배
전력공급 안정성 (가구 당 연간 정전시간: 분/년)	총 15 분 내외/년	총 15 분 내외/년	총 50 분 내외/년
전기요금 변화 (현재 월평균 5만원 기준)	5만 2천원 (4% 상승) (2천원 추가부담)	4만 7천원 (6% 하락) (3천원 하락)	5만 4천원 (8% 상승) (4천원 추가부담)
순위 (1,2,3 위)			

컨조인트 카드 B3 **일반국민 수용성 [Block 1]**

식별번호 1	석탄	가스	원자력	풍력	태양광	바이오매스
고용효과 (명)	1500 명	1500 명	2000 명	2000 명	2500 명	3000 명
온실가스 배출 (만톤 CO_2 eq/TWh)	100 만톤/TWh (1000 g/kWh)	50 만톤/TWh (500 g/kWh)	1 만톤/TWh (10 g/kWh)	5 만톤/TWh (50 g/kWh)	5 만톤/TWh (50 g/kWh)	1 만톤/TWh (10 g/kWh)
토지점유 (km^2/TWh)	5 km^2 (150만평, 잠실 운동장 60배)	5 km^2 (150만평, 잠실 운동장 60배)	7 km^2 (200만평, 잠실 운동장 60배)	70 km^2 (2000만평, 잠실 운동장 900배)	90 km^2 (2700만평, 잠실 운동장 1100배)	90 km^2 (2700만평, 잠실 운동장 1100배)
정전시간 (정전시간: 분/년)	총 15 분 내외/년	총 20 분 내외/년	총 20 분 내외/년	총 50 분 내외/년	총 60 분 내외/년	총 60 분 내외/년
전기요금 변화 (5만원 기준)	4만 9천원 (2% 하락) (1천원 하락)	5만 1천원 (2% 상승) (1천원 증가)	4만 7천원 (6% 하락) (3천원 하락)	5만 4천원 (8% 상승) (4천원 증가)	5만 2천원 (4% 상승) (2천원 증가)	5만 4천원 (8% 상승) (4천원 증가)
순위						

Part C: Survey questionnaires for Local Residence Model

Part C. 전력 에너지원에 대한 사회적 수용성 (입지지역)

※ 조사원은 다음의 내용을 주지시켜 주십시오.

<이번에는 각 발전소가 귀하가 거주하는 지역 인근 5km 이내에 입지한다고 가정하겠습니다. >

전력수요의 급증에 따라 전력의 안정적 공급을 위해서는 신규 발전소 증설을 통한 공급능력 확대가 필요합니다. 하지만 쾌적한 환경에 대한 국민의 욕구가 증대되어 에너지 공급 시설의 입지 어려움이 심화되고 있습니다.

발전소가 들어섬으로 인해 주변 지역에 피해가 발생할 수 있습니다. 전력생산 과정에서 발생하는 SOx, NOx, 먼지, 방사능 물질 등의 오염원 배출로 산성화, 부영양화 등과 같은 ① **인근지역의 환경 파괴**가 예상됩니다. 또한 이런 오염원은 인근지역 주민에게 ② **건강피해**를 미칠 수 있습니다. 또한 발전소가 입지 및 운영됨에 따라 진동, 소음 및 시각적인 영향 등을 미쳐 ③ **일상생활을 하는 데 불편함**이 발생할 수 있습니다.

발전소 입지 인근지역에 대한 다양한 피해가 예상됨에 따라 발전소 입지 선정 시 지역 주민, 환경/시민단체 등을 중심으로 격렬한 반대가 일습니다. 발전소 입지로 인한 피해는 인근 지역 주민들에게 돌아가게 되므로, 발전소 입지 선정과정에서 환경/보건적 영향에 대한 과학적인 평가, 의사결정 과정에서의 주민참여 등의 ④ **정책적 합리성**이 수용성 측면에서 중요한 요인이 됩니다. 정부/지자체 및 발전사업자는 이러한 피해를 보상 및 사회적 수용성 증진을 위해 '발전소주변지역지원에 관한 법률'을 제정하여 다양한 금전적, 비금전적 보상을 실시하고 있습니다. ⑤ **적절한 보상금액**은 에너지원 사회적 수용성을 결정하는 주요 요인으로 예상됩니다.

본 설문에서는 각 발전소가 귀하 가구의 거주지 인근 5km 이내에 입지한다고 가정하였을 때 인근 지역에 미치는 다양한 피해 및 정부/자자체의 정책에 대한 귀하의 의견을 여쭙고자 합니다. 이제 귀하에게 3개의 질문카드가 제시됩니다. 각 카드에는 아래의 서로 다른 **6가지 속성**으로 구성되어 있습니다. 귀하 가구의 소득은 제한되어 있고 그 소득은 여러 용도로 지출되어야 한다는 사실을 고려하신 후 다음 질문에 신중하게 대답하여 주시기 바랍니다. **특히 답변 시 에너지원 명만 보지 마시고, 제시되어 있는 속성과 그 수준을 동시에 보고 판단해 주시기 바랍니다.**

속성	설명	속성 수준
1. 고용창출 효과	새로운 발전소 건설 및 운영으로 창출되는 일자리 수	(발전소 건설 및 운영기간 동안 창출되는 일자리 수) **- 최소 : 500 명 ~ 최대 : 3000 명**
2. 온실가스 배출	각 발전원별로 신규 발전소 건설/운영 시 발생하는 온실가스 (CO_2) 배출 증가량 (현재의 전력부문 총 탄소배출량은 약 2억 2천만톤이며, 단위 생산 전력 당 약 450 g/kWh임)	(신규 발전소 건설로 인한 온실가스 배출 증가량) **- 최소 : 1 만톤 CO2 eq/TWh*** (10 g/kWh) **- 최대 : 100 만톤 CO2 eq/TWh** (1000 g/kWh) * 한 가구당 월 평균 240 kWh를 사용하며, 1kWh는 일반 선풍기(50W)를 약 20시간 사용하는 정도의 전력양입니다.
3. 토지 점유	각 발전원 별 동일 전력 생산에 필요한 토지점유 면적으로, 산림훼손 및 생태계 파괴가 예상됨 (발전소, 저장설비, 원료확보 등의 면적을 모두 포함)	(1TWh 전력 생산 당 사용 토지 면적) **- 최소: $3km^2$/TWh** (약 100만평, 잠실종합운동장의 약 40배) **- 최대: $90km^2$/TWh** (약 3300만평, 잠실종합운동장의 1350배)
4. 전력 공급 안정성 (연간 정전시간)	지속적이며 안정적으로 전력을 공급할 수 있는 정도. 발전원의 특징에 따른 공급 불확실성의 차이로 정전 발생 가능성이 높아질 수 있음 (연간 가구 당 정전 시간)	(연간 가구 당 정전 시간) **- 최소 : 10 분 내외 / 년** (일년 중 가구 당 약 10분 정도의 정전이 발생) **- 최대 : 60 분 내외 / 년** (일년 중 가구 당 약 60분 정도의 정전이 발생)
5. 전기요금	각 가구당 매월 지출하는 전기요금 액수 (현재 4인가구 기준 월 평균 약 5 만원)	(월 평균 약 5만원 기준으로 지출 전기료) **- 최소 : 4만 8천원** (약 4% 하락, 2천원 절감) **- 최대 : 5만 5천원** (약 10% 증가, 5천원 추가부담)

* 1TWh는 1KWh의 약 10^9 배로, 1200MW 원자력 발전소 1기가 연간 생산하는 전력양의 약 10분의 1 수준입니다.

B1. (컨조인트 카드 제시) 제시된 3개의 질문에 대해 서로 다른 3개의 대안 (발전소)이 제시되어 있습니다. 각 대안의 속성 수준을 보시고 귀하께서 가장 선호하는 발전원 별로 □란에 순위를 적어주시기 바랍니다.

※ 급증하는 전력수요를 충당하기 위해 발전소의 건설은 매우 중요합니다. 정부가 위와 같은 발전소의 증설을 계획하고 있다고 가정했을 때, 귀하께서는 이러한 중요성을 인지한 상태에서 위의 가장 선호하는 발전소의 증설을 수용하시겠습니까? 아니면 수용하지 않고 현재 상태를 유지하시겠습니까? (현재 상태를 유지할 때, 급증하는 전력 수요를 대처하기 어려워 대규모 정전 등의 위험성이 지속될 수 있습니다)

① 위의 대안 중 선호하는 발전소를 건설하여 부족한 국가 전력 공급을 늘린다
② 현재 상태를 유지한다 [전기 사용량을 대폭 (기존 대비 약 30% 정도) 절약하여 전력 수요 증가 방지에 노력한다]

(※면접원은 각 질문별로 대안에 대한 응답자의 선호, 현재상태 유지 질문의 순서로 진행하시기 바랍니다. 응답자가 총 3개 질문에 모두 체크했는지 확인해 주십시오. 면접원은 각 식별번호와 대안순위를 적어주세요)

차례	식별번호	대안 1	대안 2	대안 3
질문 1				
질문 2				
질문 3				

위 선호 대안을 수용	발전소 입지 반대
①	②
①	②
①	②

C2. (컨조인트 카드 제시) 제시된 3개의 질문에 대해 서로 다른 3개의 전력 에너지원 (발전소)이 제시되어 있습니다. 각 대안의 속성 수준을 보시고 귀하께서 가장 선호하는 발전원 별로 □란에 순위를 적어주시기 바랍니다.

※ 급증하는 전력수요를 충당하기 위해 발전소의 건설은 매우 중요합니다. 귀하께서는 이러한 중요성을 인지한 상태에서, 위의 가장 선호하는 대안의 에너지원이 거주지 인근에 입지하는 것을 수용하시겠습니까? 아니면 위의 어떠한 에너지원에 대해서도 거주지 인근 입지를 반대하시겠습니까? (입지 반대 시 대규모 정전 등의 위험이 지속될 수 있습니다)

① 위의 대안 중 선호하는 에너지원의 입지를 수용한다
② 입지를 반대한다 (입지 반대를 위한 집단 행동에 동참하거나, 타 지역 입지를 위한 기금모금에 참여하겠다)

(※면접원은 각 질문별로 대안에 대한 응답자의 선호, 현재상태 유지 질문의 순서로 진행하시기 바랍니다. 응답자가 총 3개 질문에 모두 체크했는지 확인해 주십시오. 면접원은 각 식별번호와 대안순위를 적어주세요)

차례	식별번호	화석에너지	원자력에너지	재생에너지
질문 1				
질문 2				
질문 3				

위 선호 대안을 수용	발전소 입지 반대
①	②
①	②
①	②

C3. (컨조인트 카드 제시) 제시된 3개의 질문에 대해 서로 다른 6개의 전력 에너지원 (발전소)이 제시되어 있습니다. 각 대안의 속성 수준을 보시고 귀하께서 가장 선호하는 발전원 별로 □란에 순위를 적어주시기 바랍니다.

※ 급증하는 전력수요를 충당하기 위해 발전소의 건설은 매우 중요합니다. 귀하께서는 이러한 중요성을 인지한 상태에서, 위의 가장 선호하는 대안의 에너지원이 거주지 인근에 입지하는 것을 수용하시겠습니까? 아니면 위의 어떠한 에너지원에 대해서도 거주지 인근 입지를 반대하시겠습니까? (입지 반대 시 대규모 정전 등의 위험이 지속될 수 있습니다)

① 위의 대안 중 선호하는 에너지원의 입지를 수용한다
② 입지를 반대한다 (입지 반대를 위한 집단 행동에 동참하거나, 타 지역 입지를 위한 기금모금에 참여하겠다)

(※면접원은 각 질문별로 대안에 대한 응답자의 선호, 현재상태 유지 질문의 순서로 진행하시기 바랍니다. 응답자가 총 3개 질문에 모두 체크했는지 확인해 주십시오. 면접원은 각 식별번호와 대안순위를 적어주세요)

차례	식별번호	석탄	가스	원자력	풍력	태양광	바이오매스
질문 1							
질문 2							
질문 3							

위 선호 대안을 수용	발전소 입지 반대
①	②
①	②
①	②

컨조인트 카드 C1 | **입지지역 거주자 수용성 [Block 1]**

식별번호 1	대안 1	대안 2	대안 3
지역환경 피해 (km^2/TWh)	20 km^2 (600만평) 잠실종합운동장의 250배	30 km^2 (900만평) 잠실종합운동장의 400배	20 km^2 (600만평) 잠실종합운동장의 250배
건강피해 (조기 사망자 수) (명/100만명·년·TWh)	10 명	15 명	5 명
생활피해 (불편함)	상 (일상적으로 불편함 느낌)	상 (일상적으로 불편함 느낌)	중 (종종 불편함 느낌)
정책적 합리성	없음 (일방적 통보)	있음 (투명, 공정, 민주적임)	있음 (투명, 공정, 민주적임)
보상금액 (가계에 일시불 지급)	700 만원	700 만원	700 만원
순위 (1,2,3 위)			

컨조인트 카드 C2 | **입지지역 거주자 수용성 [Block 1]**

식별번호 1	화석에너지	원자력에너지	재생에너지
지역환경 피해 (km^2/TWh)	30 km^2 (900만평) 잠실종합운동장의 400배	10 km^2 (300만평) 잠실종합운동장의 130배	10 km^2 (300만평) 잠실종합운동장의 130배
건강피해 (조기 사망자 수) (명/100만명·년·TWh)	15 명	10 명	15 명
생활피해 (불편함)	중 (종종 불편함 느낌)	중 (종종 불편함 느낌)	하 (미미한 정도의 불편함)
정책적 합리성	있음 (투명, 공정, 민주적임)	있음 (투명, 공정, 민주적임)	없음 (일방적 통보)
보상금액 (가계에 일시불 지급)	900 만원	900 만원	700 만원
순위 (1,2,3 위)			

컨조인트 카드 C3 | **입지지역 거주자 수용성 [Block 1]**

식별번호 1	석탄	가스	원자력	풍력	태양광	바이오매스
지역환경 피해 (km^2/TWh)	30 km^2 (900만평, 잠실 운동장 400배)	20 km^2 (600만평, 잠실 운동장 260배)	30 km^2 (900만평, 잠실 운동장 400배)	10 km^2 (300만평, 잠실 운동장 130배)	20 km^2 (600만평, 잠실 운동장 260배)	30 km^2 (900만평, 잠실 운동장 400배)
건강피해 (조기 사망자 수 /100만명·년·TWh)	15 명	15 명	10 명	10 명	5 명	5 명
생활피해 (불편함)	상 (일상적으로 불편함 느낌)	중 (종종 불편함 느낌)	하 (미미한 정도의 불편함)	중 (종종 불편함 느낌)	중 (종종 불편함 느낌)	중 (종종 불편함 느낌)
정책적 합리성	없음 (일방적 통보)	있음 (투명,공정,민주)	없음 (일방적 통보)	있음 (투명,공정,민주)	있음 (투명,공정,민주)	있음 (투명,공정,민주)
보상금액 (가구 일시불 지급)	900 만원	700 만원	700 만원	900 만원	700 만원	500 만원
순위						

Display card for Survey

보기카드 B-1

	석탄화력발전	가스화력발전	원자력발전
원리	 ▪ 석탄을 태워서 발생하는 열을 이용하여 물을 가열하고, 발생하는 증기를 통해 터빈을 회전시켜 전기 생산	 ▪ 천연가스를 연소시켜 발생하는 열을 이용하여 압축된 공기를 팽창시키고, 이를 통해 터빈을 회전시켜 전기 생산	 ▪ 우라늄이 핵분열 하는 과정에서 발생하는 열을 이용하여 증기를 생산하고, 이를 통해 터빈을 회전시켜 전기 생산
특징	▪ 표준용량 : 약 1000MW ▪ 대규모 발전이 가능하여 안정적 전력생산이 가능하며, 냉각을 위한 물이 필요하여 해안가에 위치 ▪ 건설비가 저렴하며 공사기간이 짧으며, 연료가 저렴하여 경제성이 높음 ▪ 석탄의 특성 상 이산화탄소 배출량이 많으며, 대기 및 수질 오염을 유발함	▪ 표준용량 : 약 800MW ▪ 대규모 발전이 가능하여 안정적 전력생산이 가능하며, 냉각을 위한 물이 필요하여 해안가에 위치 ▪ 건설비가 저렴하며 공사기간이 짧으나, 석탄 대비 높은 연료비와 연료저장이 어려워 운영비 높음 ▪ 타 에너지원 대비 이산화탄소 배출량이 높으나, 석탄대비 절반 이하 수준이며 효율이 높음	▪ 표준용량 : 약 1500MW ▪ 대규모 발전이 가능하여 안정적 전력생산이 가능하며, 냉각을 위한 물이 필요하여 해안가에 위치 ▪ 건설비가 비싸고 공시기간이 길지만, 연료비가 저렴하여 운영비가 적음 ▪ 대형 사고 시 피해가 막대하며, 방사성 폐기물이 발생하여 별도의 처리설비가 필요함
현황	▪ 현재 발전설비 비중 : 38.5%	▪ 현재 발전설비 비중 : 26.8%	▪ 현재 발전설비 비중 : 38.9%

보기카드 B-2

	풍력발전	태양광발전	바이오매스발전
원리	 ▪ 바람의 운동에너지를 이용하여 회전날개(터빈)를 회전시켜 전기 생산	 ▪ 태양의 빛 에너지를 이용하여 태양전지를 통해 직접 전기 생산	 ▪ 바이오매스 즉, 광합성 유기물 및 파생 제품 (우드칩, 우드펠렛 등)을 연소하여 발생하는 수증기로 터빈을 회전시켜 전기 생산
특징	▪ 표준용량 : 약 20MW ▪ 평균 초속 4m/s 이상의 바람이 부는 곳에서만 입지 가능하며, 바람의 속도가 일정치 않아 안정적 전력 공급에 지장 ▪ 초기 설치비용이 높으나 건설 및 설치기간이 짧고 유지보수 등의 관리비용이 타 신재생 대비 낮음 ▪ 인근지역에 소음, 저주파 등의 피해가 있으며, 경관훼손이 우려됨	▪ 표준용량 : 약 10MW ▪ 일조량이 높은 지역에만 입지 가능하며, 태양이 낮에만 운영 가능하여 안정적 전력공급에 지장 ▪ 대규모 물리적 면적이 필요하며, 고가 원재료를 이용하여 설치비와 발전원가가 가장 높음 ▪ 태양전지 제조 과정에서 많은 에너지를 사용 및 인근지역에 저주파 및 주변온도 상승이 우려됨	▪ 표준용량 : 약 30MW ▪ 주로 산간지역에 입지하며, 지속적인 전력 생산 가능하여 안정적 전력공급 가능 ▪ 초기투자비용이 높은 편이나, 다른 연료를 혼합, 변경 가능함 ▪ 자원이 풍부한 편이나, 원료공급이 계절적으로 영향을 받을 수 있으며, 운반이 비교적 어렵고 산림훼손이 우려됨
현황	▪ 현재 발전설비 비중 : 0.58%	▪ 현재 발전설비 비중 : 0.84%	▪ 현재 발전설비 비중 : 0.11%

Abstract (Korean)

장기 지속 가능한 에너지 개발을 위해서는 경제성 보장, 환경피해 최소화, 기술적 한계 극복 등 서로 상충되는 다양한 요건을 만족해야 한다. 최근 대외적으로는 온실가스 감축에 대한 전세계적 관심 증대에 따른 에너지의 환경성 문제가 부각되고 있으며, 국내적으로는 전력설비에 대한 사회적 수용성 악화 등 사회적 갈등으로 인한 에너지의 사회성 문제가 부각되고 있는 상황이다. 특히, 에너지 문제에 대한 국민의 정량화되지 않은 주관적 관심사가 더욱 중요해지고 있는 상황에서 올바른 에너지 정책 수립을 위해서는 물리적 혹은 기술적 측면뿐만 아니라 국민들의 선호가 고려되어야 한다. 많은 에너지 문제는 사회적 갈등을 동반하며, 이러한 사회적 수용성 문제는 전력계획의 이행에 중요한 영향을 미친다. 예를 들어, 발전소 입지에 대한 지역사회의 강력한 반대로 인해 발전소 건설이 지연되는 경우, 안정적 에너지 공급에 심각한 위협이 발생할 수 있으며, 이에 따른 자본적 손실 또한 발생할 수 있다. 이러한 관점에서, 전력설비 입지와 관련한 국민들의 선호와 사회적 수용성 문제를 이해하는 것은 사회적으로 적정한 에너지 정책 수립 및 이행에 있어 중요한 의미를 가진다.

일반적으로 사회적 비용은 사적비용과 외부비용의 합으로 정의되며, 외부 비용은 환경적 외부비용과 비환경적 외부비용으로 구분된다. 사적비용은 생산자가 생산활동 과정에서 발생하는 비용 중 실제로 부담하는 비용이며, 외부비용은 생산자의 비용함수에 포함되지 않아 사회가 담당해야 하는 비용이다. 지역

주민의 반대에 따라 발생하는 비용은 생산자의 비용에 포함되지 않기 때문에 전력의 사회적 비용으로 간주할 수 있다. 그러나 대부분의 기존연구는 환경적 외부비용에 초점을 맞추고 있으며 사회적 수용성과 관련된 비용과 이를 사회적 비용 체계 내에 통합하는 논의는 부족한 실정이다. 따라서 전력설비 입지에 대한 사회적 수용성 문제를 정량적으로 분석할 필요가 있다.

본 연구의 목적은 전력 설비의 입지에 대한 사회적 수용성 비용을 추정하는 것이다. 전력 설비 입지에 대한 국민의 선호를 분석하고 이를 화폐단위로 추정하기 위해, 선택실험 방법을 이용하였다. 분석을 위한 모형적 관점에서는 대중의 의사결정의 논리적 사고구조, 각 에너지원 간의 암묵적인 관계 및 전력의 다양한 영향에 대한 선호의 이질성을 반영할 필요가 있다. 따라서, 개인의 이질성을 반영하고 다항로짓모형 (Multinomial logit model)의 IIA 제약을 극복할 수 있는 계층적 베이지안 혼합 네스티드로짓모형 (Hierarchical Bayesian mixed nested logit model)을 적용하였다. 사람들은 실제로 전력설비 입지와 관련하여 해당 설비가 미치는 다양한 영향뿐만 아니라 에너지원 자체에 대한 인식에 기인하여 선택을 할 것으로 판단된다. 따라서, 모형을 대안상수를 포함하지 않은 모형 (모형 1)과 포함한 모형으로 구분하여 분석하였다. 대안 상수를 포함한 모형은 다시 두 가지 하부 모형으로 구분하였다. 즉, 화석연료, 원자력, 재생에너지와 같은 에너지원의 범주로 포함한 모형 (모형 2)과 석탄, 가스, 원자력, 풍력, 태양광, 바이오매스의 총 6가지 개별 에너지원을 대안상수로 고려한 모형 (모형 3)으로 구분하여 실증 분석을 수행하였다.

실증 분석의 결과에 따르면, 제안된 모형은 전력 설비 입지와 관련된 국민들의 선호를 잘 반영하는 것으로 나타났다. 각 에너지원에 대한 국민들의 상대적 선호 순위 결과에 따르면, 원자력 에너지의 경우 님비현상이 가장 강하게 나타나는 것으로 확인되었으며, 선호의 이질성 측면에서도 원자력 발전에 대한 이질적 선호가 가장 높은 것으로 분석되었다. 전력 설비 입지에 대한 사회적 수용성 비용을 각 에너지원 별로 추정한 결과, 원자력에 대한 수용성 비용이 가장 높게 나타났으며 재생에너지는 상대적으로 낮은 수용성 비용을 가지는 것으로 분석되었다.

결론적으로, 본 논문은 서로 다른 전력원의 설비 입지에 대한 대중들의 선호와 사회적 수용성을 이해하기 위한 중요한 정보를 제공할 수 있다. 특히, 각 에너지원에 대한 상이한 선호로 인해 각 이해당사자간의 첨예한 대립이 발생하는 경우, 본 연구의 결과는 서로간의 합의와 사회적으로 최적인 에너지 정책 수립에 유용하게 활용될 수 있다. 또한, 대중의 주관적 가치의 정량적 분석 및 화폐단위로의 추정을 통해 전력설비 입지 인근 거주자에 대한 적절한 보상수준을 결정하는 데에도 활용될 수 있다. 추가적으로, 현재까지 실증분석에서 적용되지 않은 계층적 베이지안 혼합 네스티드로짓 모형이 향후 다양한 에너지 이슈에 대한 국민의 선호를 분석하는데 유용하게 활용될 수 있음을 확인하였다.

주요어 : 사회적 비용, 외부비용, 사회적 수용성, 계층적 베이지안 혼합 네스티드 로짓 모형, 지속가능성
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