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ABSTRACT

As one of the promising energy sources for the next few decades, nuclear energy receives more attention than before as environmental issues become more important and the supply of fossil fuels becomes unstable. One of the reasons for this attention is based on the rapid innovation of nuclear technology which solves many of its technological constraints and safety issues. However, regardless of these rapid innovations, social acceptance for nuclear energy has been relatively low and unchanged. Consequently, the social perception has often been an obstacle to the development and execution of nuclear policy requiring enormous subsidies which are not based on the social value of nuclear energy. Therefore, in this study, we estimate the social value of nuclear energy-consumers' willingness-to-pay for nuclear energy—using the Contingent Valuation Method (CVM) and suggest that the social value of nuclear energy increases approximately 68.5% with the provision of adequate information about nuclear energy to the public. Consequently, we suggest that the social acceptance management in nuclear policy development is important along with nuclear technology innovation.

1. Introduction

In recent years, in addition to unstable energy supply and volatile energy prices, environmental concerns make energy security as the principal objective of energy policy in many nations. The International Energy Agency (2007) released what is probably its most pessimistic *World Energy Outlook* to date saying that, if countries do not change their energy use policies, oil and natural gas imports, coal use and greenhouse gas emissions are set to grow inexorably through 2030—trends that threaten to undermine energy security and accelerate climate change (IEA, 2007). In addition, those who examine specific energy conservation or alternative fuel technologies, such as oil conservation or the substitution of biofuels for petroleum products, frequently observe complementarity between the abatement of greenhouse gases and an increase in energy security. Although such complementarity can exist for individual technologies, policymakers are confronted with a tradeoff between these two policy objectives (Farrel et al., 2006; Tyner, 2007)

Related to the environmental issues, the major source of the carbon dioxide emissions that contribute to global climate change is the electricity generation sector. In US, electricity generations are mostly based on the fossil fuels, which are responsible for roughly 40% of all carbon dioxide emissions from human activity. Therefore, eminent reduction of carbon emission can be achieved by changing a substantial fraction of US electricity generating capacity from fossil fuels to environmentally friendly energy sources. Consequently, nuclear became highlighted due to its distinguishable economic and environmental advantage over other energy resources including non-hydroelectric renewables (McVeigh et al., 2000). In the near future, nuclear is expected to be accepted as one of the promising alternatives which can achieve both energy security supply and prevention of climate change. Nuclear power had no problems meeting technical and safety standards both on paper and in inspections. As an example, the Bush administration announced in 2005 that they were considering the additional construction of nuclear plants.

However, nuclear energy has some vulnerable points in the view of social acceptance due to the history of its development and previous accidents related with nuclear power plants such as Ukraine's Chernobyl and the Three Mile Island accident in the United States. Thirty people died in the Chernobyl disaster in 1986, the worst nuclear power plant accident ever. In the case of Three Mile Island, where a partial core melt down occurred in 1979, no one was directly killed, but nearly 2 million people were exposed to radiation. Follow-up radiological studies predicted at most one long-term cancer fatality in the region. The accident led

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to a complete cessation of nuclear construction in the United States, with over 100 planned reactor constructions being canceled.

Consequently, low social acceptance for nuclear energy has been obstructing us from using more nuclear energy which can be a good solution for the coming decades of environmental problems and fossil energy depletion, although nuclear technology has been developed rapidly lowering the risk of using it.[1] Opposition from local residents who live near the area where nuclear facilities are expected to be built has often been the major obstacle for the execution of nuclear policy. Many countries which use nuclear power as one of their major energy sources have been solving the problem by providing enormous subsidies to local governments. For example, Korea decided to give 300 million dollars to the local government, *Gyeongju*, for constructing low level waste management facilities. Japan also paid 120 million dollar to the *Rokkasho-mura* area for constructing a nuclear waste repository. *Sellafield* in England and *El Cabril* in Spain also have been receiving subsidies every year from the related industries and their governments.

However, these subsidies have been provided without any appropriate estimate of the value of risk taking of nuclear energy. In addition, those subsidies are expected to increase and burden on the central government for the further development and usage of nuclear energy. This study, therefore, aims to evaluate the value of nuclear energy in view of its social acceptance in order to contribute to an effective application of nuclear policy for the future development of nuclear energy. We estimate the Willingness-To-Pay (WTP) for nuclear energy using the Contingent Valuation Method (CVM) in order to measure the social cost of nuclear energy due to the asymmetry of information or the limited diffusion of information about the safety of nuclear energy.

2. Social acceptance and nuclear energy

Issues on global warming, climate change, energy security, and the availability of fossil fuels are causing many countries to reconsider nuclear energy as a remedy for those problems. In addition, more and more governments realize that renewable energy sources can solve the problems only partially. However, social acceptance of nuclear energy has been withheld in many countries to an extent that the role of nuclear power has to be significantly restricted in international energy economy (Golay, 2001). Consequently, social acceptance became more and more impending issue for those governments, which plan energy supply and demand for their countries.

In the case of Korea, the government announces a basic plan of power supply and demand every two years based on the estimates for electricity demand and makes plans for the number and the types of power plants to meet the demand for the next 15 years. Korea also considers the issues of climate change and energy security problem together with the expected increase of electricity demand. As mentioned above, low carbon fuels such as renewable and nuclear energy are preferred and important in the production of electricity in order to mitigate the problem of climate change, so that the phase-out of coal power plants and fuel switch can be introduced (Lee, 2006).[2]

However, in the case of nuclear energy, concern about public acceptance has been an important issue for its planning. As seen from the Table 1 below, it took more than 20 years to make a low level waste site. Finally *Gyungju* was selected from a voluntary vote of 89.5% in favor. But to draw this result, Korean government promised to pay a 300 million dollar subsidy and move Korea Hydro and Nuclear Power (KHNP)'s headquarters to the area as the price for constructing low level waste site in the region.

Not only Korea, but also many other countries, such as Taiwan, India, China and Sweden, confront similar social acceptance issues when they try to expand or restart their nuclear power plant operations. In their policy development, the social acceptance problem has been one of the key issues to overcome in order to successfully develop their nuclear energy policy in the new environmental situation.

For example, Sweden reversed its nuclear phase-out and released a policy document in February, 2009 that stated that "The climate issue is now in focus, and nuclear power will thus remain an important part of Swedish electricity production for the foreseeable future". *Svensk Kärnbränslehantering AB* (*SKB*), the utility-owned organization responsible for managing Sweden's radioactive waste, is expected to decide between two competing localities, *Oskarshamn* and *Östhammar*. Both locations actively try to host the deep geological repository. The $240 million is part of a preliminary agreement of community support to be finalized by SKB with the councils of the two locations. In addition to this money, the host region would benefit from infrastructure upgrades, an influx of spending during construction and operation as well as a long-standing supply of high-quality local jobs. *Oskarshamn* already hosts Sweden's interim store for used nuclear fuel, CLAB, as well as the Äspö hard rock laboratory and the lab researching the manufacture of waste containers. *Östhammar* has the final repository for the short-lived radioactive waste SFR. Both have nuclear power plants nearby, *Oskarshamn* and *Forsmark*, respectively.

In the case of US, until mid 1960s nuclear energy was generally accepted as a valuable and highly favorable energy source. During these years, the orders for most of the currently operating nuclear power plants were placed or planned. However, after the Vietnam war, US experienced economic stagnation and uncertainty, and internal conflict regarding government policies. Without doubt, nuclear energy was also caught in these policy conflicts because of fear for nuclear accidents, radioactive wastes and weapons. Later in early 1990s, sustained economic growth and stable improvements in the operation of nuclear power plants with good operation records changed the social climate toward nuclear energy. Gradually, NRC (Nuclear Regulatory Commission) relaxed regulation on nuclear power plants reflecting growing social acceptance of nuclear energy. However, until now, no new nuclear power plants are being constructed in the US after 1977 (Golay, 2001).

However, recent surveys conducted by European Commission (the Eurobarometer series) and IAEA (International Atomic Energy Agency) between 2005 and 2007 showed gradual increase of social acceptance of nuclear energy internationally. Especially, Finland, Hungary, Japan, Sweden, the United Kingdom and the US slowly increasing trend in their attitude for nuclear energy.

[1] The first successful civilian reactors for electricity production were fueled by uranium. Uranium shortages were a long-term concern only and it was recognized that the energy potential of uranium could be multiplied through breeder reactors, whereby uranium resources offered an essentially inexhaustible fuel resource. With the use of advanced fuel cycles and breeder reactor systems, nuclear energy offered the possibility of meeting the worlds, nuclear energy (Kim et al., 2009). In 2000, eleven countries developed a technology roadmap for Generation IV Nuclear Energy Systems (Gen IV systems) in 2002. They, especially, South Korea, emphasizes development of sodium-cooled fast reactors (SFR) and pyroprocess systems. Pyroprocesses are fuel recycling processes and are considered to have excellent proliferation-resistant features. SFR systems feature a fast-spectrum reactor and a closed fuel recycling system (GIF, 2002).

[2] Another is to increase the reliance on low carbon fuel like LNG. However, the LNG price is expected to be high and has been increasing, while Korea depends on the import of LNG from foreign countries.

Table 1
Historic data for selecting a low level waste management site.

Period	Site	Office in charge	
1st phase ('86–'89)	Youngduk, Youngil, Uljin	KAERI[a]/MOST[b]	Failed
2nd phase ('90–'91)	Ahnmyundo	KAERI/MOST	Failed
3rd phase ('91–'93)	Kosung, Yangyang, Uljin, others	KAERI/MOST	Failed
4th phase ('93–'94)	Yangsan, Uljin	KAERI/MOST	Failed
5th phase ('94–'95)	Goolupdo	KAERI/MOST	Failed
6th phase (2000–'06)	1. Buan	KEPCO[c]/MOCIE[d]	Failed
	2. Gyungju, Gunsan, Pohang and Youngduk	KEPCO/MOCIE	Voluntary vote
	3. Gyungju was selected[e]	KEPCO/MOCIE	89.5% in favor

[a] Korea Atomic Energy Research Institute.
[b] Ministry of Science and Technology, Korea.
[c] Korea Electric Power Companies.
[d] Ministry of Commerce, Industry and Energy, Korea.
[e] Nov. 2005.

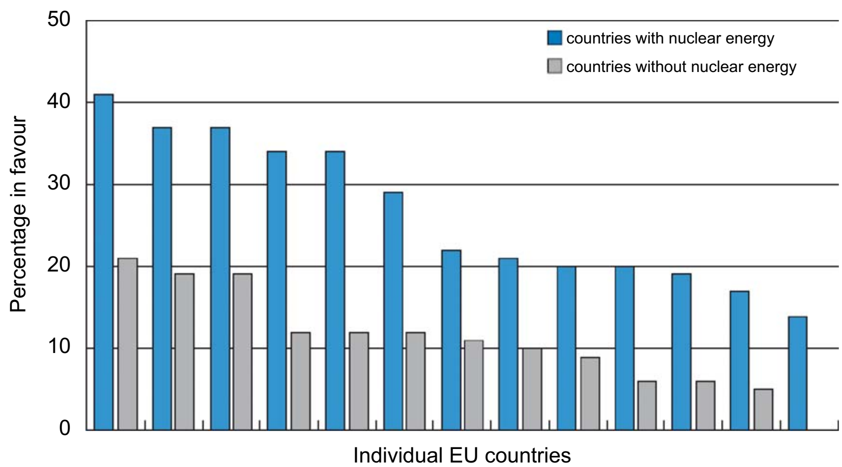

Fig. 1. Percentage of people supporting the use of nuclear power in each of the 25 EU countries, after dividing them into countries with and without nuclear power plants (Kovacs and Gordelier, 2009).

Only that of France has been relatively constant around 50% for the support of nuclear energy. Nevertheless, in the countries of the European Union (25 countries with survey), the percentage of people who are favorable for nuclear energy is only 20% in average ranging between 5% (Austria) and 41% (Sweden). In the case of the support for the expansion of the nuclear power in each country, the average was only 28% ranging from 13% (Morocco) and 52% (South Korea) (Kovacs and Gordelier, 2009).

Interesting finding from the survey is that people living in countries with nuclear power plants are more supportive of nuclear energy (Fig. 1) because they are more familiar with it, better informed about it and more aware of its benefits (Kovacs and Gordelier, 2009). They also segmented respondents into pro-nuclear, anti-nuclear and middle-ground categories, and found that, in those countries with nuclear power plants, the middle ground is the largest group whereas in countries without nuclear power, those who are anti-nuclear group are the largest. Consequently, these findings support the importance of information and communication in social acceptance of nuclear energy and make us to further explore the relationship between the information provision and the social acceptance of nuclear energy.

3. Empirical design and data collection

3.1. Theoretical framework of Contingent Valuation Methodology

The Contingent Valuation Method (CVM) has become popular and widely applied in many countries for assessing the benefits from non-market goods or projects accruing to society (Carson and Hanemann, 2005; Mitchell and Carson, 1989). The CVM involves directly asking people how much they are willing to pay for non-market goods or services, such as environmental preservation or the impact of contamination, using a survey. Many times, people are asked for the amount of compensation they would be willing to accept to give up specific goods or services. It is called "contingent" valuation, because people are asked to state their willingness-to-pay contingent on a specific hypothetical scenario and description of the situations or 'market' where the goods or services are provided. The CVM is often referred to as a "stated preference" model, in contrast to a price-based revealed preference model, because it asks people to directly state their values, rather than inferring values from actual choices. CVM is also widely accepted as a real estate appraisal technique (Spash, 2006; Vatn, 2004), not only as the method for the valuation of environmental benefits (Bateman et al., 1996; Biship et al., 1983; Carson et al., 2001; Knetsch, 2005), cultural goods (Aabø and Strand, 2000; Bille-Hansen, 1997; Bravi et al., 1998; Ehrenberg and Mills, 1990), health care services (Bergstrom et al., 1985; Olsen and Smith, 2001; Protière et al., 2004), and other public goods and services (Gerking et al., 1988; Gordon and Knetsch, 1979).

CVM is required that the respondents obtain a complete perception of the non-market goods or services and the expected benefits from it, and that they balance their expected increase in well-being and the loss of market consumption in the future as a consequence of having to pay for the goods. Moreover, respondents must believe the payment mechanism, i.e., that their answers to the survey are consequential and that they would actually have to pay the stated amount if the project is to be implemented (Carson and Groves, 2007).

Therefore, in order to measure the depreciation of the social valuation on nuclear energy stemming from the lack of information about nuclear energy, such as safety, environmental and economic benefits, etc., a survey with information about nuclear energy and another on without it was conducted—a survey with and without information about nuclear energy. The difference of the WTP between the two surveys will explain the amount of the depreciation of social valuation on nuclear energy due to low social acceptance originated from the information asymmetry in society.

3.2. Willingness-To-Pay Model

The Hicksian compensating surplus was induced by the Dichotomous Choice-Contingent Valuation Methodology (DC-CVM) based on Hanemann's (1984, 1989) utility difference model. The utility difference model is one of the methodologies that quantify the magnitude of the Hicksian compensation based on the CVM data (Cameron and James, 1987). Here we assume that a respondent's choices reflect the maximum process of utility. If the respondent's response increment (Δv) of the indirect utility function is positive, the respondents will maximize their utility as the answer 'yes'. Therefore, the probability that the respondent answers 'yes' can be expressed as Eq. (1)

$$Pr(\text{Yes}) = Pr(\Delta v \geq \eta) = F\eta(\Delta v) \quad (1)$$

$F\eta(\cdot)$ is a cumulative distribution function of the random variable η. But if the respondent's answer is 'yes,' the probability of the WTP which is the random variable B, can be denoted $Pr(\text{Yes}) = Pr(B \geq A) = 1 - G_c(A)$ where A is a bid price and $G_c(A)$ is a cumulative distribution function of the random variable B. Therefore, $G_c(A)$ can be defined as the following Eq. (2):

$$F\eta(\Delta v) = 1\text{-}G_c(A) \quad (2)$$

(Hanemann, 1984) pointed out that Eq. (2) can be explained by the utility maximizing response within a Random Utility Theory and $G_c(\cdot)$ is a cumulative distribution function of each person's maximum WTP. Therefore, the estimation of the WTP model means a parameter estimation of the cumulative distribution function.

1) Single-Bounded Choice question model
Only one bid price is offered in the Single-Bounded Choice question (SBDC) model. If we assume $G_c(A_i)$ represents the probability of the ith respondent's response as 'No' to the bid price (A), the log likelihood function can be denoted as follows:

$$\ln L = \sum_{i=1}^{N} \{I_i^Y \ln[1\text{-}G_c(A_i)] + (1\text{-}I_i^Y)\ln G_c(A_i)\} \quad (3)$$

when the ith respondent's answer is 'yes,' will be 1, which is an indicator function. Namely, if the respondent's response is 'yes,' the indicator function will be 1, and if not, it will be 0. If we assume the logarithmic distribution, $G_c(\cdot)$ can be formulated as $G_c(A)[1+e^{a-bA}]^{-1}$ QUOTE QUOTE . Hanemann (1984) described that if the WTP is equal to or over 0, the truncated average WTP(C^{++}) is calculated as follows:

$$C^{++} = \frac{1}{b} ln\left[1+e^{a}\right] \quad (4)$$

Otherwise, if some of the respondents regard that nuclear energy is not needed, they will choose the value lower than 0. In this case the truncated average WTP (C^{+}) can be defined like Hanemann (1984) as follows:

$$C^{+} = \frac{a}{b} \quad (5)$$

To analyze the effect of each respondent's social and economic characteristics to the WTP question, covariates need to be included in the model. A CVM study generally estimates the WTP including covariates. Then, the feasibility of the model and internal consistency can be verified. If covariates are included, a in the above equations will be replaced by . Here means the respondent' social and economic characteristic vector and β the parameter vector which is to be estimated.

2) Double-Bounded Choice question model
The bid price is offered twice in the Double-Bounded Choice question (DBDC) model. The second bid price is determined by the first bid's answer. If the respondent's answer is 'yes,' a higher bid price is given. Otherwise, a lower bid price is given to the second bid price. When respondent's response is 'No' to the first bid price, A_i, its probability can be expressed as $G_c(A_i)$. If the respondent's response is 'yes' to the first bid price and 'no' to the second bid price, A_i^u, its probability can be expressed as $G_c(A_i^u)$, and if the answers are 'no' to both bid prices, the probability will be $G_c(A_i^d)$. Therefore the log likelihood function in the DBDC model is

$$ln\, L = \sum_{i=1}^{N} \{I_i^{YY}\, ln[1\text{-}G_c(A_i^u)] + I_i^{YN}\, ln[G_c(A_i^u)\text{-}G_c(A_i)]\} + I_i^{NY}\, ln[G_c(A_i)\text{-}G_c(A_i^d)] + I_i^{NN}\, ln[G_c(A_i^d)] \quad (6)$$

I_i^{YY}, I_i^{YN}, I_i^{NY} and I_i^{NN} will be 1 when the ith respondent's response is 'yes'–'yes', 'yes'–'no,' 'no'–'yes,' and 'no'–'no' to each bid price, respectively. The WTP of the DBDC model will be derived the same way as the SBDC model.

3.3. Survey design

This study uses a direct face-to-face interview which has been shown to be the most reliable approach in contingent valuation studies (Carson et al., 1996). The survey was conducted in eight different cities in South Korea in May 2007. In order to consider the regional heterogeneity, 4 metropolitan areas (*Seoul*, *Busan*, *Daegu* and *Daejeon*) and 4 local areas with nuclear power plants (*Yeonggwang*, *Gyungju*, *Ulchin* and *Kijang*) were selected. The gender ratio of respondents is equally balanced. Also to remove the bias problem, the face-to-face interview method was selected.

The structure of the survey questionnaires is shown in Fig. 2. Two types of questionnaires are prepared to estimate the willingness-to-pay of people in the areas. Type 1 includes no specific information about nuclear energy and type 2 includes precise and specific information about nuclear energy, about its risk or safety, economic and environmental benefits such as accident histories, electricity generating cost, low carbon generation and radiation hormesis. However, both types have the same questionnaires and, therefore, the only difference is whether the information is given prior to the answer or not. Each questionnaire has three sections: The first section collects information on the respondents' socio-economic characteristics, such as gender, age, region, education and occupation, and the second one includes questions related with the perception, attitudes and awareness of the respondents towards nuclear energy in the perspective of risk or safety. In the third section, we ask the amount of the respondents' willingness-to-pay based on the Double-Bounded Choice question (DBDC) model. The information about nuclear energy and the structure of the survey questionnaires are shown in Fig. 2. Table 2 shows the specific questionnaires about Sections 2 and 3.

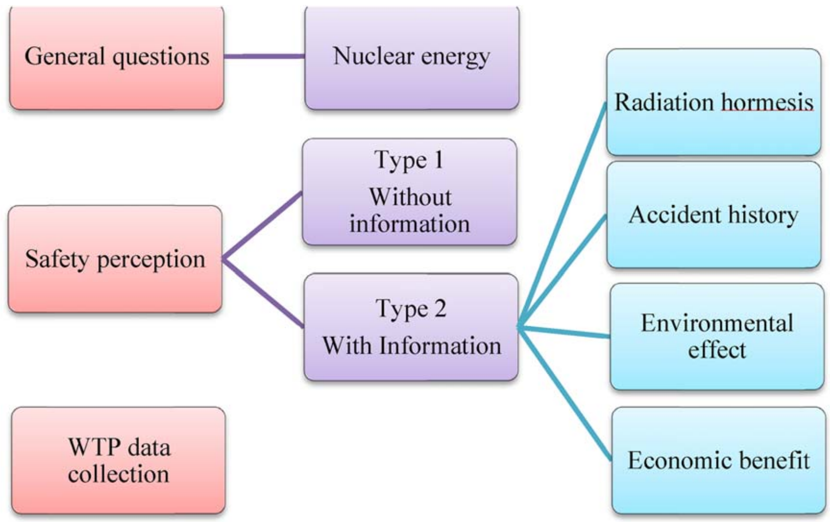

Fig. 2. Given information about nuclear energy and the structure of the survey design.

Table 2
Survey questionnaires including willingness-to-pay.

	Category	Questionnaires
1	Perception towards nuclear energy	How well did you know about nuclear energy before?
2	Attitudes towards nuclear energy	How safe/dangerous do you think nuclear energy is?
3	Awareness towards nuclear energy	How well did you know about the risk/safety of nuclear energy?
4	Willingness-to-pay (DBDC)	Is your household willing to pay monthly for electricity an increase of $xx in order to maintain current nuclear power generation?

Table 3
Descriptive statistics of the respondents.

		Person	Ratio
Gender	Male	170	50.00%
	Female	170	50.00%
Age group	20's	27	7.94%
	30's	83	24.41%
	40's	107	31.47%
	50's and over 50's	123	36.18%
Geographic areas	*Seoul*	43	12.64%
	Busan	43	12.64%
	Daegu	42	12.35%
	Daejeon	42	12.35%
	Yeonggwang	42	12.35%
	Gyungju	43	12.64%
	Ulching	42	12.35%
	Kijang	43	12.64%
Education	Middle school or less	74	21.76%
	High school	166	48.82%
	College or more	100	29.41%
Occupation	Public officer	5	1.47%
	Company worker	80	23.53%
	Self-employed	123	36.18%
	Housewife	90	26.47%
	Agriculture/fisheries	20	5.88%
	Services	9	2.65%
	Student	3	0.88%
	Others	10	2.94%

4. Results

The survey was conducted by a survey company and its agents conducted face-to-face interviews with the people in the geographic areas specified above. There were 329 available data after eliminating outliers with a 99% confidence interval. The descriptive statistics of the respondents are shown in Table 3.

Table 4 shows the distribution of people corresponding to the different types of surveys. The number of people in type 1 who do not have any information about nuclear energy is more skewed towards the 'no'–'no' responses, which means they are not willing to pay for nuclear energy production. In contrast, the number of people in type 2 who received precise information about nuclear energy is more skewed towards the 'yes'–'yes,' which means they are willing to pay for nuclear energy more than the initial value suggested. Interestingly, people who are accustomed to nuclear energy are more in favor of nuclear energy than others. Therefore, contrary to our expectations, people who live in areas where nuclear power plants are located have a higher value than metropolitan areas. The results show that the degree of safety perception and knowledge level has a positive and significant effect on the public for nuclear energy. This shows the importance of communication with honest information between the public and the stakeholders.

4.1. Willingness-To-Pay estimation

Table 5 below shows the Mean Willingness-To-Pay (MWTP) based on the estimation of Eq. (6)—DBDC model—using a maximum likelihood estimation.

Table 5 shows that the MWTP for both types are significant and the MWTP of type 2 is greater than that of type 1 (type 2, $0.59 > $ type 1, 0.35) indicating that people with precise information about nuclear energy are willing to pay more by $0.24 (68.5%). This quantitative difference in the WTP suggests the approximate amount of the subsidy in the region where a new nuclear plant is expected to be built or the amount of investment needed for the management of social acceptance. At least, in addition, this result enables us to recognize that it is important to deliver precise and appropriate information about nuclear energy to the public since it will increase the social acceptance of nuclear energy.

Table 4
Results of the survey.

Survey type	Type 1		Type 2	
Response	'yes'–'yes'	14.59%	'yes'–'yes'	32.22%
	'yes'–'no'	34.65%	'yes'–'no'	41.95%
	'no'–'yes'	10.33%	'no'–'yes'	9.11%
	'no'–'no'	40.43%	'no'–'no'	16.72%
Total		100.00%		100.00%

Table 5
Results of parameter analysis.

Parameter	Estimate ($)	*t*-statistic	CHISQ
MWTP_type1	0.35	5.35**	28.59
MWTP_type2	0.59	10.17**	103.55

Note: The *t*-values are computed by delta method.
The Wald test for the hypothesis that the given sets of parameters are jointly zero.
** Significant within a 1% significant level.

These WTP estimates provide preliminary information about the cost and benefits of different nuclear policy scenarios. We can approximate the social value of nuclear energy if we calculate yearly WTP of the public by multiplying the respondents' monthly WTP by the number of households in a country and by 12. In the case of Korea, the yearly WTP of the public is USD 278 million.[3] This result is close to the amount that the Korean government subsidized to the *Gyungju* area for the construction of low level waste management facilities. However, the Korean government subsidized more than this amount since the government moved the headquarters of the Korea Hydro and Nuclear Power company (KHNP), which is the largest power generating subsidiary accounting for approximately 25% of electricity producing facilities, hydro and nuclear in Korea to the region. The movement of headquarters is a considerable benefit to the region both economically and socially. However, unfortunately, the amount of subsidy and the decision to move the headquarters has not been based on concrete estimate of the cost and benefit for the local area. These findings suggest the need for some quantitative and pivotal analysis and information when the government designs nuclear policy which is many times related with social acceptance and when it needs to estimate the cost and benefit for constructing nuclear facilities persuading the public.

5. Conclusion

Nuclear is becoming a more important energy source for electricity generation when considering the environmental impact, energy security, and depletion of fossil fuels. However, public acceptance is still one of the major barriers for further development and its expansion, although recent technological and institutional innovation clearly lowered its risk and enhanced its relative and absolute benefit compared to other energy sources. Consequently, many countries are spending tremendous amounts of money to overcome the barriers of social acceptance in establishing and executing their policy for nuclear energy. However, the amount spent on social acceptance had weak supporting information and analysis without a concrete measurement of social benefit and cost of nuclear energy. In this study, we used the Contingent Valuation Method and measured the social value of nuclear energy, which is based on public evaluation of its benefit. In our study, the CVM estimated the public's WTP for electricity generation using nuclear energy.

We found that the amount of the WTP is about 68.5% greater when precise information is given to the public than when it is not. This result suggests that one of the major reasons for the social undervaluation of nuclear energy comes from lack of communication and delivery of information to the public regarding nuclear energy. The results are consistent with the findings of recent survey of European Commission (the Eurobarometer series) and IAEA (International Atomic Energy Agency) between 2005 and 2007, which showed that more and better public information increase support for nuclear energy and people in countries without nuclear power plants feel less informed and more likely to say that the risks outweigh the advantages.

In addition, our finding suggests that the barriers in social acceptance for nuclear energy can be reasonably managed by providing appropriate and precise information. Therefore, we can more reasonably manage the current spending on social acceptance management of the regions directly or indirectly associated with nuclear energy and, in addition, different communication strategies can be suggested depending on the circumstances of the region or countries. For example, following France, early education of young children about the situation of energy can be one of the effective policies for future policy implementation. In addition, it will be also effective to incorporate a process of social testing and of modifying nuclear technology development efforts to be in accordance with social attitudes as an integral part of the overall nuclear facility development can be another option. In other words, incorporating the phase of social acceptance management in the process of nuclear policy development and implementation seems to be more effective and efficient in overall policy implementation than when it is ignored. The subsidy saved by the appropriate delivery of information about nuclear energy, can be reinvested to the innovation of the nuclear energy, which, in return, will be able to enhance its safety and benefit in the future fulfilling the environmental requirement of the coming ages.

One limitation of our research is that the information and scenarios we provided to the public were restricted to a few cases. By changing the information and scenarios, we will be able to measure the order of importance in the delivery of information about nuclear energy and persuade the public more effectively and, consequently, lower the social acceptance barriers. In addition, by conducting similar approaches together with other energy sources, we will be able to measure the role of information and communication for different energy sectors and deliver integrated energy policy in managing social acceptance which can be more effective and efficient. On the other hand, social acceptance will vary according to countries' economic, political, cultural and historical backgrounds. Therefore, an international comparison of social acceptance and the measurement of WTP for different energy sources will give us more profound and valuable information and insight for social acceptance management and nuclear energy policy.

References

Aabø, S., Strand, S., 2000. Public Library Assessment and Motivation by Altruism. In: Proceedings of the Eleventh Annual Conference on Cultural Economics, Minneapolis, mimeo.
Bateman, I.J., Diamand, E., Langford, I.H., Jones, A., 1996. Household willingness to pay and farmers' willingness to accept compensation for establishing a recreational woodland. Journal of Environmental Planning and Management 39, 21–44.

[3] Based on the Korea Statistical Information Service (KSIS), Korea's population is 47,278,951 as of June, 2008. Multiplying this by the respondents' yearly WTP yields the total WTP which is about USD 278 million.

Bergstrom, J., Dillman, B., Stoll, J., 1985. Public environment amenity benefits of private land: the case of prime agricultural land. Journal of Agricultural Economics 17, 139–149.

Bille-Hansen, T., 1997. The willingness-to-pay for the royal theatre in copenhagen as a public good. Journal of Cultural Economics 21, 1–28.

Biship, R.C., Herberlein, T.A., Kealy, M.J., 1983. Contingent valuation of environmental assets: comparisons with a simulated market. Natural Resources Journal 23, 619–633.

Bravi, M., Scarpa, R., Sirchia, G., 1998. Measuring WTP for Cultural Services in Italian Museums: a Discrete Choice Contingent Valuation Analysis. In: Proceedings of the Tenth International Conference on Cultural Economics, Barcelona.

Cameron, T.A., James, D., 1987. Efficient estimation method for closed-ended contingent valuation surveys. Review of Economics and Statistics 69, 269–276.

Carson, R.T., Flores, N.E., Martin, K.M., Wright, J.L., 1996. Contingent valuation and revealed preference methodologies: comparing the estimates for quasi-public goods. Land Economics 72, 80–99.

Carson, R.T., Flores, N.E., Meade, N.F., 2001. Contingent valuation: controversies and evidence. Environmental and Resource Economics 19, 173–210.

Carson, R.T., Groves, T., 2007. Incentive and informational properties of preference questions. Environmental and Resource Economics 37, 181–210.

Carson, R.T., Hanemann, W.M., 2005. Contingent valuation. In: Mäler, K.G., Vincent, J.R. (Eds.), Handbook of Environmental Economics, vol. 2. Elsevier, Amsterdam, North-Holland, pp. 821–936.

Ehrenberg, A., Mills, P., 1990. 'Viewers' Willingness to Pay—A Research Report, Broadcast, London.

Farrel, A.E., Plevin, R.J., Turner, B.T., Jones, A.D., O'Hare, M., Kammen, D., 2006. Ethanol can contribute to energy and environmental goals. Science 311, 506–508.

Gerking, S., Haan, M., Shulze, W.D., 1988. The marginal value of job safety: a contingent value study. Journal of Risk and Uncertainty 1, 185–199.

GIF, 2002. A Technology Roadmap for Generation IV Nuclear Energy Systems. Issued by the US DOE Nuclear Energy Research Advisory Committee and the Generation IV International Forum.

Golay, M.W., 2001. A Policy Framework for Micro-Nuclear Technology, New Energy Technology. The James A. Baker III Institute for Public Policy of Rice University, Huston.

Gordon, I.M., Knetsch, J., 1979. Consumers surplus and the evaluation of resources. Land Economics 55, 1–10.

Hanemann, W.M., 1984. Welfare evaluations in contingent valuation experiments with discrete responses. American Journal of Agricultural Economics 66, 332–341.

IEA, 2007. World Energy Outlook, International Energy Agency.

Kim, H.J., Jun, E.J., Chang, S.H., Kim, W.J., 2009. An assessment of the effectiveness of fuel cycle technologies for the national energy security enhancement in the electricity sector. Annals of Nuclear Energy 36, 604–611.

Knetsch, J.L., 2005. Gains, losses, and the US EPA economic analysis guidelines: a hazardous product? Environmental and Resource Economics 32, 91–112.

Kovacs, P., Gordelier, S., 2009. Nuclear Power and the Public, NEA News, Facts and Opinions. Nuclear Energy Agency.

Lee, Y.E., 2006. Analysis on the role of various power generation resources for the sustainable development of Korean electric industry. In: International conference on sustainable energy and environment, Bangkok, Thailand.

McVeigh, J., Burtruw, D., Darmstadter, J., Palmer, K., 2000. Winner, loser, or innocent victim? Has renewable energy performed as expected?. Solar Energy 68, 237–255.

Mitchell, R.C., Carson, R.T., 1989. Using surveys to value public goods: the contingent valuation method, Resources for the Future.

Olsen, J.A., Smith, R.D., 2001. Theory versus practice: a review of "willingness to pay" in health and health case. Health Economics 10, 39–52.

Protière, C., Donaldson, C., Luchini, S., Moatti, J.P., Shackley, P., 2004. The impact of information on non-health attributes on willingness to pay for multiple health care programmes. Social Science & Medicine 58, 1257–1269.

Spash, C.L., 2006. Non-economic motivation for contingent values: rights and attitudinal beliefs in the willingness to pay for environmental improvements. Land Economics 82, 602–622.

Tyner, W.E., 2007. Policy alternatives for the future biofuels industry. Journal of Agricultural and Food Industrial Organization 5, 1–13.

Vatn, A., 2004. Environmental valuation and rationality. Land Economics 80, 1–18.