Willingness to Pay for Renewable Energy and Nuclear Power and their Determinants Factors

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Abstract

Development of low carbon electric power system is significant to prevent global warming. Nuclear power is and will be largest composition ratio as low carbon power generation in Japan. Feed-in Tariff (FIT) for solar power generation has been introduced since November 2009 in Japan, and introduction of FIT for the other renewable energy such as wind power is discussed. However, power generation costs from renewable energy are so higher than thermal power generation that building of mechanism for their cost burden is needed. It is important to win public acceptance of introduction of nuclear power and renewable energy, and the cost burden. In this study, consumers' willingness to pay (WTP) for nuclear power and renewable energy in Japan are assessed based on a consumer questionnaire survey conducted in September and October 2009. 3101 people answered our questionnaire. We assumed two options that all of thermal power generation in Japan, which supply about 60%-kWh of electricity, were replaced by nuclear power or renewable energy. Respondents answered acceptable increase percentage of additional electricity cost as their WTPs for the two options. The results revealed that consumers are ready to pay higher cost for renewable energy (about 1.6 yen/kWh, 4000 yen/ton-CO2) than nuclear power (about 0.4 yen/kWh, 1000 yen/ton-CO2). Determinants factors including consumers' environmental consciousness, evaluations of nuclear and renewable energy are also analyzed by using tobit model. The results illustrated that consumers who accept purchase obligation of highly-efficient electric appliances would be likely to pay higher cost for both nuclear power and renewable energy. This suggested that it would be important to build consensus on fair cost burden. Consumers who concern global environmental issues would be likely to pay higher cost for renewable energy only. On the other hand, consumers who emphasize convenience of electric appliances would be likely to pay higher cost for nuclear power. Consumers who value nuclear and renewable power highly in terms of their safety and low CO2 emission, etc. would be also likely to pay higher cost.

Keywords: *low carbon power, nuclear power, renewable energy, willingness to pay, consumer questionnaire*

1. Introduction

Renewable energy and nuclear power are important as low carbon power in Japan as same as in the Europe and the US. Japanese government set a target that 70 percent of electricity would be generated from CO2 free power generation (Basic energy plan of Japan, 2010). Feed-in Tariff (FIT) for solar power generation has been introduced since November 2009 in Japan, and introduction of FIT for the other renewable energy such as wind power is discussed. However, power generation costs from renewable energy are so higher than thermal power generation that building of mechanism for their cost burden is needed. It is important to win public acceptance of introduction of nuclear power and renewable energy, and the cost burden.

In order to develop how to win the public acceptance, understanding of willingness to pay (WTP) for low carbon power and the determinants factors is important. WTP for renewable energy was investigated by several literatures as described in detail in Chapter 2. WTP for nuclear power was investigated by Roe et al. (2001). However, they did not analyze the determinants factors in detail.

Firstly, this study show that willingness to pay (WTP) for nuclear power and renewable energy in Japan are assessed and compared based on a consumer questionnaire survey. Secondly determinants factors including consumers' environmental consciousness and evaluations of nuclear and renewable energy are also analyzed.

2. Literature review and focus of this study

The WTP for low carbon energy are studied by Farhar and Houston (1996), Farhar(1999), Roe et al. (2001), Wiser (2003), Wustenhage et al. (2003), Nomura and Akai (2004), Borchers et al. (2007), Hansla et al. (2008), European Commission and European Parliament (2008), European Commission (2009), Scarpa and Willis (2010).

Most of the previous studies focused on WTP for renewable energy. The previous studies except for Roe et al. (2001) did not investigate WTP for nuclear power. No studies analyzed determinants factors of WTP for nuclear power considering effects of environmental consciousness, consumers' preferences to several power generations in addition to consumers' attributes.

This study focused on comparing WTP for renewable energy and nuclear power and the determinants factors. Hereafter we show a result of WTP based on consumer questionnaire survey and statistical analysis.

3. Willingness to pay for renewable energy and nuclear power

3.1 Consumer questionnaire

This study conducted a consumer questionnaire survey shown in Table 1 to reveal the WTP for renewable energy and nuclear power. We surveyed environmental awareness and subjective evaluation of several power generations, which are assumed as determinants factors of the WTP, in addition to the WTP.

The WTP are surveyed based on Contingent Valuation Method (CVM). Firstly, respondents were informed composition ratio of generated electricity in Japan[1], that CO2 as Green House Gases is emitted from thermal power generation plant, and that a ratio of the amount of CO2 emission from thermal power plant was about 30 percent in total CO2 emission in Japan. Secondly, respondents were proposed virtual scenario that thermal power would be replaced with renewable energy or nuclear power to reduce CO2 emission to zero. Finally, respondents answered acceptable increase ratio in electricity cost as WTP for installation of renewable energy or nuclear power.

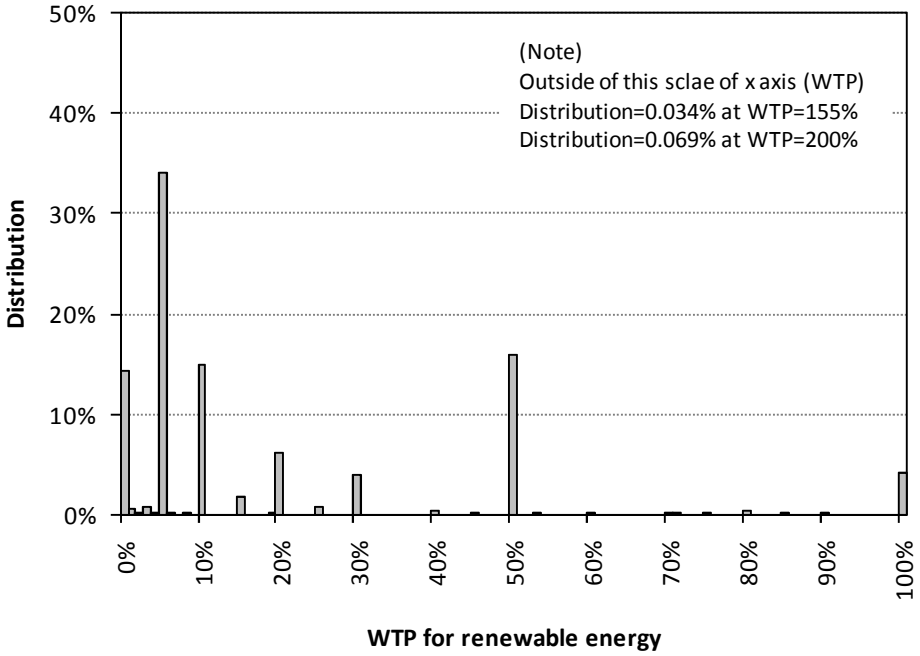
Table 1 Outline of consumer questionnaire survey

Survey period	About four weeks from September to October 2009
Survey area	Japan
Survey object	Residential customer (Consumer)
Respondent	Home manager (familiar with electricity cost)
Survey content	Willingness to pay for low carbon power Environmental awareness Subjective evaluation of several power generations Respondent attributes (income, sex, age, region and etc.)
Method	Mailing
Sampling	Stratified random sampling
Survey planner	Central Research Institute of Electric Power Company
Sample size (response rate)	3,101s (66.2%)

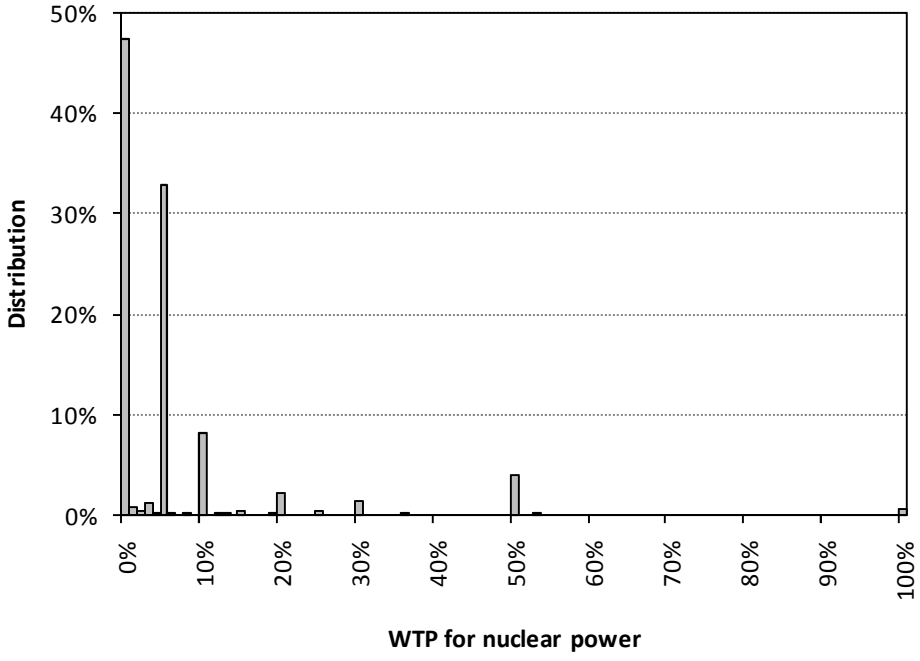
3.2 Survey result

Distribution of the WTP as the survey result is shown in Figure 1. Estimated medians[2] of the WTP for renewable energy and nuclear power are 7.8 percent and 1.9 percent respectively. Medians of the WTP for renewable energy and nuclear power are and about 1.6 JPY/kWh and 0.4 JPY/kWh respectively estimated by being multiplied by electricity rate. Medians of unit CO2 reduction value by renewable energy and nuclear power are about 4000 JPY/ton-CO2 and 1000 JPY/ton-CO2 respectively if CO2 emission intensity is assumed to be 0.4 kg/kWh[3].

[1] Composition ratios of hydro power, thermal power and nuclear power in the total generated electricity were about 10 percent, 60 percent and 30 percent, respectively.
[2] Medians were estimated by applying log-logistic distribution to surveyed distribution.
[3] Actual CO2 emission intensities are different by electric power companies in Japan.



(a) Renewable energy



(b) Nuclear power

Figure 1 Distribution of WTP

4. Determinants factors of the WTP

4.1 Model and data

We analyzed determinants factors of the WTP in order to discuss and develop how to win public acceptance of new and additional installation of renewable energy and nuclear power. We use tobit model because the WTP is more than or equal to zero.

Some of the previous studies assumed environmental awareness, preferences of power generations, and respondents' attributes. We also assumed environmental awareness and respondents' attributes as determinants factors. We assumed subjective evaluation of several power generations' characteristics, such as safety, power instability, and resource depletion, which were substituted for preferences of power generations. In addition to these factors, generated electricity ratios by regions in Japan are assumed as the factors.

We tried to verify two hypotheses regarding environmental awareness (H1 and H2).

H1: High environmental awareness increases the WTP, because consumers who have these environmental attitudes would evaluate CO2 emission reduction higher than the others.

H2: Preferences for convenient lifestyle decrease the WTP.

Five variables, including environmental knowledge, environmental consciousness, acceptability of energy efficiency regulation, desire for environmental information, and purchase of high-efficient appliances, were assumed to verify H1 as shown in Table 2. We assumed that high decrees of environmental knowledge, environmental consciousness, acceptability of energy efficiency regulation, and purchase of high-efficient appliances increased the WTP. High desire for environmental information decreased the WTP because a consumer, who had this kind of attitude, could wonder benefit to reduce CO2, and could be low environmental awareness. In order to compare an effect of purchase of high-efficient appliances, we also assumed that energy conservation behavior did not influence WTP because this behavior spent no money.

On the other hand, two variables, involvement in home appliances and preference of convenience of appliances, were assumed to verify H2 as shown in Table 2, We assumed that high involvement in home appliances and preference of convenience of appliances decreased WTP, because a consumer who had these kinds of attitudes would like to pay more money for convenient lifestyle than for CO2 reduction.

Data representing these eight variables were collected as five-point scale in consumer questionnaire survey[4].

[4] Survey items are shown in Appendix.

Next, we tried to verify two hypotheses regarding subjective evaluations of power generations (H3 and H4).

H3: High/low evaluations of characteristics of renewable energy and nuclear power and increase/decrease WTP for renewable energy and nuclear power respectively.
H4: High/low evaluations of characteristics of thermal power decrease/increase WTP, because consumers, who evaluate thermal power as low, highly evaluate replacing them.

Nine variables were assumed as subjective evaluations shown in Table 2, which were surveyed in consumer questionnaire survey as five-point scale. We used cost volatility risk of coal-fired thermal power and concern about coal depletion as characteristics of thermal power, low carbon emission of nuclear power, safety of nuclear power, and concern about uranium depletion as characteristics of nuclear power, and low carbon emission of solar power, safety of solar power, power instability of solar power, and concern about solar power (opposite to *renewable*) as characteristics of renewable energy.

We tried to verify three hypotheses regarding composition ratio of generated electricity.

H5: High ratio of nuclear power decreases WTP of nuclear power only, because of NIMBY about nuclear power.
H6: High ratio of thermal power decreases WTP both renewable energy and nuclear power, because consumers, who lives where ratio of thermal power is higher, should pay more money for replacing thermal power with low carbon power.
H7: High ratio of solar power increases WTP for renewable energy only, because consumers, who live where more solar power is used, would like to utilize efficiently it.

Composition ratios of nuclear power and thermal power by regions were applied to data based on ten power companies supplying regions where each respondent lives. We used installed ratio of solar power generation system in home by prefectures as composition ratio of solar power.

Table 2 Explanatory variables and hypothesis

Categories	Explanatory variables	Related hypothesis
Environmental awareness	Environmental knowledge	H1
	Environmental consciousness	H1
	Acceptability of energy efficiency regulation	H1
	Desire for environmental information	H1
	Energy conservation behavior	(H1)
	Purchase of high-efficient appliances	H1
	Involvement in home appliances	H2
	Preference of convenience of appliances	H2
Subjective evaluations of characteristics of power generations	Cost volatility risk of coal-fired thermal power	H4
	Concern about coal depletion	H4
	Low carbon emission of nuclear power	H3
	Safety of nuclear power	H3
	Concern about uranium depletion	H3
	Low carbon emission of solar power	H3
	Safety of solar power	H3
	Power instability of solar power	H3
	Concern about solar power (opposite to renewable)	H3
Composition ratio of generated electricity by region	Ratio of nuclear power	H5
	Ratio of thermal power	H6
	Ratio of solar power for home	H7
Household and respondent's attributes	Electricity cost of household	
	Sex of respondent	
	Age of respondent	
	Annual income of household	

4.2 Empirical result

Environmental awareness

We found that H1 and H2 were supported partially as below.

The results illustrated that consumers who accept purchase obligation of highly-efficient electric appliances would be likely to pay higher cost for both nuclear power and renewable energy. This suggested that it would be important to build consensus on fair cost burden.

Consumers who concern global environmental issues, have much knowledge of the issues, and often purchase high-efficient appliances would be likely to pay higher cost for renewable energy only. On the other hand, consumers who are highly involved in electric appliances and emphasize convenience of electric appliances would be likely to pay less for renewable energy only. On the contrary of H2, consumers who emphasize convenience of electric appliances would be likely to pay higher cost for nuclear power.

Subjective evaluations of several power generation

We found that H3 was supported as expected as below.

Consumers who value nuclear and renewable power highly in terms of their safety and low CO2 emission, etc. would be also likely to pay higher cost.

On the other hand, we found that H4 was rejected.

Subjective evaluations of coal thermal power generation did not influence WTP for both renewable energy and nuclear power.

Composition ratio of generated electricity by region

We found that H5 was supported as expected, and that H6 and H7 were supported partially as below.

High composition ratio of nuclear power decreases WTP for nuclear power. It would be because consumers, who live in these regions, would not hope that additional nuclear power would be installed in their regions (NIMBY). High ratio of thermal power decreases WTP for nuclear power because consumers would like to avoid large cost burden to replace thermal power plant with nuclear power. High composition ratio of solar power increases WTP for renewable power, which suggests that consumers, who live where more solar power is used, would like to utilize renewable energy.

Respondent attributes

Female would like to pay less for both renewable energy and renewable power than male. Older people would like to pay more for nuclear power only. High income household would like to pay more for renewable energy only.

Table 3 Analysis result

		Renewable energy			Nuclear power		
		coefficient	s.e.		coefficient	s.e.	
Environmental awareness	Environmental knowledge	2.348	0.613	**	-0.423	0.482	
	Environmental consciousness	3.096	0.786	**	0.132	0.610	
	Acceptability of energy efficiency regulation	3.466	0.480	**	2.194	0.386	**
	Desire for environmental information	0.848	0.615		-0.643	0.485	
	Energy conservation behavior	-0.122	0.684		0.417	0.532	
	Purchase of high-efficient appliances	0.910	0.493	+	0.038	0.389	
	Involvement in home appliances	-1.204	0.507	*	0.088	0.400	
	preference of convenience of appliances	-0.993	0.590	+	0.878	0.463	+
Subjective evaluations of characteristics of power generations	Cost volatility risk coal-fired thermal power	-0.190	0.512		-0.164	0.404	
	Concern about coal depletion	0.276	0.517		0.085	0.403	
	Low carbon emission of nuclear power	-0.081	0.445		1.795	0.358	**
	Safety of nuclear power	-1.729	0.535	**	3.215	0.408	**
	Concern about uranium depletion	0.866	0.461	+	-0.879	0.367	*
	Low carbon emission of solar power	0.704	0.732		0.617	0.586	
	Safety of solar power	2.646	0.663	**	0.196	0.518	
	Power instability of solar power	-1.203	0.736		-0.011	0.572	
	Concern about solar power depletion(opposite to renewable)	-0.967	0.489	*	0.634	0.383	+
Composition ratio of generated electricity by region	Ratio of nuclear power	-8.933	13.900		-29.780	10.842	**
	Ratio of thermal power	-8.239	12.643		-31.216	9.942	**
	Ratio of solar power for home	260.763	128.943	*	180.601	100.998	+
Household and respondent's attributes	Electricity cost of household	-0.026	0.238		0.242	0.185	
	Sex of respondent (1=male, 2=female)	-2.898	1.165	*	-3.486	0.912	**
	Age of respondent	0.748	0.508		0.932	0.393	*
	Annual income of household	1.222	0.378	**	0.424	0.295	
Constant		-16.357	14.214		2.087	11.079	
Pseudo R^2		0.0113			0.018		

Note: superscripts **, * and + indicate statistical significance at the level of 1%, 5% and 10%, respectively.

4.3 Discussion

We would like to discuss what conditions would increase WTP for renewable energy and nuclear power, and policy implications to increase the WTP.

As illustrated above, acceptability of energy efficiency regulation is only common determinant factor of WTP for both renewable energy and nuclear power in environmental awareness. This implies that consumers would accept additional cost burden of low carbon power when consensus that all consumers should pay fair obligation for measures against climate change.

However, we could point two important attitudes which influence the WTP. One is an attitude toward public interest regarding to climate change. The other is an attitude toward private interest regarding to convenient lifestyle. The above result indicates that renewable energy would be accepted when public interest would be emphasized by consumers in the future, and that nuclear power would be accepted when private interest would be emphasized.

Opinion polls[5] of Cabinet Office of Government of Japan showed that consumers' environmental awareness has risen from the latter 1990s to 2000s. If this trend would continue, renewable energy would continue to be valued by consumers.

In addition to low carbon emission, it is important that the other characteristics such as safety and resources depletions would be understood by consumers to increase the WTP.

Additional installation of nuclear power would be more acceptable in the region where ratios of nuclear power and thermal power are low in the present. New installation of solar power would be more acceptable in the region where installation potential of solar power is high.

5. Conclusion

This study showed that WTP for renewable energy is larger than nuclear power. The analysis on determinants factors of the WTP illustrated that building consensus of fair cost burden are important for new and additional installation of both renewable energy and nuclear power. The result also showed that though increase of public interest regarding climate change could increase the WTP for renewable energy, consumers' preference to convenient lifestyle could increase the WTP for nuclear energy. In addition to low carbon emission, it is important that the other characteristics such as safety and resources depletions would be understood by consumers. We also discussed about location of new and additional renewable energy and nuclear power based on the result that composition ratio of generated electricity also influences the WTP.

[5] Total percentage of response to "interested" and "somewhat interested" in global warming, ozone depletion and decrease of tropical forest has increased from 79% to 93% from 1997 to 2007.

Appendix

Figure A-1 Survey items used as explanatory variables

Categories	Variables	Survey items	Answer alternatives
Environmental awareness	Environmental knowledge	I know much about global warming and energy resources depletion.	5=yes 4=somewhat yes 3=neutral 2=somewhat no 1=no
	Environmental consciousness	I think that to prevent global warming is a significant issue in the 21 century.	
	Acceptability of energy efficiency regulation	I think regulation on purchase of high-efficient appliances is unavoidable.	
	Desire for environmental information	I think information provided by electric power and gas companies is not enough.	
	Energy conservation behavior	My family reduces electricity used by lighting.	
	Purchase of high-efficient appliances	My family often purchases high-efficient but expensive home appliances such as air-conditioner and refrigerator.	
	Involvement in home appliances	I often read advertisements and magazines about new release of appliances.	
	Preference of convenience of appliances	I think function and convenience of appliances are more important than energy efficiency.	
Subjective evaluations of characteristics of power generations	Cost volatility risk coal-fired thermal power	same as on the left	5=yes 4=somewhat yes 3=neutral 2=somewhat no 1=no
	Concern about coal depletion	same as on the left	
	Low carbon emission of nuclear power	same as on the left	
	Safety of nuclear power	same as on the left	
	Concern about uranium depletion	same as on the left	
	Low carbon emission of solar power	same as on the left	
	Safety of solar power	same as on the left	
	Power instability of solar power	same as on the left	
	Concern about solar power depletion (opposite to renewable)	same as on the left	

Figure A-1 Survey items used as explanatory variables (continued)

Household and respondent's attributes	Monthly electricity cost of household	1=less than or equal to 2000JPY, 2=2000-4000JPY, 3=4000-6000JPY, 4=6000-8000JPY, 5=8000-1000JPY, 6=10000-12000, 7=12000-14000JPY, 8=14000-16000, 9=16000-18000, 10=18000-20000JPY, 11=20000～22000JPY, 12=more than or equal to 22000JPY
	Sex of respondent	1=male, 2=female
	Age of respondent	1=less than or equal to 29 years old, 2=30 - 39 years old, 3=40-49 years old, 4=50-59 years old, 5=60-69 years old, 6= more than or equal to 70 years old
	Annual income of household	1= less than or equal to 2 million JPY, 2=2 - 4 million JPY , 3=4 - 6 million JPY, 4= 6 - 8 million JPY, 5=8 - 10 million JPY, 6=10 - 15 million JPY, 7=15 - 20 million JPY, 8= more than or equal to JPY

Figure A-2 Composition ratio of generated electricity by region

Ratio of nuclear power	Average from 2006 to 2008 Different by electric power companies in different regions
Ratio of thermal power	Average from 2006 to 2008 Different by electric power companies in different regions
Ratio of solar power for home	Cumulative install ratio in home Different by 47 prefectures Ratio = Number of household where home PV is installed / Number of household

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