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Conjoint analysis of Japanese households' preferences for renewable energy and the conditions for its diffusion

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ABSTRACT

Recently, in Japan and other countries, renewable energy sources such as solar power are being promoted as alternative energy sources instead of nuclear power and fossil fuels. Renewable energy is "green energy," in that it does not emit greenhouse gases that contribute to global warming. Following the Great East Japan Earthquake, nuclear power plants ceased operations and have not yet resumed. Although these plants are planned to resume operations, Japan cannot rely on nuclear power as these plants will be decommissioned in the future.
This research utilizes conjoint analysis to investigate the common conditions and use of renewable energy in Japanese households. The researcher presents hypothetical renewable energy programs to households, analyzes the conditions under which they participate in the programs, and examines which renewable energy sources they prefer. Four types of renewable energy sources are considered: solar power, wind power, biomass, and fuel cells/private electric generators.
Other conditions are monthly bills, management suppliers (major existing suppliers, major new suppliers, or small/medium new local suppliers), new local employment, benefits for participants (tax credits, coupon tickets in a local area, awards from local public organizations, name listed on a local government website, and free tickets for green parks and environmental plants). Many studies about energy are focused on social norms, which are defined as social behavior, considering sociality and social issues such as climate change. Sometimes, individuals accommodate themselves to neighbors. The current study examines whether individuals choose renewable energy programs based on non-monetary incentives such as social norms or monetary incentives such as monthly bills. A random parameter logit model is used for this estimation. From the estimation results, households clearly prefer lower bills. Households evaluate solar power above biomass and do not highly evaluate wind power and fuel cells. Though households with children below the age of thirteen are supposed to be altruistic and interested in climate change issues and renewable energy for future generations, significant results to this effect were not obtained. However, in the subsample of households interested in advanced appliances, such as solar panels, micro-home wind generators, storage batteries, and fuel cells, the coefficient of the renewable energy ratio was positive and significant. A higher renewable energy ratio is preferred among such households. The coefficient of local new employment was generally positive and significant. Households support renewable energy electric power plants if these plants contribute to local new employment. They prefer major new suppliers to major existing suppliers and do not prefer new small/medium local suppliers. Regarding benefits, they did not evaluate tax credits compared with awards or names listed on the website of the local government, and negatively evaluated local coupon tickets and free tickets of environmental plants and national parks. Households do not respond to monetary incentives and prefer non-monetary incentives. The results conclude that monetary incentives are not always necessary for the common use of renewable energy.

Key words: Renewable energy, conjoint analysis, random parameter logit model
Category Number: 10
JEL Classification Code: C25, L51, L94, L95, Q28

Conjoint analysis of Japanese households' preferences for renewable energy and the conditions for its diffusion[1]

1. Introduction

Recently, in Japan and world countries, renewable energy such as solar energy and wind power has been promoted as an alternative energy source to replace nuclear power and fossil fuels. Renewable energy also called green energy does not emit green-house gases such as CO_2, and thus does not contribute to global warming. Japan after the 2011 earthquake, suspended the operation of nuclear power plants and did not resume its operation yet. Nuclear power plants are planned to resume; however, Japan cannot largely rely on nuclear power since almost all nuclear power plants will be decommissioned in the future. For this reason, renewable energy should be promoted as early as possible. Some studies have shown that Japanese people negatively evaluate nuclear power after the recent earthquakes. [2]

Since July 2012, the Japanese government has started the feed-in-tariff system to promote renewable energy. Households and companies can sell electricity generated by renewable energy such as solar and wind power, and major electric power companies are obliged to purchase electricity. Moreover, the Japanese government released the energy composition in the fiscal year 2030 as an energy plan. The composition is as follows: fossil fuels are 56% [liquefied natural gas (LNG) 27%, coal 26%, oil 3%], nuclear power is 20–22%, and renewable energy is 22–24% (solar 7%, hydraulic power 8.8–9.2%, wind 1.7%, biomass 3.7–4.6%, geothermal 1–1.1%). In the fiscal year 2016, fossil fuels were 83%, nuclear power was 2% and renewable energy was 15%, the Japanese government plans to reduce the use of fossil fuels, resume nuclear power plants, and implement renewable energy.

This study examines the conditions in which Japanese households is using renewable energy. The study presents hypothetical renewable energy programs to households, analyzes the conditions in which they participate in the programs and examine renewable energy sources they prefer.

A conjoint analysis, which is one of the stated preference methods, is used to analyze individual decision to participate in hypothetical renewable energy programs. Four types of renewable energy sources are considered such as solar energy, wind power, biomass, and fuel cells/private electric generator. Fuel cells are not renewable energy but do not emit any green-house gases. Fuel cells are a similar to other renewable energy sources. Fuel cells are essential to save energy and should be considered as one of renewable energy sources.

Other conditions are monthly electricity bills, suppliers that provide electricity, local new employment in new electric power plants, benefits for participants. Social norm is discussed in many studies on renewable energy sources and is energy saving[3]. It is defined as social behavior, considering sociality and social issues such as global warming and neighbors. This study examines whether individuals choose renewable energy, caused by non-monetary incentives such as social norm as well as by monetary incentives such as electricity bills. For example, individuals who support local new employment rather than lower electricity bills are motivated by non-monetary incentives and social norm. Also, benefits related with monetary and non-monetary incentives are considered.

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[2] Morita and Managi (2015) and Murakami et al. (2015) concluded that individuals negatively evaluated nuclear power and positively renewable energy from willingness to pay (WTP) using a conjoint analysis.

[3] Allcott (2011) is one of the famous energy studies about social norm. Households were received reports of electricity consumption and compared with neighbors to promote energy saving by a field experiment.

Many studies have reported on the importance of renewable energy as an energy source. Since big earthquakes often occur in Japan, nuclear power plants cannot be resumed. Under these conditions, it is essential to promote renewable energy. The contribution of this study is to investigate the preferences for renewable energy in Japanese individuals who experience a great and urgent change in the energy environment.

This article consists of the following sections. Section 2 describes the literature. In Section 3, the contents of questionnaire and the results are explained. Section 4 describes the research design of the conjoint analysis. In Section 5, a random parameter logit model as an econometric method is illustrated. In Section 6, the estimation results are considered. Lastly, in Section 7, the conclusions and policy implications are considered.

2. Literature review

Worldwide, many studies on renewable energy sources have been published. Some studies examined individual preferences for general renewable energy and others for individual renewable energy such as solar and wind power. Some studies use the stated preference methods (SPMs) and others use the revealed preference methods to estimate individual preferences. The conjoint analysis, an experiment of choice, and Contingent Valuation Method (CVM) are popular as SPMs.

This paper examines households' preferences for individual renewable energy using the conjoint analysis and the future conditions in which renewable energy can be used. Especially, Bae and Rishi (2018) referred to conjoint profiles. They analyzed the conditions in which individuals participate in renewable energy programs in South Korea using the conjoint analysis. Three alternatives were presented to individuals. Two alternatives were renewable energy programs, and one was an opt-out option, where individuals did not participate in any renewable energy programs. Solar energy, wind power, fuel cells, and biomass energy were considered as renewable energy sources. Other attributes were renewable energy ratio in electricity generation, additional electricity bills, distance from electric power plants to individual residence, the number of workers employed in electric power plants, incentives to participate in renewable energy programs. The conditional logit model, random parameter logit model, and latent cluster model were used for estimation, and the distribution of parameters or variations of preferences among individuals were derived.

Yoo and Ready (2014) also used the conjoint analysis to estimate individual preferences for renewable energy such as solar power, wind power, and biomass. The variations of individual preferences were analyzed at Pennsylvania, United States. Willingness to pay (WTP) was calculated using the random parameter logit model and hybrid-typed random parameter latent class model which expressed the variations of individual preferences. The results found variations in individual preferences, especially a large variation in solar power. Other attributes were new employment in Pennsylvania and electricity bills. One alternative was status-quo. Gracia et al (2012) estimated individual preferences for renewable energy in Spain using the conjoint analysis. Individual expressed high WTP for higher solar power ratio and low WTP for higher wind power and biomass ratio. They expressed high WTP for locally used renewable energy. Yang et al. (2016) estimated individual preferences for renewable energy in Denmark using the conjoint analysis. When the ratio of all energy sources became higher, especially wind power, it causes temporal energy shortages. Consumers highly evaluated renewable energy but they even more highly evaluated the mix of renewable energy sources. They preferred the current supplier than other famous suppliers. Our study also takes in account the suppliers from whom households purchase electricity. Kaenzig et al. (2013) estimated German individual preferences for suppliers in a deregulated electricity market using the conjoint analysis. The renewable energy ratio was one of the attributes of electric power suppliers. German individuals gave 16% additional payment for electricity generated from renewable energy by WTP. They also found that individuals preferred local suppliers. Our study also takes local suppliers into consideration. Caedella et al. (2017) analyzed that households chose electricity generated by conventional fossil fuels or renewable energy such as solar and wind power when each electricity bill was volatile using the conjoint analysis. Risk-averse households would avoid volatile electricity bills generated by renewable energy even if they preferred renewable energy. The probability of choosing renewable energy plans would decrease if the electricity bills generated by renewable energy were volatile. The probability that households chose renewable energy plans would increase if the electricity bills generated by fossil fuels were volatile. Electric power generation by renewable energy such as solar and wind power depends on weather conditions; however, electricity supply is unstable. The prices are volatile and spike in case of increasing demand and decreasing supply. Individual energy choices when the prices are volatile needs to be analyzed. Shin et el. (2014) estimated the individual preferences for renewable energy portfolio in Korea using the conjoint analysis. People thought new employment was the most important rather than higher renewable energy ratio and higher bills. They accepted 1.39% higher bills from WTP. Bordhers et al. (2007) estimated the individual WTP for green energy using the conjoint analysis. This study analyzed that individuals decided whether to participate in green energy programs or remain in the status-quo at the first stage and which green energy program they choose at the next stage by the nested logit model. Bergman et al. (2006) estimated the individual preferences for renewable energy in Scotland using the conjoint analysis. The study analyzed the external cost and benefit caused by investment of renewable energy such as wind power. Wind power generation plants create new local employment but ruin the scenery around the area. The study suggested the investment of renewable energy considering local total benefits. Sundt and Rehdanz (2015) estimated individual WTP for renewable energy and analyzed the differences in individual evaluation for the type of renewable energy using the meta-regression analysis in which WTP is a dependent variable. Hydraulic power got the worst evaluation. Roe et al. (2001) were the first to analyze individual preferences for renewable energy. This study analyzed consumers' WTP for green energy in the United States by a hedonic analysis in which the price premium was a dependent variable. Consumers highly evaluated green energy to reduce the global heating gases.

Some studies estimated the preferences for generation techniques using renewable energy such as solar panels and home micro-wind generators. Scarpa and Willis (2010) estimated that British households' preferred generation techniques using renewable energy using the conjoint analysis. From WTP, households positively evaluated such generation techniques, but they did not reveal high monetary evaluation to cover expensive installation cost. Willis et al. (2011) also estimated British households' preferences for generation techniques using renewable energy using the conjoint analysis. The study found that elder households did not prefer such generation techniques. In near future, aging society will be going. If elder households do not need such generation techniques, generation techniques using renewable energy will not be widely used even though the techniques should be promoted.

Various approaches about individual preferences for renewable energy have been proposed. Herbes et al. (2015) estimated WTP for renewable energy by using a novel neuro-science method. According to some studies, strategic bias is caused in the CVM and conjoint analysis. A neuro-science method revealed 15% higher WTP for renewable energy compared with other energy sources. Boeri and Longo (2017) estimated the preferences by the regret-minimization approach as well as the utility-maximization approach. The study used the conjoint analysis and estimated parameters by the random parameter logit model and hybrid-latent cluster model. Electricity generated by renewable energy is highly priced and unstable in electricity supply even though it reduces the global heating gases. Considering these negative features of renewable energy, after households choose renewable energy, they will regret. The regret-minimization approach is suitable to analyze the choice behavior of renewable energy. Bartczak et al. (2017) analyzed risk-preferences and loss-aversion to avoid negative externality of renewable energy using conjoint analysis. Gracia et al. (2016) estimated individual willingness to accept in Norway using the conjoint analysis when wind power plants were built.

Nudges, which are used in behavior economics, are also commonly used in energy research. Nudges, which are non-monetary incentives, affect individual behavior. For example, nudges induce households to save energy. Momsen and Stoerk (2014) noted the effects of nudges when individuals choose renewable energy. From the results of simple experiment, default nudge raised the probability to choose renewable energy by 44.6%.

There are some studies for Japanese households. Morita and Managi (2015) estimated consumers' preferences for energy sources after the great east earthquake in 2011 by a conjoint analysis. Especially, considering higher consumers' interest in renewable energy, the preferences for renewable energy were estimated. The WTPs for energy sources were used for the policy suggestion of energy-mix. Consumers revealed negative WTP for nuclear power, and positive WTP for renewable energy such as solar and wind power. Murakami et al. (2015) also found that consumers in Japan and United States showed negative WTP for nuclear power, and positive WTP for renewable energy which is the mix of solar, wind power, biomass, and geothermal power using the conjoint analysis. But WTP for each renewable energy source was not estimated. Rehdanz et al. (2017) estimated consumers' preferences for energy sources after the accidents in nuclear power plants in 2011 in Fukushima prefecture in Japan using the conjoint analysis. Consumers revealed positive WTP for renewable energy and negative WTP for nuclear power. The WTPs were different by the distance from nuclear power plants and Fukushima prefecture and the values in absolute were greater as the distance was nearer.

Some studies use a CVM to estimate individual preferences for renewable energy. CVM is also a SPM. Lee and Heo (2016) estimated WTP for renewable energy in Korea and found consumers would pay additional 3.21 USD per month for electricity generated by renewable energy. Guo et al. (2014) estimated WTP for renewable energy in Beijing and found consumers would pay additional 2.7 to 3.3 USD per month for electricity generated by renewable energy. Kim et al. (2013) estimated consumers' WTP for renewable energy in Korea. Electricity generated by renewable energy was considered as a differentiated good. The differentiation was observed between renewable energy and other energy sources but was not observed between renewable energy sources, and perfect substitution was observed between renewable energy sources.

Some studies about renewable energy did not use SPMs. Conte and Jacobsen (2016) used consumer data of all electric utility companies in the United States. and analyzed the attributes of households who purchased green electricity generated by renewable energy through local utilities. The results showed that highly educated households tended to purchase green electricity. Inhoffen et al. (2019) found that the investment in renewable energy power plants such as solar panels allocation inefficiencies would be caused when minimum prices and individual decision were affected by individual social environment through the household data in Germany.

3. Questionnaire and its results

The data were collected via a web-based questionnaire, using the services of the Rakuten Insight Company. Monitors that registered Rakuten services answered the questions. The Rakuten Insight Company randomly sent the questionnaire to the registers that are the potential respondents by E-mail, and they decided to answer or not. The data were collected in February 2019. The sample size is 1,000 households in total, with 668 from the Kanto region around Tokyo and 332 from the Kansai region around Osaka. These two areas are the biggest two major urban areas in Japan. The sample is weighted by each area's population. In the questionnaire, households were asked individual socio-demographic attributes such as occupation, annual income, and perception about energy problems. Table 1 is socio-demographic attributes of sample households. The sample does not seem to be extremely biased.

Table 1 Socio-demographic attributes of sample households.

Total		**Number**	**%**
		1000	100
Occupation	Employed and own-employed	691	69.1
	Unemployed (including students, housewives, and retirees)	192	19.2
	Other	117	11.7
Household annual income (million JPY)	Less than 2	239	23.9
	2–3.99	218	21.8
	4–5.99	231	23.1
	6–7.99	134	13.4
	8–9.99	85	8.5
	More than 10	93	9.3
Education	Junior high school and high school	224	22.4
	Technical school and junior college	236	23.6
	University and graduate school	530	53
	Other	10	1
Family composition (including multiple answers)	Single	224	22.4
	Couple (including in-house and not in-house)	430	43
	In-house with parents or grand parents	180	18
	In-house with brothers and sisters	53	5.3
	With less than six years old children (including in-house and not in-house)	157	15.7
	With six-thirteen years old children (including in-house and not in-house)	118	11.8
	With thirteen-nineteen years old children (including in-house and not in-house)	96	9.6
	With more than nineteen years old children (including in-house and not in-house)	115	11.5
	Other	13	1.3
Dwelling type	Detached house (including two households house)	413	41.3
	Collective housing (condominium, apartment, housing complex, etc.)	545	54.5
	Company housing, dormitory housing, etc.	30	3
	Other	12	1.2
Gender	Male	510	51
	Female	490	49
Age (years old)	Average	40.6	
	Minimum	20	
	Maximum	59	
Age (years old)	20–29	212	21.2
	30–39	241	24.1
	40–49	307	30.7
	50–59	240	24
Residential area	Kanto	668	66.8
	Kansai	332	33.2

Households were asked about their interest in solar panels, home micro-wind generator, storage battery, and home generation fuel cells (gas cogeneration) related to their interest in renewable energy. More than half of the households were not interested in any appliances. Only few (less than 5%) households have already owned renewable energy appliance. About 20% of households, especially 29.3% in solar panels, are interested in these appliances but cannot purchase due to the limitations in their residence. Some solutions are needed so that households purchase these appliances. Households were asked about their most desirable energy source. About 40.4%of households agree that solar power is the most desirable. Next, 19% of households find nuclear power as the most desirable. About 21.4% of households think wind power is the second desirable energy source. About 10% of households think geothermal power and biomass are the third desirable energy source. On the other hand, very few households think fossil fuels are the most desirable energy source. Overall, households are interested in renewable energy.

About 44.5% of households think that the realization of lower electricity and gas bills is the most important for future energy problem. About 26.4% of households think that stable electricity and gas supply is the most important and 35.8% households think it is the second important energy problem. About 17.5% of households think energy saving is the second important and 30% of households think energy saving is the third important energy problem. Only 13.2% of households think that the promotion of renewable energy is the second and 17.9% households think it is the third important energy problem. Less than 5% households think the promotion and consumption of local energy sources, suspension of nuclear power, and resumption and promotion of nuclear power are important.

About 47.2% households think electricity bills become higher after the Great East Japan Earthquake. About 77.6% of households are more aware of energy savings after the earthquake. About 90.5% of households think CO_2 should be reduced. About 23.5% of households think that the future suitable dependence on nuclear power in Japan is 0%, which is the most popular. About 20.7% of households think it is from 40 to 59% and 20.3% households think it is from 20 to 39%. On the other hand, 27.7% of households think that the future suitable dependence on renewable energy in Japan is from 40 to 59%, which is the most popular. About 25.2% of households think it is from 20 to 39% and 19.1% households think it is from 60 to 79%. About 44.8% of households worry about unstable electricity supply due to weather conditions as the most serious problem in the promotion of renewable energy. About 24.3% of households worry about the higher prices due to expensive installment cost of solar panels and home wind generator. About 21% of households worry about the destruction of landscape by solar panels and wind generators. Only 9.4% of households do not have any serious problems about renewable energy.

4. Conjoint analysis

The conjoint analysis is used to examine the future condition in which renewable energy will be used[4]. It is one of the SPMs, where researchers present some hypothetical alternatives to individuals and individuals choose the most preferred one. This study analyzes the individual choice under change of energy sources, monthly electricity bills, suppliers etc. Alternatives express renewable energy programs with various attributes. This study examines households' preferred attributes of renewable energy programs.

The CVM is another popular SPM, but it is not a choice experiment and can be used to evaluate users' valuation of non-marketable targets such as forests and beaches. CVM does not

[4] Louviere et al. (2000), Hensher et al. (2005), Kuriyama and Shoji (2005), Tsuge et al. (2011), and Kuriyama et al. (2013) are referred for a conjoint analysis.

evaluate each attribute. The conjoint analysis is adopted because this study adopts a choice experiment.

Next, the researcher decides on the number of attributes, keeping in mind that a small number of attributes will not fully reveal consumer preferences, while many attributes make it difficult for participants to choose among options. This study adopts six attributes—energy sources, monthly electricity bills, renewable energy ratio, local new employment, suppliers that provide electricity and benefits that household's gain from renewable energy programs. After the selection of attributes and their levels, their profiles are compiled. However, if all combinations of attributes and levels are used, the patterns are numerous, which can cause strong correlation between some attributes, i.e., multicollinearity. To avoid these problems, profiles are created by the orthogonal planning method. Various option cards are obtained, and profiles are made by selecting cards and their combinations, after deleting unrealistic and dominant cards. An example of unrealistic cards is when monthly electricity bill is lower, despite higher renewable energy ratio. This example is also one of the dominant cases. Table 2 represents an example of profile. Excel conjoint analysis version 2.0 (Esumi) was used for the orthogonal planning.

Table 2 An example of profile.

Attributes	**Alternative 1: Conventional energy program**	**Alternative 2: Renewable energy program**	**Alternative 3: Renewable energy program**
Energy sources	Fossil fuels	Biomass	Solar power
Monthly electricity bill	0 (unchanged)	+1000 JPY	+4000 JPY
Renewable energy ratio	15%	25%	25%
Local new employment	0 employee	70 employees	30 employees
Suppliers	Major existing supplier	Small-medium local new supplier	Major new supplier
Benefits	Nothing	Tax credit	Free tickets

The following three alternatives are presented to households. They choose the most preferred one.

Alternative 1: Conventional energy program (status-quo)
Alternative 2: Renewable energy program
Alternative 3: Renewable energy program

In Alternative 1, households use conventional energy sources such as fossil fuels (LNG, coal, and oil). The composition is assumed such that nuclear power is 2%, fossil fuels are 83% and renewable energy is 15%, which is the composition for the whole of Japan in the fiscal year 2016. The composition in Alternative 1 is the current energy composition[5]. In Alternative 2 and 3, households mainly use renewable energy. The renewable energy ratio is much higher than in Alternative 1.

These alternatives have several attributes that are energy sources, monthly electricity bills, renewable energy ratio, local new employment, suppliers that provide electricity, and benefits that households obtain from renewable energy programs. A detailed explanation about attributes is as follows:

[5] Bae and Rishi (2018) adopted an opt-out option, where households do not choose any renewable energy options. The current study considers the more prevalence of renewable energy compared with the current one and assumes that Alternative 1 consists of the current composition. Yang et al. (2016) adopted higher renewable energy ratio in all options to avoid the status-quo bias.

1. Energy sources

In Alternative 1, households use conventional energy sources such as fossil fuels (LNG, coal, and oil). The composition is assumed such that nuclear power is 2%, fossil fuels are 83%, and renewable energy is 15%, which is the whole Japanese composition in the fiscal year 2016. In Alternative 2 and 3, renewable energy (green energy) ratio is much higher. Either solar or wind power or biomass or fuel cells is used. Respondents gain information about the pros and cons of each renewable energy to facilitate the energy sources. The following statements are used for respondents. In econometric analysis, dummy variables are used for each renewable energy source, where biomass is the base category.

Solar power: Solar panels are settled on the sunlight spaces and electricity is generated by solar power. Only with solar power, electricity is generated. Solar power does not emit any noises and green-house gases such as CO_2. Solar panels are durable and can be used for many years. On the other hand, solar power has several problems. The installation of solar panels needs large spaces. The power depends on weather conditions such as sunlight-hours and is unstable. The investment cost is rather expensive. The panels may break due to typhoons and earthquakes. The panels are reflected by sunlight.

Wind power: Wind power generators are built on land or ocean and electricity is generated by wind power. With wind, electricity is generated even during night. Wind power does not emit the green-house gases and generate electricity highly efficiently. Large-scale production can greatly reduce its cost. On the other hand, wind power has several problems. Since wind power generators are huge, large spaces are needed. Wind power generators emit noises and vibrations during electric power generation. The power depends on air volume and is unstable.

Fuel cells: Chemical reaction between hydrogen and oxygen generates electricity. Fuel cells do not emit the green-house gases and noises. Fuel cells can generate electricity with higher energy availability. On the other hand, investment costs are high, and its durability is low, usually less than 10 years. Fuel cells are not renewable energy but green energy that does not emit the green-house gases.

Biomass energy: Electricity is generated by renewable and organic resources from animals and plants such as woodchips and raw garbage. Biomass energy is a carbon-neutral energy source that does not increase CO_2 levels and leads to reuse of garbage. On the other hand, it utilizes edible fuels and has risk to cause increase in food prices.

2. Monthly electricity bills

In Alternative 2 and 3, when renewable energy is used, monthly electricity bills will be higher compared with Alternative 1. Bills depend on electricity-generation costs and investment costs of electric power plants and managing status of suppliers. The levels are +1000 JPY, +2000 JPY, +3000 JPY, +4000 JPY, and +5000 JPY. In Alternative 1, the bills never change.

3. Renewable energy ratio

Renewable energy ratio is considered. The levels are 25%, 50%, 75%, and 100%. Fossil fuels are used for other energy sources. In Alternative 1, the ratio is 15% which is the ratio in the fiscal year 2016.

4. Local new employment

When electric power plants are built, residents are employed. Local new employment is considered as economic effects. The levels are 10, 30, 50, 70, and 100 employees. New local employment means a positive externality for local economy. Positive coefficient associated with this variable means individuals are altruistic and respond to non-monetary incentives.

5.Suppliers that provide electricity

Households are concerned about renewable energy programs and the suppliers of electricity. In Japan, since April 2016, the deregulation of electricity and gas retail sales for general households has begun. Various suppliers start to provide electricity and gas. Major existing suppliers, major new suppliers, or small and medium local new suppliers provide electricity. In Alternative 1, conventional major existing suppliers provide electricity. The examples of major existing suppliers are major electric power companies such as the Kansai Electric Power Corporation and the Tokyo Electric Power Corporation and major urban gas companies such as the Osaka Gas Corporation and the Tokyo Gas Corporation. These companies have provided electricity or gas till now. Major new suppliers have not provided either electricity or gas so far. Telecommunication companies have started to provide electricity after the deregulation in April 2016. Local suppliers manage operation in the region where the respondents live. If households choose local suppliers, they support local economy. In econometric analysis, dummy variables for each supplier are used, where major existing suppliers are the base category.

6. Benefits from renewable energy programs

When households choose renewable energy programs, they receive some benefits. For example, they obtain tax credit, coupon tickets which are used in local areas where households live, awards from local public organization or name listed on the local government website and free tickets to green parks and environmental power plants[6]. When households choose Alternative 1, they do not receive any benefit. Some benefits are monetary incentives, and some are non-monetary ones. Tax credit and coupon tickets are monetary incentives, while name listed on the local government website and free tickets to green parks are non-monetary incentives. However, coupon tickets are limited to the local area where households live. The preferences for coupon tickets can also express the individual interests in contributions to local communities. In econometrics analysis, dummy variables are used for each benefit, where name listed on the website is the base category.

The levels of each attributes are listed in Table 3.

Table 3 The levels of attributes.

Attributes	**Levels**
Renewable energy sources	Solar power, wind power, fuel cells, biomass
Monthly electricity bills	+1000 JPY, +2000 JPY, +3000 JPY, +4000 JPY, +5000 JPY
Renewable energy ratio	25%, 50%, 75%, 100%
Local new employment	10, 30, 50, 70, 100 employees
Suppliers	Major existing, major new, small-medium local new suppliers
Benefits	Tax credit, coupon tickets, award from local public organization or name listed on a local government web site, free tickets for green parks and environmental plants

Households are presented profiles in Table 3 and choose their most preferred alternative among 10 choice scenarios. Each question has various levels of attributes. Respondents' age is limited under 59. In the questionnaire, householders were asked whether they have children. It is found that households which have small children have interests in future energy sources and environmental problems. They are altruistic. They are against nuclear power and fossil fuels which causes global warming and express their support for renewable energy. Households with elderly people do not have small children at the time of questionnaire.

5. Random parameter logit model (RPLM)

In a choice experiment, the dependent variable is discrete. Therefore, a discrete choice econometric model should be used. A conditional logit model is a popular option in this context. However, it assumes an Independent and Identical Distribution (IID), which is derived from the Independence of Irrelevant Alternatives (IIA). Since the IIA is restricted and easily violated in many cases, a RPLM (mixed logit model) is often used as a general discrete choice econometric

[6] Bae and Rishi (2018) took tax credit, green mileage, eco-leveling, free tickets for green parks into consideration. The current study uses benefits that are easier to understand for Japanese households.

model[7]. It allows for random variation of individual preferences, unrestricted substitution patterns, and correlation among unobserved factors over time.

A RPLM assumes that each parameter has a specific distribution. The utility is specified as

$$U_{nj} = \alpha' x_{nj} + \beta_n' z_{nj} + \varepsilon_{nj}$$

This function specifies that individual *n* chooses alternative *j*, where α is a non-random parameter and β_n is a random parameter that represents an individual's preference and therefore varies across individuals. In this paper, constant terms and the parameter of a monthly electricity bill, which is a price parameter, are non-random parameters, and x_{nj} is a variable vector that includes a monthly bill. On the other hand, the parameters of each renewable energy, renewable energy ratio, local new employment, suppliers and benefits are random parameters; z_{nj} is a variable vector that includes these factors. ε_{nj} is a random error term and has an IID extreme value.

The probability conditional on β_n is

$$L_{ni}(\beta_n) = \frac{\exp(\beta_n' x_{ni})}{\sum_j \exp(\beta_n' x_{nj})}$$

The random parameter logit probability is

$$P_{ni} = \int \left(\frac{\exp(\beta' x_{ni})}{\sum_j \exp(\beta' x_{nj})} \right) f(\beta) d\beta$$

This probability is the unconditional choice probability calculated as the integral of $L_{ni}(\beta_n)$ over all β_n.

The distribution of β_n must be assumed. Usually, a normal, log-normal, or triangular distribution, etc., can be assumed. In this paper, a normal distribution is assumed because it is a general distribution and easy to estimate.

Simulation methods were used for estimation. The simulated probability is

$$\widetilde{P_{ni}} = \frac{1}{R} \sum_{r=1}^{R} L_{ni}(\beta^r)$$

where R is the number of draws. This simulated probability is an unbiased estimator of P_{ni}. The simulated log likelihood (SLL) is

$$SLL = \sum_{n=1}^{N} \sum_{j=1}^{J} d_{nj} \ln \widetilde{P_{nj}}$$

where d_{nj} is an indicator. It equals 1 if an individual *n* chooses Alternative *j*, or 0 otherwise. The SLL was maximized to capture the maximum simulated likelihood estimator. In addition, 100 Halton draws were used for simulation. For estimation, *Limdep NLOGIT 5* was used.

WTP for each attribute is calculated using estimated coefficient parameters[8]. If the utility function is linear, it is expressed as

$$V_{nj} = \alpha' x_{nj} + \beta_n' z_{nj}$$

[7] The explanation of a random parameter logit model derives from Train (2003).
[8] Kuriyama et al. (2005) and Murakami et al. (2015).

where V_{nj} is the deterministic term of the utility function. The total differentiation of the V_{nj} formula is

$$dV_{nj} = \frac{\partial V_{nj}}{\partial x_{nj}} dx_{nj} + \frac{\partial V_{nj}}{\partial z_{nj}} dz_{nj}$$

Now the WTP of z_1 which is one of the attributes, such as each renewable energy is obtained. If the utility level does not change ($dV_{nj} = 0$) and other variables except z_1 are not changed, the marginal WTP (MWTP) is obtained as follows:

$$MWTP = -\left. \frac{\partial V_{nj}}{\partial z_{nj1}} \middle/ \frac{\partial V_{nj}}{\partial x_{njm}} \right.$$

where x_m is a monetary variable such as a monthly electricity bill. MWTP is also written by using parameters as follows:

$$MWTP = -\beta_i / \beta_m$$

where β_i is the coefficient of each attribute and β_m denotes a monetary coefficient such as a monthly electricity bill. WTP is obtained by dividing the coefficient of each attribute by a monetary coefficient.

6. Estimation results

6.1 Estimation results in full sample

In this section, the estimation results are discussed. Table 4 illustrates the choice number and ratio for each alternative.

Table 4 Choice number and ratio for each alternative.

	Alternative 1	**Alternative 2**	**Alternative 3**	**Total**
Number	3769	3264	2967	10000
Ratio	37.69	32.64	29.67	100

Alternative 1 is the most popular. There are many households that prefer the current and conventional energy usage. However, the total ratio of Alternatives 2 and 3 is about 60%. More than half of the households chose renewable energy programs. Table 5 shows the estimation results in full sample.

Table 5 Estimation results in full sample.

Variables	**Coefficient**	**Z value**	**P-value**	
Random parameter (mean)				
Solar power	0.16542	2.11	0.0347	**
Wind power	−0.15045	−1.46	0.1438	
Fuel cells	−0.5871	−6.81	0	***
Renewable energy ratio	−0.00107	−0.6	0.5513	
Local new employment	0.00326	2.68	0.0073	***

Major new supplier	0.15381	2.47	0.0134	**
Small-medium local new supplier	−0.01984	−0.22	0.8273	
Tax credit	−0.06797	−0.64	0.5252	
Local coupon ticket	−0.38621	−3.62	0.0003	***
Free ticket for green parks	−0.22147	−1.83	0.067	*
Non-Random parameter				
Monthly electricity bills	−0.00056	−20.97	0	***
Constant 1	−1.57691	−9.52	0	***
Constant 2	−0.0463	−0.62	0.5357	
Standard deviation				
Solar power	1.4247	21.49	0	***
Wind power	1.35296	13.74	0	***
Fuel cells	0.37944	2.42	0.0157	**
Renewable energy ratio	0.04123	20.81	0	***
Local new employment	0.02312	22.8	0	***
Major new supplier	0.62559	8.31	0	***
Small-medium local new supplier	0.48912	4.34	0	***
Tax credit	0.96063	15.17	0	***
Local coupon ticket	0.40086	2.81	0.0049	***
Free ticket for green parks	0.04368	0.38	0.7053	
McFadden R^2	0.2255611			
Log likelihood	−8508.0814			
Sample size	10000			

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

The coefficient for the monthly electricity bills is negative and significant at the 1% significance level. Households clearly prefer lower electricity bills. To establish renewable energy throughout Japan, electricity generated by renewable energy should be lower.

Next, the results of each renewable energy source are discussed. Dummy variables are used for each renewable energy source, where biomass energy is the base category. Thus, positive coefficient means that certain renewable energy is preferred to biomass and negative means that it is not preferred to biomass. The coefficient of solar power is positive and significant at the 5% significance level. Solar power is preferred to biomass. Wind power has a negative coefficient, but it is not significant. Significant differences in preferences are not observed between wind power and biomass. The coefficient of fuel cells is negative and significant at 1% significance level. Fuel cells are not significantly preferred to biomass. Bae and Rishi (2018) obtained positive and significant coefficients for every renewable energy source in South Korea. The results were different in Japan and South Korea. Fuel cells are not popular in Japan and are expensive for households. Therefore, fuel cells are not preferred to biomass. On the other hand, biomass is widely known to households as renewable energy though only a small percent of the households prefer biomass as the most desirable future energy source in the questionnaire. Renewable energy ratio is not significant. Households do not choose alternatives with higher renewable energy ratio[9].

[9] Bae and Rishi (2018) used the quadratic term of renewable energy ratio. If the coefficient of the quadratic term is negative, the quadratic function is concave down and has renewable energy ratio where the choice probability reaches maximum. Individuals do not prefer higher and higher renewable energy ratio and they have the best renewable energy ratio. They also do not prefer much higher ratio. The current study tried it. However, positive and significant coefficient of the quadratic term were obtained, which is the reverse result of Bae and Rishi (2018). In Japan, renewable energy ratio where

The coefficient associated with local new employment is positive and significant at the 1% significance level. Households hope new employment will increase in the region where they live after renewable energy electric power plants are built. They are altruistic and hope positive economic effects in the region. The results are consistent with Bae and Rishi (2018) [10].

The estimation results about electric power suppliers that provide renewable energy programs are discussed. Three types of suppliers are considered—major local existing suppliers, major new suppliers, and small and medium local new suppliers. Dummy variables are used for each supplier. Major existing suppliers are the base category. The coefficient of major new suppliers is positive and significant at the 5% significance level. Households prefer major new suppliers to major local existing suppliers. Major local existing suppliers have long-time experience in providing electricity and have been securing constant electricity supply. But households may expect new services and cheaper bill plans from major new suppliers. After the deregulation in April 2016, new suppliers have provided electricity and gas. Japanese households have become favorable for new suppliers. In Alternative 1, major local existing suppliers provided electricity generated by fossil fuels. If households do not support fossil fuels and support renewable energy, they prefer new suppliers who provide electricity generated by renewable energy than major local existing suppliers who provided electricity generated by fossil fuels. The coefficient of small-medium local new suppliers is negative and not significant. The significant differences in preferences between small-medium local new suppliers and major local existing suppliers are not observed. The results imply that small-medium local new suppliers can acquire customers if they use renewable energy instead of fossil fuels in electricity generation.

Lastly, the estimation results regarding benefits from renewable energy programs are discussed. Households receive benefits such as tax credit, coupon tickets which are used in only local areas where households live, award from local public organization or name listed on a local government website and free tickets to green parks and environmental power plants. Dummy variables are used for each benefit, where name listed on a local government website is the base category. Tax credit is a monetary incentive. Local coupon tickets are also a monetary incentive, but households can contribute to their local area. Award from local public organization or name listed on a local government website is a non-monetary incentive. Free tickets to green parks and environmental plants are a kind of monetary incentive but for households that are not interested in free tickets to green parks and environmental power plants is non-monetary incentive. From the estimation results, tax credit is not significant. Households do not respond to monetary incentives. The coefficient of coupon tickets is negative and significant at the 1% significance level. Households prefer awards or name listed on the local government website to coupon tickets. The coefficient of free tickets is negative and significant at the 10% significance level. Households prefer to award or name listed to free tickets. These results imply that households do not respond to monetary incentives[11].

The random parameter logit model estimates the variation of individual preferences. Estimated standard deviation of coefficient parameter expresses the variation of individual preferences and

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the choice probability reaches minimum exists. The ratio is 50%. Japanese individuals prefer more than 50% ratio with quadratic proportion.

[10] Bae and Rishi (2018) considered the distance from households' residence to electric power plants as an attribute. Sometimes electric power plants cause negative externalities. Wind power generators emit noises and vibrations, and solar panels reflect sunlight. These electric power plants cause some troubles to neighbors. Households hope local economic effects but oppose electric power plants which are built near their house to avoid these troubles. Bae and Rishi (2018) analyzed individual behavior to avoid negative externalities. From the results, households did not hope that electric power plants were built near their house. The current study adopted other attributes and did not adopt the distance from households' residence due to the restriction of the number of attributes.

[11] Bae and Rishi (2018) obtained the results that the coefficient of green mileage is positive and significant but other benefits are not significant.

distribution. From the results, variables except free tickets have significant standard deviation. The variation of individual preferences and distribution is observed in variables except free tickets.

Table 6 shows WTP for each attribute. WTP is obtained after dividing each parameter of attributes by a monthly electricity bill that is monetary parameter. WTP expresses households' evaluation or monthly additional payment for each attribute.

Table 6 WTP.

Solar power	295.3929
Wind power	−268.661
Fuel cells	−1048.39
Renewable energy ratio	−1.91071
Local new employment	5.821429
Major new supplier	274.6607
Small-medium local new supplier	−35.4286
Tax credit	−121.375
Local coupon tickets	−689.661
Free tickets for green parks	−395.482

Households pay additional 295 JPY per month for solar power. On the other hand, they show large negative evaluation for wind power and fuel cells. Especially, households do not choose fuel cells unless the price is discounted by 1048 JPY. Households express highly positive WTP for major new suppliers and they pay additional 275 JPY per month. Households have negative WTP for every benefit. They do not evaluate benefits except award or name listed. WTP for local new employment is very small value of only 5.8 JPY.

6.2 Estimation results in subsamples

In this sub-section, the differences of preferences across individual socio-demographic attributes and perceptions for renewable energy and energy problems are analyzed. WTP in each subsample is compared. The random parameter logit model is used for estimation.

6.2.1 Children

Table 7 illustrates WTP of households that have children less than 13 years old and households that do not have children. Households that have infant children are altruistic and are interested in renewable energy and environmental problems for future generations.

Table 7 WTP: households with and without less than 13 years old children.

Attributes	**With less than thirteen years old children**		**Without less than thirteen years old children**	
Solar power	520.073	*	370.444	**
Wind power	−350.09		−358.17	
Fuel cells	−988.8	***	−1089.6	***
Renewable energy ratio	7.12727		1.64815	
Local new employment	7.41818		4.24074	*
Major new supplier	47.8909		387.611	***
Small-medium local new supplier	348.964		−62.981	
Tax credit	201.709		−172.61	
Local coupon ticket	−473.25		−821.78	***
Free ticket	−93.109		−428.39	*
Sample size	2350		7650	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

In both subsamples, WTP of solar power is positive and that of fuel cells is negative. Both households prefer solar power and do not prefer fuel cells to biomass. Wind power is not significant. Renewable energy ratio is not significant. Difference in preferences for renewable energy between households with children less than 13 years old and households without infant children are not observed. WTP of households without children less than 13 years old showed a positive and significant correlation for local new employment; however, WTP of households with children less than 13 years old is not significant. Households with children less than 13-year-old are not interested in local new employment when they decide to participate in renewable energy programs. They are not altruistic. WTP of households with children less than 13 years old children for local coupon tickets and free tickets to green parks and environmental plants are not significant. They do not decide to participate in renewable energy programs to get coupon tickets or free tickets compared with award from local public organization or name listed on a local government web site. On the other hand, WTP of households without less than thirteen years old children for these benefits are negative and significant. They do not prefer these benefits.

6.2.2 Age

Table 8 expresses WTP of younger and older households. The average age is 40.6 years old. Younger households are under 39 years old and older households are over 40 years old.

Table 8 WTP: younger and older households.

Attributes	Younger		Older	
Solar power	465.224	*	349.095	**
Wind power	−597.878	*	−169	
Fuel cells	−958.082	***	−1172.7	***
Renewable energy ratio	6.32653		4.15873	
Local new employment	8.5102	**	5.06349	*
Major new supplier	109.898		540.857	***
Small-medium local new supplier	−47.1837		58.127	
Tax credit	396.245		−425.51	*
Local coupon ticket	−281.02		−1072.7	***
Free ticket	−202.98		−616.86	**
Sample size	4530		5470	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

WTP of both subsamples for solar power is positive and significant, and WTP of both subsamples for fuel cells is negative and significant. On the other hand, WTP of younger households for wind power is negative and significant at 10% significant level. Younger households do not prefer wind power compared with biomass. WTP of both subsamples for local new employment is positive and significant. WTP of younger households for tax credit, local coupon tickets, and free tickets to nature parks and environmental plants are not significant, but WTP of older households for these benefits are negative and significant. Older households do not prefer these benefits compared with award from local public organization or name listed on a local government web site. Or they prefer the award.

6.2.3 Education

Table 9 illustrates WTP of higher and lower education households. Highly educated householders graduated from university and graduate school, while lower education households are not university graduates.

Table 9 WTP: higher and lower education households.

Attributes	Higher education		Lower education	
Solar power	90.6875		566.1385	***
Wind power	−1040.4	***	−17.9077	
Fuel cells	−1107.5	***	−1025.52	***
Renewable energy ratio	4.66667		2.061538	
Local new employment	5.14583		3.661538	
Major new supplier	165.958		460.5077	***
Small-medium local new supplier	−27.521		13.03077	
Tax credit	130.729		−263.2	
Local coupon ticket	−649.65	**	−777.615	***
Free ticket	−328.31		−483.585	*
Sample size	5300		4700	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

WTP of highly educated households for solar energy is not significant, while WTP of lower education households is positive and significant. Higher education households do not prefer solar energy; however, lower education households prefer that compared with biomass. WTP of higher education households for wind power and fuel cells is negative and significant. Higher education households do not prefer wind power and fuel cells. In both subsamples, local new employment is not significant. The result is different from the results of full sample. Lower education households prefer new major suppliers.

6.2.4 Area

Table 10 expresses WTP of households in Kanto area and households in Kansai area.

Table 10 WTP: households who live in Kanto area and Kansai area.

Attributes	Kanto		Kansai	
Solar power	460.1481	***	374.7966	
Wind power	−351.278		−580.22	*
Fuel cells	−1170.43	***	−936.339	***
Renewable energy ratio	0.185185		8.779661	*
Local new employment	6	**	3.508475	
Major new supplier	311.8148	**	389.3559	**
Small-medium local new supplier	312.2778		−449.559	*
Tax credit	−264.333		150.2542	
Local coupon ticket	−872.648	***	−628.831	**
Free ticket	−421.148		−441.712	
Sample size	6680		3320	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

WTP of households in Kanto area for solar power is positive and significant, but it is not significant in Kansai area. Households in Kanto area prefer solar power but households in Kansai area do not prefer it. In both areas, fuel cells are not preferred. WTP of households in

Kansai area for renewable energy ratio is positive and significant at 10% significant level. Households in Kansai area prefer the higher renewable energy ratio. Households in Kanto area positively evaluate local new employment but households in Kansai area do not evaluate local new employment when they participate in renewable energy programs. Households in both areas positively evaluate major new suppliers and negatively evaluate local coupon tickets.

6.2.5 Annual income

Table 11 expresses WTP of higher and lower income households. Higher income households are those whose annual income is over 6 million JPY, while lower income households are those whose annual income is under 6 million JPY.

Table 11 WTP: higher and lower income households.

Attributes	Higher income		Lower income	
Solar power	139.86		496.5263	***
Wind power	−523.7		−308.842	
Fuel cells	−1311.02	***	−1073.18	***
Renewable energy ratio	5.2		6.140351	*
Local new employment	4.52		4.070175	
Major new supplier	263.2		379.193	***
Small-medium local new supplier	317.92		−49.4737	
Tax credit	206.78		−239.175	
Local coupon ticket	−913.06	**	−730.895	***
Free ticket	45.92		−571.053	**
Sample size	3120		6880	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

WTP of higher income households for solar energy is not significant, while WTP of lower income households is positive and significant. Higher income households do not prefer solar energy, while lower income households prefer it. In both higher and lower income households, WTP for wind power is not significant and WTP for fuel cells are negative and significant. Wind power and fuel cells are not preferred. Local new employment is not significant in both households. Lower income households prefer major new suppliers.

6.2.6 The perception of energy saving

Households were also asked about their perception of energy saving. Energy saving household is defined as a household conscious about energy saving after the earthquake, while non-energy saving household is defined as a household not conscious about energy saving after the earthquake. Table 12 expresses WTP.

Table 12 WTP: households that are conscious about energy saving and non-energy saving households that are not conscious about energy saving.

Attributes	Energy saving		Non-energy saving	
Solar power	279.1379	**	886.9318	**
Wind power	−523.276	***	232.2045	
Fuel cells	−1071.57	***	−879.864	**
Renewable energy ratio	2.655172		−16.5455	
Local new employment	3.844828		2.409091	
Major new supplier	293.3448	*	300.5455	
Small-medium local new supplier	−191.655		617.5909	
Tax credit	−82.6207		−294.614	

Local coupon ticket	−622.517	***	−904.227	*
Free ticket	−351.517		−487.273	
Sample size	7760		2240	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

Both household groups revealed positive and significant WTP for solar energy. Households who are conscious about energy saving had revealed negative and significant WTP for wind power. Both household groups revealed negative and significant WTP for fuel cells and local coupons.

6.2.7 Interest in appliances associated with renewable energy

Households were asked about their interest in appliances associated with renewable energy such as solar panels, home micro-wind generator, storage battery and fuel cells. Table 13 and 14 illustrates WTP of households which already have appliances, have an interest in appliances and have a plan to purchase, have an interest in appliances but do not have a plan to purchase and have an interest in appliances but cannot purchase due to the limitation of their residence. The sample excludes households which are not interested in these appliances. Different results from other analysis are obtained, in which WTP for renewable energy ratio is positive and significant. Households who are interested in these appliances support higher renewable energy ratio.

Table 13 WTP: households who are interested in solar panels and home micro-wind generator.

Attributes	**Solar panels**		**Home micro-wind generator**	
Solar power	357.9848	**	120.1754	
Wind power	−412.47	*	−671.211	**
Fuel cells	−1144.85	***	−1105.23	***
Renewable energy ratio	14.21212	***	14.38596	***
Local new employment	8	***	10.54386	***
Major new supplier	348.6364	***	175.193	
Small-medium local new supplier	105.0909		153	
Tax credit	−164.439		−142.912	
Local coupon ticket	−832.212	***	−769.193	**
Free ticket	−534.773	**	−355.175	
Sample size	5270		3400	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

Table 14 WTP: Households who are interested in storage battery and fuel cells.

Attributes	**Storage battery**		**Fuel cells**	
Solar power	246.1667		138.1667	
Wind power	−345.75	**	−499.9	*
Fuel cells	−921.783	***	−971.467	***
Renewable energy ratio	16.16667	***	12.46667	***
Local new employment	9.716667	***	9.316667	***
Major new supplier	384.0167		331.3833	*
Small-medium local new supplier	207.95		−25.6	
Tax credit	−107.783		−361.033	
Local coupon ticket	−759.45	**	−980.883	***
Free ticket	−292.267		−515.933	

Sample size	4610		3720	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level, no * insignificant

6.3 Discussion

Various estimations have been tested. All estimation results, including subsample analysis gave negative significant coefficient of monthly electricity bills. Regardless of individual social attributes and perception of energy problems, households prefer cheaper electricity. Generally, to promote renewable energy, electricity generated by renewable energy is used.

Regarding the estimation results of renewable energy sources, in general, the coefficient of solar energy is positive and significant. A higher positive WTP was observed. Households prefer solar energy than biomass. However, in some household groups such as those living in the Kansai area, solar power is not preferred. The coefficient of fuel cells was negative and significant among all household groups. Any households with social attributes and perception of energy problems do not choose electricity generated by fuel cells. Results of wind power were obtained using subsample analysis. But results could not gain positive and significant coefficient. In general, wind power is not significantly preferred than biomass. Solar energy is familiar to Japanese households, but fuel cells and wind power are not familiar to them and are expensive to households. This explains why different results are obtained. Generally, renewable energy ratio was not significant. Electricity with higher renewable energy ratio is not preferred for households. However, households which are interested in appliances related with renewable energy prefer higher renewable energy ratio since the coefficient was positive and significant. Households who have less than thirteen years old children were expected to be altruistic and to be interested in future environmental and energy problems and positively highly evaluate renewable energy, but expected results were not obtained.

Many households are favorable for local new employment after renewable energy electric power plants are built. Regarding the preference for suppliers who provide electricity generated by renewable energy, in general, households tend to prefer new major suppliers, but do not prefer small-medium local new suppliers. In Alternative 1, major existing suppliers use fossil fuels. On the other hand, in Alternatives 2 and 3, major new suppliers use renewable energy. Households who prefer renewable energy will choose suppliers that use renewable energy even if the suppliers are newcomers.

To analyze households' response to monetary and non-monetary incentives, benefits that households receive by participating in renewable energy programs were considered. All households prefer awards from local public organization or name listed on a local government web site to tax credit, which is a monetary incentive. Households do not prefer local coupons and free tickets of nature parks and environmental institutions. Households totally do not respond to monetary incentives.

7. Conclusions and policy implications

This article examined the conditions in which renewable energy would be widely used and what kind of renewable energy sources would be preferred by Japanese households using the conjoint analysis. Since the earthquake in March 2011, nuclear power plants have been shut down; however, operations are planned to resume. However, in the future, nuclear power plants would be reduced due to decommissioning of plants. The use of fossil fuels should also be reduced to avoid the global warming, although Japan has relied on fossil fuels such as LNG after the earthquake. Based on these reasons, the use of renewable energy such as solar power should be encouraged in Japan than in other countries. Many studies have estimated individual preferences for renewable energy. Some studies estimated preference for higher total renewable energy ratio, but not for individual renewable energy. Some estimated preferences for individual renewable energy such as solar and wind power. Some studies propose government energy policy such as energy-mix and other studies examined individual decision to participate in renewable energy programs. Our study is linked to latter studies. Alternative 1 expresses the current energy usage, in which households use electricity generated by fossil fuels. In Alternative 2 and 3, they use electricity generated by renewable energy. The choice experiment finds out the kind of renewable energy source, bill plans, suppliers, and benefits persuading individuals to participate in renewable energy programs.

From the estimation results, Japanese households highly evaluate solar power and do not evaluate wind power and fuel cells. Especially, they negatively evaluated fuel cells. Solar power is familiar to people, while other renewable energy sources are not so familiar. That is why households do have clear idea to use wind power and fuel cells. Fuel cells that do not emit the green-house gases are classified as renewable energy source. However, fuel cells are too expensive, and households do not have any idea how to use fuel cells as an energy source. Hence, households express negative evaluation. Similarly, Bae and Rishi (2018) in their study on Korean households found that Koreans did not prefer wind power and biomass but positively evaluated solar power and fuel cells. In contrast, our study showed a different result in fuel cells. Renewable energy ratio was not significant. Even though households who have children under the age of thirteen are supposed to be altruistic and interested in global warming and renewable energy, the significant results were not obtained.

The coefficient of local new employment was generally positive and significant. Households hoped that renewable energy power plants would contribute to new employment and economy. Regarding the estimation results of suppliers of renewable energy programs, households prefer major new suppliers to major existing suppliers and do not prefer small-medium local new suppliers. Kaenzig et al. (2013) showed that German households highly evaluated local suppliers. The results showed that households preferred major suppliers to local ones. Since Alternative 1 suppliers were major existing suppliers of fossil fuels, many households choose new suppliers who use renewable energy to avoid fossil fuels.

Lastly, regarding benefits, households did not evaluate tax credit, local coupon tickets, and free tickets obtained from environmental institutes and national parks in many estimation results compared with award or their names listed on the of the local government web site. Households do not respond to monetary incentives such as tax credit, and they prefer non-monetary incentives such as awards or names listed on the local government website. The results conclude that monetary incentives are not so needed to promote renewable energy. This study analyzed the Japanese households' preferences for renewable energy and the conditions in which they use renewable energy. Since Japan has experienced the Great East Japan Earthquake in the recent past, it is difficult to resume nuclear power plants for energy generation. Under these situations, the use of renewable energy is the only solution.

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