

October 8-9th, 2010
In Berlin University of Technology
9th Conference on Applied Infrastructure Research, INFRADAY

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

Hisanori Goto * and Toshio Ariu **

Socio-economic Research Center,

Central Research Institute of Electric Power Industry (CRIEPI)

Address: 2-11-1, Iwadokita, Komae-city, Tokyo, 201-8511, JAPAN

Tel.: +81 (0)3 3480 2111 Fax.: +81 (0)3 3480 3491

* Research Scientist, hisanori@criepi.denken.or.jp

** Senior Researcher, ariu@criepi.denken.or.jp

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1. Introduction

1. Introduction

CO2 emission and electricity in Japan

- CO2 emission from power generation has increased by 33% since 1990 in Japan.
- About 60% of electricity are generated from thermal power plants, which emit CO2.

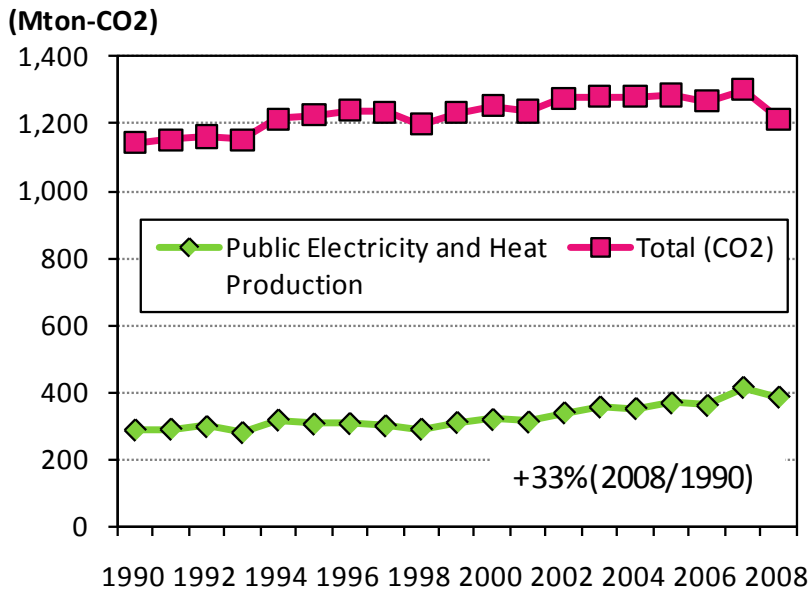


Figure CO2 emission in Japan

Source: Greenhouse Gas Inventory Office of Japan

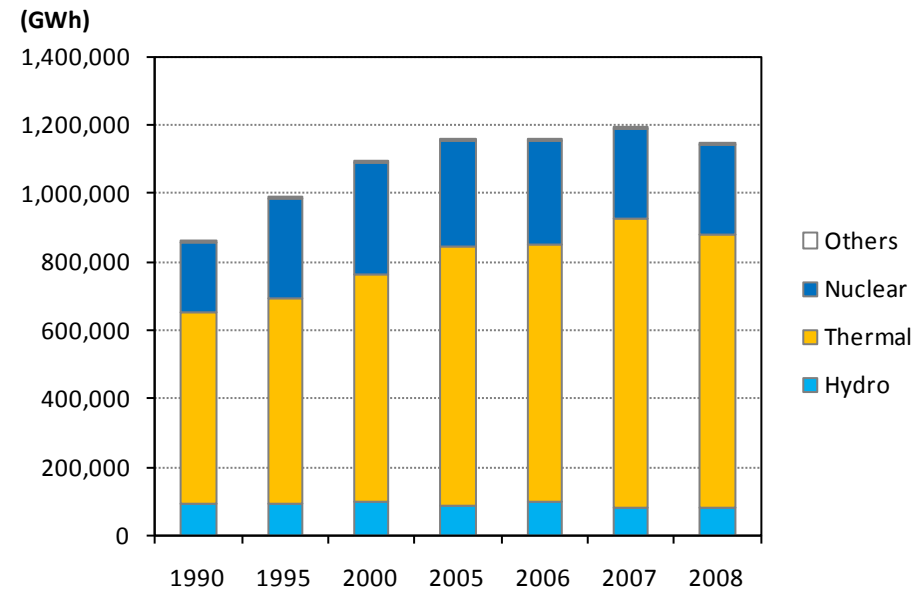


Figure Generated electricity in Japan

Source: Hand book of electric power industry

1. Introduction

Electric power industry in Japan

- 10 electric power companies (incumbent)
 - Vertically integrated (generation, transmission, distribution and retail supply)
- Liberalization
 - Wholesale market: 1995-
 - Retail market
 - Extra-high voltage customers ($\geq 2000\text{kW}$): 2000.3-
 - High voltage customers ($\geq 500\text{kW}$): 2004.4-
 - High voltage customers ($\geq 50\text{kW}$): 2005.4-
 - Retail market for residential customers and low voltage customers is regulated in 2010.

1. Introduction

Policy about low carbon power generation in Japan

● Low carbon power generation

- Renewable energy
 - RPS (Renewable Portfolio Standard) 2003-
 - FIT (Feed-in Tariff)
 - Feed-in tariff for photovoltaic for home (PV-FIT) started in 2009.11
 - Feed-in tariff for renewable energy (including PV, wind power, biomass, etc.) is discussed in METI (Japanese government).
- Nuclear power
 - 2030 Target (Basic Energy Plan, 2010.6)
 - New and additional installation: more than 14plants
 - Capacity factor: 90%
 - 2030 Target (Basic Energy Plan, 2010.6)
 - Low carbon power generation 70% (capacity)

● Economic policy instrument

- Carbon tax and Cap&Trade are under consideration.

1. Introduction

Research motivation and objective

● Public acceptance is important

- How much do consumers value for low carbon power to reduce CO₂?
- How do consumers accept installation of low carbon power and cost burden?
- Is WTP different by power generations?

● Research objective

- Measurement of WTP for low carbon power
- Analysis on determinants factors of the WTP

2. Literature review and focus of this study

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Literature review

- Focused on renewable energy

- Farhar and Houston (1996), Farhar(1999), 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).

- A few studies on nuclear power

- Roe et al. (2001) focused on nuclear power.
- However, they did not analyze the determinants factors in detail.

2. Literature review and focus of this study

Focus of this study

● Issues not focused in the previous studies

- To reveal WTP for nuclear power and the determinants, in addition to renewable energy.
- To compare the determinants between renewable energy and nuclear power.

	Renewable energy	Nuclear power
Survey and estimation of WTP	Focus in the previous studies	Few previous studies Focus of this study
Analysis on determinants factors of WTP	Focus in the previous studies	Focus of this study

Comparison differences between
Renewable energy and nuclear power
Focus of this study

3. Willingness to pay for renewable energy and nuclear power

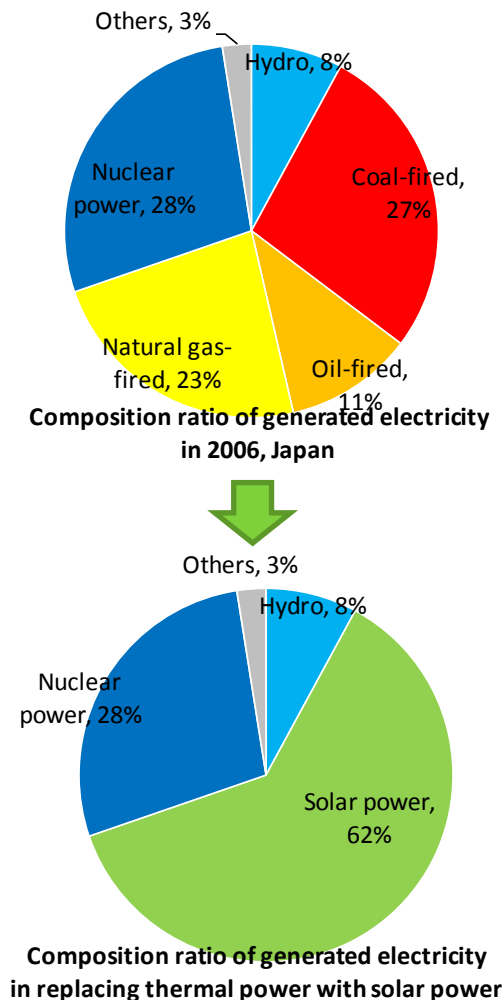
3. Willingness to pay for renewable energy and nuclear power

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. Willingness to pay for renewable energy and nuclear power

Survey method of WTP: Contingent Valuation Method



(1) Respondents were informed that

- Composition ratio of generated electricity in Japan
- CO₂ as GHG is emitted from thermal power plant
- This CO₂ emission is about 30 percent of total CO₂ emission in Japan

(2) Assumption: “If thermal power is replaced with low carbon power to reduce CO₂ emission from thermal power plant to zero,”

(3) How much additional electricity cost increase ratio could you accept to pay by each measurements?

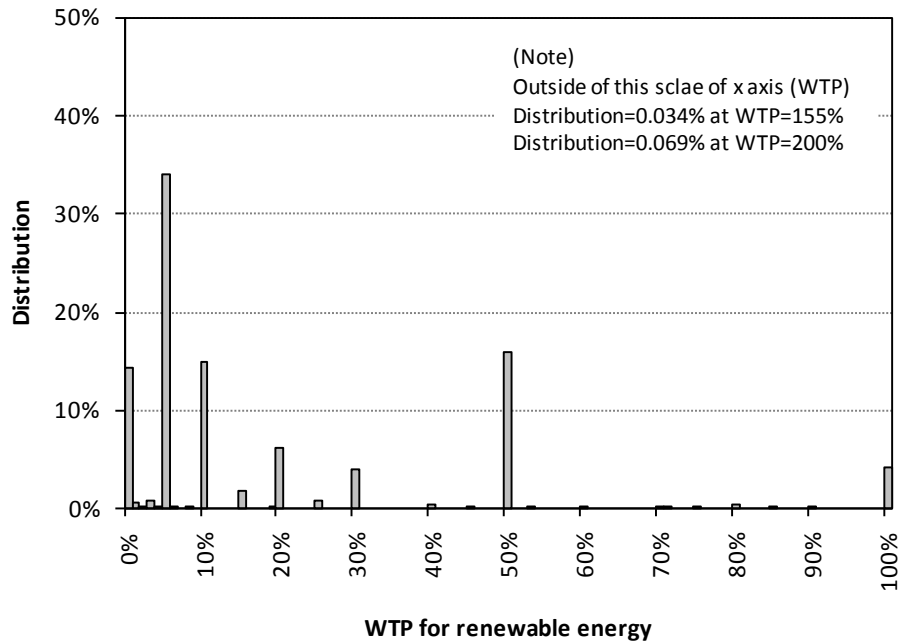
Nuclear power _____ %
 Renewable energy* _____ %

(* Renewable energy includes solar, wind power, geothermal power and biomass generation)

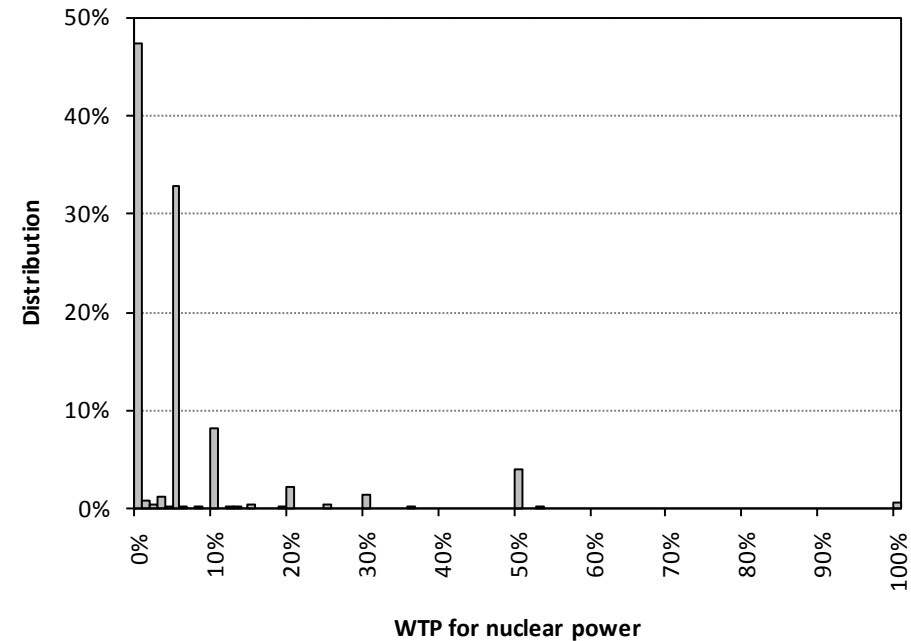
(Note: In addition to Nuclear power and renewable energy, hydro power, Mix of nuclear power, hydro power and renewable energy, and CCS (carbon dioxide capture and storage) were proposed as measurements)

3. Willingness to pay for renewable energy and nuclear power

Survey result



(a) Renewable energy



(b) Nuclear power

Figure Distribution of WTP

3. Willingness to pay for renewable energy and nuclear power

Survey result

- **WTP (Renewable energy) > WTP (Nuclear power)**
 - Median: 7.8%, 1.6JPY/kWh, 4000JPY/ton-CO₂
> 1.9%, 0.4JPY/kWh, 1000JPY/ton-CO₂
 - estimated by applying log-logistic distribution to surveyed distribution
 - assumption: CO₂ intensity=0.4kg-CO₂/kWh
- **However, median of WTP for renewable energy is lower than generation cost of solar power* in the present.**
 - median of WTP for renewable energy = 7.8%
< additional cost for replacing thermal power with solar power
= more than 100% (= twice of the present electricity cost)
 - * Solar power has the largest capacity in renewable energy in Japan.

4. Determinants factors of the WTP

4. Determinants factors of the WTP

Objective of analysis

● Renewable energy

- High WTP
- However, generation cost of solar power is much higher than WTP

● Nuclear power

- Major low carbon power in Japan
- However, low WTP
 - More than 40% consumers do not accept to pay additional cost for additional nuclear power.

● Public acceptance

- We analyzed determinants factors of WTP in order to discuss and develop **how to win public acceptance of additional installation of renewable energy and nuclear power.**

4. Determinants factors of the WTP

Model

- Objective variables: WTP
 - More than or equal to 0(%) → Tobit model
- Explanatory variables
 - Environmental awareness
 - Subjective evaluation of several power generations' characteristics
 - Respondents' attributes
 - Generated electricity ratios
- Two estimation equation
 - WTP for renewable energy ← Determinants
 - WTP for nuclear power ← Determinants

4. Determinants factors of the WTP

Hypothesis(1) Environmental awareness

- H1: High environmental awareness increase WTP,
 - because consumers who have these environmental attitudes would **evaluate CO2 emission reduction higher** than the others.
 - 5 variables
 - environmental knowledge, environmental consciousness, acceptability of energy efficiency regulation, and purchase of high-efficient appliances
→ (+) WTP
 - desire for environmental information
→ (-) WTP
- H2: Preferences for convenient lifestyle decrease WTP,
 - because a consumer who had these kinds of attitudes **would like to pay more money for convenient lifestyle** than for CO2 reduction.
 - 2 variables
 - involvement in home appliances and preference of convenience of appliances
→ (-) WTP
- Data were collected as five-point scale in consumers questionnaire.

4. Determinants factors of the WTP

Hypothesis(2) Subjective evaluations of characteristics of power generations

- H3: High/low evaluations of characteristics of renewable energy and nuclear power increase/decrease WTP for renewable energy and nuclear power respectively,
 - Characteristics of nuclear power
 - low carbon emission of nuclear power, safety of nuclear power, and concern about uranium depletion
 - Characteristics of renewable energy
 - low carbon emission of solar power, safety of solar power, power instability of solar power, and concern about solar power (opposite to *renewable*)

4. Determinants factors of the WTP

Hypothesis(2) Subjective evaluations of characteristics of power generations (continued)

- H4: High/low evaluations of characteristics of thermal power decrease/increase WTP,
 - because consumers, who evaluate thermal power as low, highly evaluate replacing them
 - Characteristics of thermal power
 - cost volatility risk of coal-fired thermal power and concern about coal depletion
- Data were collected as five-point scale in consumers questionnaire.

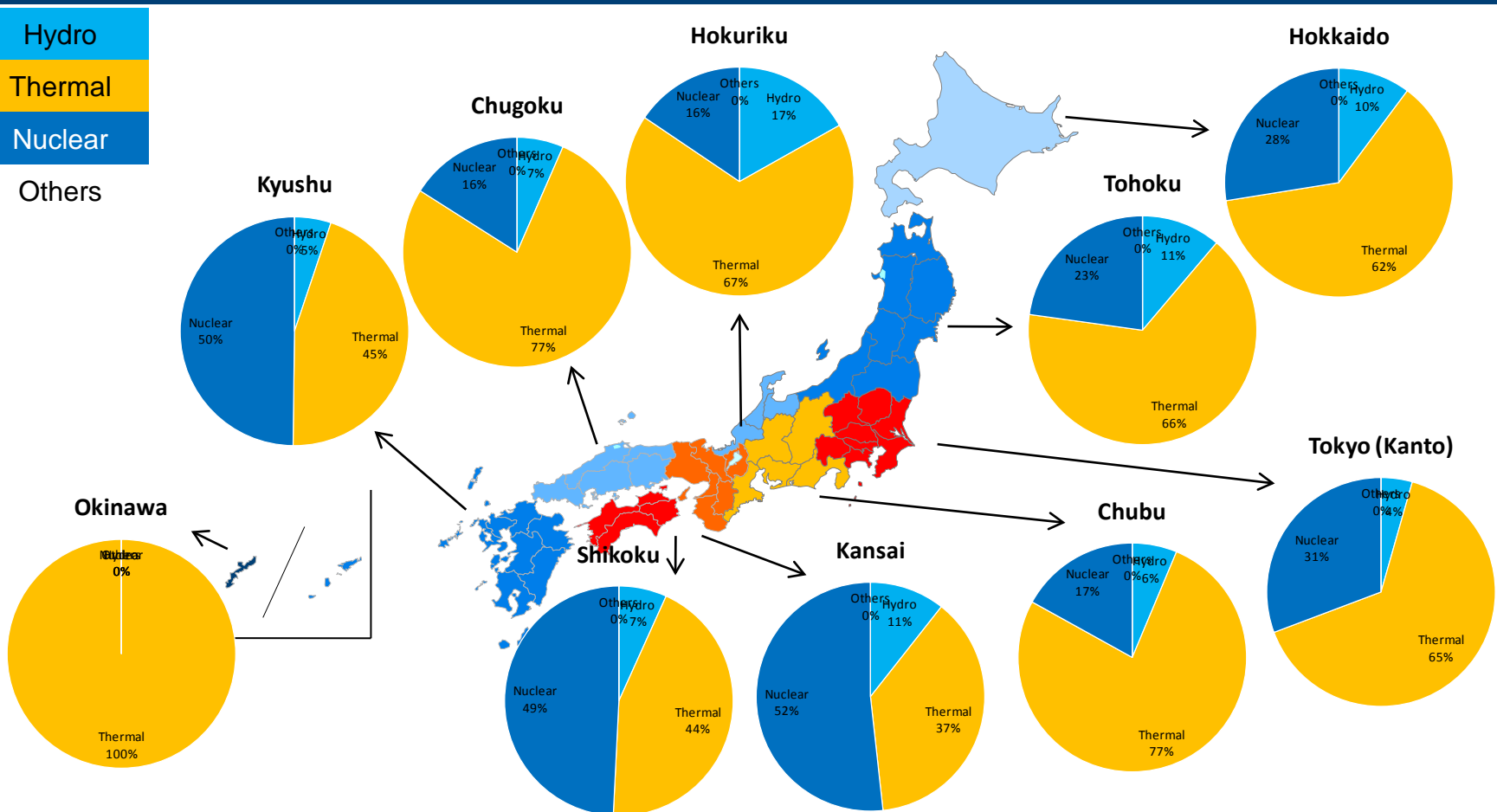
4. Determinants factors of the WTP

Hypothesis(3) Composition ratio of generated electricity

- H5: High ratio of nuclear power decreases WTP of nuclear power only,
 - because of **NIMBY (not in my backyard)** 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.

4. Determinants factors of the WTP

Composition ratio of generated electricity by regions



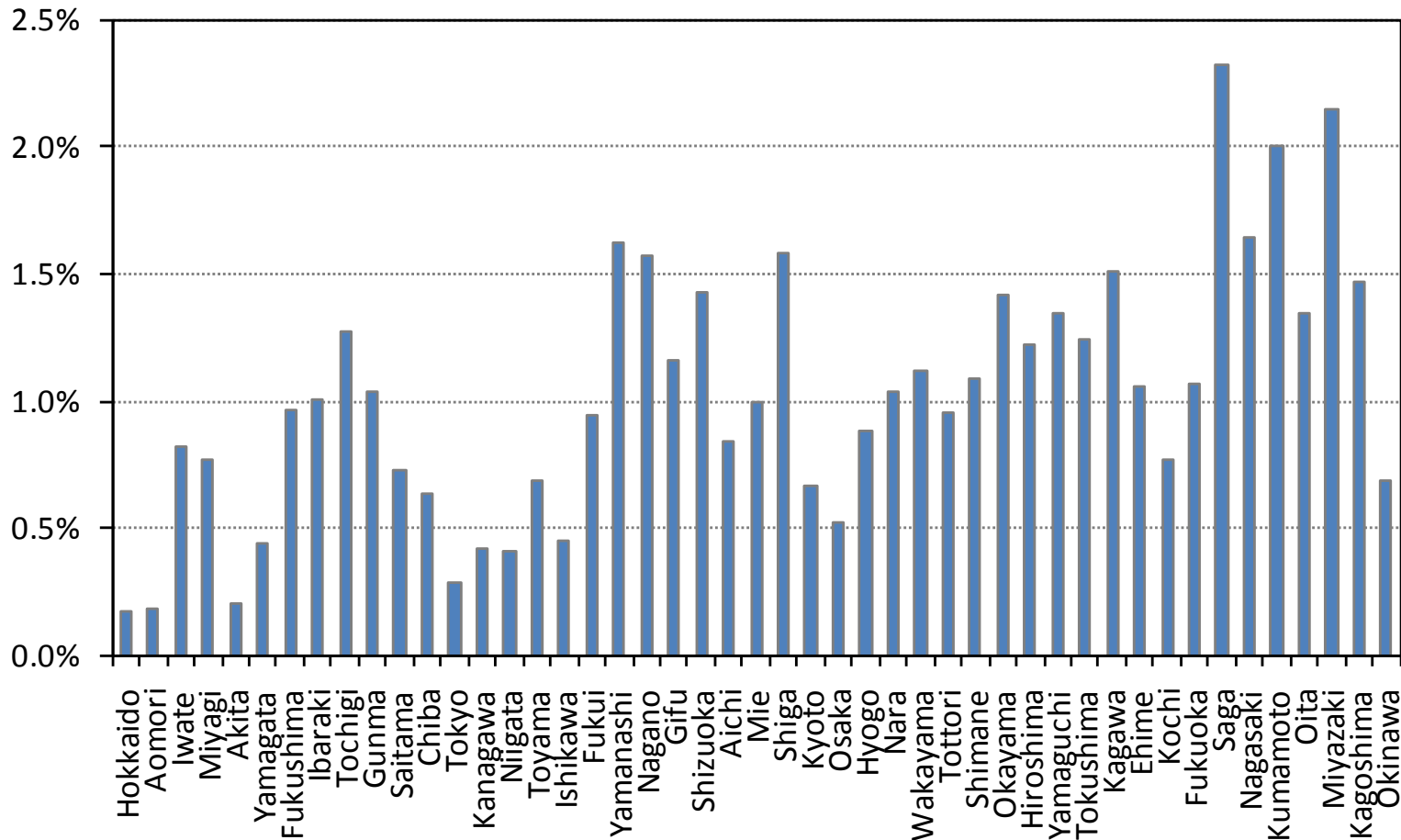
Note: (1) Ratios are average from FY2006 to FY2008.

(2) Some prefectures are divided into more than one region where different electric power companies supply.

Source: Hand Book of Electric Power Industry (Japan)

4. Determinants factors of the WTP

Ratio of home PV as ratio of solar power



Note: Calculated from the number of home PV (source: New Energy Foundation) and the number of households (source: Population Census)

4. Determinants factors of the WTP

Analysis result

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

		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		

4. Determinants factors of the WTP

Result(1) Environmental awareness

- H1 (High environmental awareness increases WTP) was supported partially.
- One Common factor
 - 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 **avoid free rider** and to build **consensus on fair cost burden**.
- The others influence WTP for renewable energy only.
 - Environmental knowledge, Environmental consciousness, Purchase of high-efficient appliances → (+) WTP for renewable energy

4. Determinants factors of the WTP

Result(1) Environmental awareness (continued)

- H2 (Preferences for convenient lifestyle decrease WTP.) was supported partially.
 - Higher involvement in home appliances and preference of convenience of appliances decreased WTP for renewable energy only.
 - On the contrary of H2, higher preference of convenience of appliances increased WTP for nuclear power.

4. Determinants factors of the WTP

Result(2) Subjective evaluations of characteristics of power generation

- H3 was supported as expected.
 - 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.
- H4 was rejected on the contrary of expectation.
 - Subjective evaluations of coal thermal power generation do **not influence** WTP for both renewable energy and nuclear power.

4. Determinants factors of the WTP

Result(3) Composition ratio of generated electricity

- H5 was supported as expected
 - High composition ratio of nuclear power decreased WTP for nuclear power, because consumers, who live in these regions, would not hope that new and additional nuclear power would be installed in their regions (NIMBY).
- H6 and H7 were supported partially.
 - High ratio of thermal power decreased 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 increased WTP for renewable power, which suggests that consumers, who live where more solar power is used, would like to utilize renewable energy (including solar power).

4. Determinants factors of the WTP

Discussion(1)

- **Consensus on fair obligation**

- Consumers would accept additional cost burden of low carbon power when **consensus that all consumers should pay fair obligation** for measures against climate change.

- **Two different attitudes**

- **Public interest** regarding climate change → (+) Renewable energy
- **Private interest** regarding convenient lifestyle → (-) Renewable energy, (+) nuclear power

4. Determinants factors of the WTP

Discussion(2)

- Characteristics of low carbon power generation
 - In addition to low carbon emission, it is important that **the other characteristics such as safety and resources depletions** would be understood by consumers.
- Location of new and additional power plant
 - New and 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 ratio of home PV is high**(, which indicates the high installation potential of solar power).

5. Conclusion

5. Conclusion

Conclusion

- **WTP for low carbon power**
 - Renewable energy > Nuclear power
 - However, median of WTP for renewable energy is lower than generation cost of solar power in the present.
 - Important to win public acceptance
- **Determinants factors of the WTP**
 - Consensus on fair obligation
 - Public interest and private interest
 - Characteristics of low carbon power generation
 - Location of new and additional nuclear power plant

Thank you for your attention.
