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Consumers' willingness to pay for renewable and nuclear energy: A comparative analysis between the US and Japan

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ABSTRACT

This paper examines consumers' willingness to pay for nuclear and renewable electricity as two alternatives to fossil fuels for the reduction of greenhouse gas emissions. We conduct a choice experiment of consumer-stated preferences on the basis of an online survey in four US states and Japan after the Fukushima nuclear plant accident. First, the results suggest that US consumers' willingness to pay for a 1% decrease in greenhouse gas emissions is $0.31 per month, which is similar to the results for the US a decade ago. Japanese consumers show a slightly lower willingness to pay of $0.26 per month. Second, the average consumer in both countries expresses a negative preference for increases in nuclear power in the fuel mix (to a greater extent in Japan). Third, renewable energy sources were endorsed by both US and Japanese consumers, who show a willingness to pay $0.71 and $0.31 per month for a 1% increase in the use of renewable source energy. This study also examines the differences in respondents' characteristics. Approximately 60% of the US respondents who did not change their perception concerning the use of nuclear energy subsequent to the Fukushima nuclear crisis have almost no preference for variation in nuclear power, which is in stark contrast to the Japanese respondents' opposition to nuclear energy.

1. Introduction

Increasing awareness of global environmental problems and the requirements for greenhouse gas (GHG) emissions reduction is the motivation for this study. The Great East Japan Earthquake of March 2011 and the subsequent accident at the Fukushima nuclear plant raised concerns about the trade-offs involved in replacing fossil fuels with renewable sources and nuclear power to meet climate change goals.

Changing power sources present advantages and disadvantages that add to a complex process. For example, nuclear power has the potential to meet emissions reduction targets; however, it also brings nuclear power generation risks such as the environmental impact of radioactive waste and damage to the health of populations in the event of a catastrophe. Renewable energy also has the potential to drastically reduce GHG emissions and, as is the case with nuclear energy, it may have additional benefits such as decreasing the need for imported energy sources. The pursuit of renewable energy entails substantial investment, intermittent supply, and associated negative local externalities, such as altered landscapes, noise, and potential harm to birds. Therefore, consumer opinion should be sought concerning the benefits and drawbacks of each power source.

According to previous social survey findings, substantial public opposition to nuclear energy exists in conjunction with the endorsement of renewable energy investment (Ertor-Akyazi et al., 2012; Greenberg, 2009).[1] Moreover, the extent to which people are willing to pay a price premium for green electricity is examined in numerous empirical studies. These studies find that people prefer renewable energy (Goett and Hudson, 2000; Menges et al., 2005; Grösche and Schröder, 2011; for a comprehensive review of recent literature, see Menegaki, 2008; 2012 and Zoric and Hrovatin, 2012). Consumers prefer to avoid the risks related to nuclear power generation and prefer the implementation of future renewable energy generation systems. However, recent evidence concerning relative consumer willingness to pay (WTP) for emissions reduction through changing electricity sources, particularly nuclear relative to renewable sources, is insufficient. The extent to which WTP differs according to the source type, and according to the characteristics of the consumer, is unknown. The Fukushima nuclear crisis revealed evidence of change in consumer attitudes toward the

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[1] Extensive literature addresses public preference for different energy sources. Ertor-Akyazi et al. (2012) provide a comprehensive review of previous social surveys and results concerning the endorsement of and opposition to renewables and nuclear power. Greenberg (2009) reports the recent preferences of US households.

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electric power source mix that includes nuclear and other alternative energy (Hartmann et al., 2013; Kato et al., 2013; Kim et al., 2013; Siegrist et al., 2014; Stoutenborough et al., 2013).[2] The extent to which this affects relative WTP is a key issue and lends support to the further investigation of consumer preferences.

Roe et al. (2001) were the first to evaluate consumers' WTP for green electricity using a choice experimental design that included a mix of fuels. The research finds that a higher level of WTP for emissions reduction stems from increased reliance on renewable resources, and a lower level of WTP for emissions reduction stems from a reliance on nuclear power (for questionnaire details, see Winneg et al., 1998). Based on this, Borchers et al. (2007) estimate the WTP for each renewable energy source such as wind, solar, farm methane, and biomass, individually, and find that solar energy is the first preference for US households, although nuclear energy was not considered.

The results of Roe et al. (2001) also suggest that US consumers' WTP varies depending on the population segment. For certain segments only, larger premiums can be obtained for emissions reduction that is accompanied by increased reliance on renewable fuels. Recent studies such as Komarek et al. (2011) and Cicia et al. (2012) investigate those who prefer each energy source in the context of market segmentation and public decision making.[3] The study for the US by Komarek et al. (2011), and that for Italy by Cicia et al. (2012), showed that consumer WTP varies according to socio-economic characteristics and environmental awareness. Yoo and Ready (2014) is the most recent paper investigating consumers' attitudes toward multiple renewable energies in Pennsylvania using choice experiments. The paper addresses preference heterogeneity concerning different renewable technologies. Nuclear energy was not included for consideration.[4]

This paper addresses consumer preference for two alternative fuels, nuclear and renewable sources, as replacements for fossil fuels. We estimate the trade-off involved in replacing fossil fuels with renewable sources and nuclear power with the aim of reducing GHG emissions. This study expands the work of Roe et al. (2001) in terms of sample size and estimation model and compares the results from four US states and Japan. This is the first comparative study of US and Japanese preferences for renewable and nuclear energy, and the first to use a choice experiment method and the same questionnaire. The trade-offs with respect to different renewable sources are dependent on local geographical characteristics (e.g., the amount of sunlight or wind), whereas the priorities for renewable sources relative to nuclear and fossil fuels are dependent on broader social or political choices. The latter are of primary interest in this study and narrow the scope of the survey. Additionally, the results of this study have policy implications concerning future decisions to adopt renewable portfolio standards and target levels. For more details on these policies, see Schmalensee (2012).

The rest of this paper is organized as follows. Section 2 explains the online stated preference survey method and the experimental design. Section 3 describes the discrete choice model used for estimation. Section 4 contains details of the estimation results and compares the WTP values of the mixture of electric energy sources. Section 5 extends the analysis to differences in respondents' characteristics, the expected acceptability for several future energy services, and several policy implications. Section 6 presents the conclusions.

2. Survey and design

Approximately 1 year after the Fukushima disaster, in February 2012, we randomly drew a sample from 4202 US households from four US states (web survey)—California, Michigan, New York, and Texas.[5] These states were chosen to reflect the diversity of circumstances and attitudes that exist across the US. The selected states differ from one another and from other areas of the country and use different electricity management systems.[6] However, the survey responses were similar in each of the four states. Thus, this study will sometimes refer to the average as the US result. For comparison, we conducted a similar survey in Japan, which randomly drew a sample of 4000 Japanese households 1 year later in February 2013 (approximately 2 years after Fukushima).[7] In contrast to some of the US states, Japanese consumers cannot choose their electricity provider and energy sources, but public interest in the ability to do so has been increasing since the Fukushima nuclear crisis.[8]

The respondent demographic profiles are presented in Table 1. No remarkable differences are observed between the four US states and Japanese households with respect to age. However, the percentage of female respondents in the US and Japan is in the range of 55% to 67% (US) and 50% (Japan), respectively. Additionally, there are a greater number of respondents with no bachelor's degree and lower household income in the Michigan state sample. There are differences in monthly electricity expenses between the US and Japan. Over half of US respondents pay at least $100 for electricity each month, whereas many Japanese

[2] Kato et al. (2013) report the negative shift of attitudes toward the advantages and disadvantages of hosting nuclear power plants by comparing local citizens' response data from 2010 and 2011. The authors explain change in consumers' attitudes and safety perceptions concerning nuclear power plants based on public sector knowledge and information (Stoutenborough et al., 2013) and the perception of risk and emotional fear (Hartmann et al., 2013; Siegrist et al., 2014). For a review of changes in consumers' attitudes toward the mixture of electric sources, see Kim et al. (2013). The authors examine the effect of the Fukushima disaster on global public acceptance of nuclear energy using extensive Global Snap Poll data, which was conducted by WIN–Gallup International in 42 countries.

[3] Komarek et al. (2011) compare different preferences for campus energy strategies with respect to fuel portfolios including nuclear power among three types of members of a large university campus community in the US. Cicia et al. (2012) estimate preferences for wind, solar, biomass, and nuclear energy using a latent class model in Italy. The authors utilize choice experiments to investigate the WTP for different shares and types of renewable energy sources.

[4] Shin et al. (2014) is another recent study that investigates consumers' preferences concerning renewable policy using choice data. The authors focus on specific attributes of the renewable portfolio standard policy such as employment, length of electricity shortage, and damage to forest areas in Korea.

[5] The US sample was randomly drawn from the panel. Participants were aged between 18 and 79 years and pre-recruited by the US research company, Lightspeed GMI (http://www.lightspeedgmi.com/). From a total of 11,740 individuals who had visited the survey site, 4637 questionnaires were submitted (a gross response rate of 39.5%). Of those, 435 were unusable because of unreasonably rapid response times. This led to a net response rate of 35.8%. This observed response rate was higher than the traditional mail survey reported by previous studies (cf. 24% (Mannesto and Loomis, 1991), 30% (Bateman et al., 1997)). For the definition and discussion of response rates for web-based surveys, see Fleming and Bowden (2009) and Morrison et al. (2013).

[6] California is in the west, Michigan the mid-west, New York the northeast, and Texas the south. Texas has by far the greatest amount of competition at both wholesale and retail levels (where customers can choose from competing power suppliers), followed by New York, which has substantially less retail competition for residential customers. California is next and has substantial wholesale competition but almost no retail competition for residences, followed by Michigan, which has limited power supply options.

[7] The Japanese sample was randomly drawn from the panel aged between 20 and 79 years and pre-recruited by the Japanese Internet research company, MyVoice (http://www.myvoice.co.jp/). From a total of 5289 individuals who had visited the survey site, 4673 questionnaires were submitted (a gross response rate of 88.4%), of which 673 were unusable because of unreasonably rapid response times. This led to a net response rate of 75.6%.

[8] With the rapid growth of the application of web-based surveys in stated preference studies, the sample representativeness and hypothetical bias of Internet users are examined by recent literature. Although there are some mixed results in recent studies on survey mode effect on WTP, several studies found Internet-based CV surveys to provide similar results to telephone surveys (Berrens et al., 2003; Li et al., 2009), traditional mail surveys (Banzhaf et al., 2006; Fleming and Bowden, 2009), and face-to-face surveys (Nielsen, 2011). In a choice experiment study, Olsen (2009) reported no significant differences in the unconditional WTP estimates in spite of differences in demographics between Internet and traditional mail survey modes. Olsen also found that Internet surveys have an advantage over traditional mail surveys in terms of receiving valid replies, leading to higher effective response rates. These findings suggest that the Internet has the potential to become a valuable tool for non-market valuation. Mozumder et al. (2011), which is a recent study using an online sample in a context of energy policy, reported WTP highly adjusted for sampling bias and hypothetical bias. For a very recent and comprehensive study, see Meyerhoff et al. (2014), which explores the effects of respondent and survey characteristics and Internet survey mode effects through a meta-study based on datasets from previous stated preference studies including choice experiments.

Table 1
Summary statistics of sample respondents.

Region	California	Michigan	New York	Texas	Japan
Number of participants in sample	1022	1070	1021	1089	4000
Age (mean)	44	48	49	50	46
Female	55%	67%	62%	63%	50%
Education					
High school graduate or more	99%	99%	99%	98%	98%
Bachelor's degree or more	48%	33%	47%	40%	45%
Annual household income (mean)[a]	$67,436	$54,640	$70,994	$57,989	$57,071
Under $30,000	23%	26%	19%	26%	20%
Between $30,000 and $50,000	18%	27%	19%	24%	29%
Between $50,000 and $70,000	18%	20%	20%	21%	21%
Between $70,000 and $100,000	21%	16%	19%	17%	19%
Between $100,000 and $150,000	14%	8%	15%	9%	7%
Over 150,000	6%	2%	8%	3%	2%
Monthly electricity bill (mean)[a]	$101	$105	$118	$141	$96
Household structure					
1: Single	33%	25%	29%	27%	14%
2: Couple	19%	22%	20%	25%	22%
3: Married or single parent and unmarried child	35%	42%	39%	38%	41%
4: Two adult generations under one roof	9%	8%	8%	8%	8%
5: Three adult generations under one roof	2%	2%	2%	2%	8%
6: Other	3%	1%	2%	1%	6%
Residential type					
1: Owned house	53%	73%	65%	70%	53%
2: Owned townhouse, condominium, or apartment	7%	5%	9%	2%	15%
3: Leased house	9%	6%	4%	8%	3%
4: Leased townhouse, condominium, or apartment	21%	12%	17%	15%	25%
5: Dormitory or corporate housing	0%	0%	1%	0%	3%
6: Other	9%	5%	5%	4%	1%

[a] 1 USD = 100 JPY.

respondents pay less than $100 per month. Despite a lower monthly electricity bill, household size is relatively larger in Japan than in the US. With respect to residential type, the percentage of home owners is high in Michigan, New York, and Texas.[9]

The questionnaire surveyed the current electricity usage of respondents and their perceptions of certain alternative fuels. The questionnaire posed several hypothetical electricity choice situations. The respondents received a small remuneration for completing the questionnaire.

We considered the attributes of electricity service using the choice experiment method. Our focus was on consumer preferences for GHG emissions reduction and two alternative fuels, nuclear and renewable, which would replace fossil fuels. After conducting several pretests, we determined the alternatives, attributes, and attribute levels, shown in Table 2.[10]

The attributes of the choice experiment are (1) the monthly electricity bill, (2) air emissions, and (3) the fuel mix (the portfolio of different electricity sources). We determined these attributes by referring to the work of Roe et al. (2001). This paper examines the trade-off between renewables and nuclear power as alternatives to fossil fuels; we determined the level of "nuclear" and "renewable" as independent, and the level of "hydroelectric" as fixed. After excluding these sources, the remaining ratio is the level of "fossil fuels." Therefore, a 1% increase in the fuel mix from renewable sources is accompanied by a 1% decrease in fossil fuels and vice versa. Similarly, a 1% increase in the fuel mix from nuclear power is accompanied by a 1% decrease in fossil fuels. Because there are two different types of hydroelectric plants—small- or

Table 2
Electricity service attributes and levels used in the choice experiment.

Attribute		Levels
Monthly bill[a]		$90, $100, $110, $120 for US respondents 7000 JPY, 8000 JPY, 9000 JPY, 10,000 JPY for Japanese respondents
Air emission (Nox, SO2, CO2) —fraction of regional average		No reduction, 20% lower, 40% lower, 60% lower
Fuel mix —ratio of energy generation	Fossil fuels (coal, oil, gas)	(Display the remaining %)
	Nuclear[b]	0%, 10%, 20%, 30%
	Renewable[c] (solar, wind, biomass, geothermal, etc.)	0%, 10%, 20%, 30%
	Hydroelectric	(10%, fixed)[d]

[a] With advisory note for respondents "*Monthly bill is for a consumer using 1000 kilowatt hours (kWh) per month. Actual bill will vary according to how much electricity you use*" in the questionnaire. In this survey, US respondents' actual monthly average bill is between $100 and $125, while Japanese respondents' actual monthly average bill is between $75 and $100. We determined this attribute level for each country according to their actual monthly bill.

[b] A 1% increase in fuel mix from nuclear power is accompanied by a 1% decrease in fossil fuels, and vice versa.

[c] A 1% increase in fuel mix from renewable resources is accompanied by a 1% decrease in fossil fuels, and vice versa.

[d] To focus on the tradeoff between renewables and nuclear power as alternatives to fossil fuels, we determined the level of "nuclear" and "renewable" as independent and the level of "hydroelectric" as fixed. We determined these attributes by referring to the work of Roe et al. (2001).

[9] Table A in the Appendix presents similar socio-demographic data from the US Census Bureau (2010) and the Statistics Bureau of Japan (2010). While there is no remarkable difference in age in both countries, the US samples are overrepresented by females. In general, the survey respondents are more highly educated than the population. Concerning the distribution of income, the composition of income level is comparable to that of the population. Olsen (2009), which examines the mode effect comparing Internet and traditional mail surveys, found no significant differences in the unconditional WTP estimates although differences are observed in the demographics.

[10] Current electricity generation by fuel is denoted as the following combination of nuclear, renewables without hydroelectric, hydroelectric, and fossil fuels: 19%, 5.4%, 6.7%, 68.9% in the US, respectively; 9.3%, 15%, 13.7%, 62% in California; 25.9%, 3.5%, 0.4%, 70.2% in Michigan; 30%, 3.8%, 17.9%, 48.3% in New York; and 8.9%, 7.9%, 0.1%, 83% in Texas in 2012 (EIA, 2014b). In Japan, 28.8%, 1.1%, 8.5%, 61.7% in 2010, and 1.7%, 1.6%, 8.4%, 88.3% in 2012 (FEPC, 2013).

medium-scale, which are classified into renewable sources, and large-scale plants such as dams, which are not sustainable—we fixed the level of hydroelectric power generation at 10% to reflect the current status.

The questionnaire contained information required by the respondents to answer questions including a description of the various energy sources used for the choice experiment. This information is presented in Table 3. After the explanations, respondents were asked to choose their preferred option from two alternatives, which denote different hypothetical electricity services. Table 4 shows an example of one of the choice sets provided in the questionnaire. All respondents were asked the same eight questions.

3. Model specification

The response data collected from the survey were statistically analyzed using a random parameter logit (RPL) model, which has greater flexibility than a conditional logit (CL) model by assuming stochastic variation in the preference intensity. For example, the preference for a specific energy source varied depending on the respondent. The RPL model allows for random taste variation (McFadden and Train, 2000). The RPL model is based on the random utility theory that assumes that utilities vary at random. A utility function involving a defined term V and a random term ε is given by:

$$U_i = V_i(x_i,\ m_i) + \varepsilon_i, \tag{1}$$

Table 3
The descriptions of each energy source.

Category	Source	Description
Renewable	Solar power	Light energy from the sun is converted into electricity by solar panels. Solar energy has no environmental impact. The output varies depending on the amount of solar radiation (e.g., during cloudy and rainy weather).
	Wind power	Rotational kinetic energy generated from windmill rotation is transmitted to power plants and converted to electricity. The conversion of airflow into energy results has no environmental impact. Production varies depending on wind levels, but 24-hour output is possible.
	Biomass	Heat generated from burning wood, garbage, dead animals, and waste is converted into electricity. Carbon dioxide produced by burning resources is absorbed in the resource growing process. Thus, there is no environmental impact. Output can be controlled.
	Geothermal heat	Steam power generated by pumping hot water deep within the earth is used to rotate turbines and generate electricity. Japan is a volcanic country and rich in geothermal energy. This energy source is not influenced by weather or time of day and has the potential to provide a long-term steady supply of energy.
	Small/medium hydro-energy	Small and medium-sized (under 1000 kw) hydro-energy plants generate electricity from the flow and vertical interval of rivers and canals. Unlike large-scale facilities, natural landscapes are utilized and the construction of large-scale dams is not necessary.
Exhaustible	Thermal energy (Fossil fuels)	Electricity is generated by burning fossil fuels (exhaustible resources) such as petroleum, coal, and natural gas. Carbon dioxide is released in the burning process and has significant environmental impact. Output is controllable and a steady supply of electricity is possible.
	Nuclear power	The heat energy released by nuclear fission of uranium is used to heat water and generate steam. The electricity is produced by steam power that rotates a steam turbine. Carbon dioxide is not released in the process, but a high level of radioactive materials is produced as waste.

Table 4
An example of one of the choice sets provided in the questionnaire.

		Electricity 1	Electricity 2
Monthly bill[a,b]		\$110	\$90
Air emission (Nox, SO2, CO2) —fraction of regional average		60% lower	40% lower
Fuel mix —ratio of energy generation	Fossil fuels (coal, oil, gas)	50%	70%
	Nuclear	10%	10%
	Renewable (solar, wind, biomass, geothermal, etc.)	30%	10%
	Hydroelectric	10%	10%

[a] Monthly bill is for a consumer using 1000 kilowatt hours (kWh) per month. Actual bill varies according to how much electricity is used.
[b] Minimum contract length: 2 years.

where x_i is an attribute vector of an alternative i, and m_i is a monetary attribute, which is a monthly electricity bill in this study.

In linear-in-parameter form, the utility function can be written as follows.

$$V_{nit} = \beta_n{}' x_{it} + \gamma' m_{it}, \tag{2}$$

where x_{it} and m_{it} denote observable variables, β_n denotes random parameter vectors, and γ denotes a fixed parameter set as a numeraire. Subscript n represents distinctive parameters for each individual, and subscript t represents choice situations. Thus, V_{nit} denotes the conditional utility of respondent n choosing alternative energy service i in choice situation t.

Assuming that parameter β_n is distributed with density function $f(\beta_n)$ (Louviere et al., 2000; Train, 2003), the model specification allows for repeat choices by each respondent such that the coefficients vary according to the respondent but are constant over each respondent's choice situation. The logit probability of respondent n choosing alternative energy service i in choice situation t is expressed as

$$L_{nit}(\beta_n) = \prod_{t=1}^{T} \left[\exp(V_{nit}(\beta_n)) / \sum_{j=1}^{J} \exp(V_{njt}(\beta_n)) \right], \tag{3}$$

which is the product of normal logit formulas given parameter β_n, the observable portion of utility function V_{nit}, and alternatives j = 1, …, J (J = 2 *in this study*) in choice situations t = 1, …, T (T = 8 *in this study*). Therefore, choice probability is a weighted average of logit probability $L_{nit}(\beta_n)$ evaluated at parameter β_n with density function $f(\beta_n)$, which is written as

$$P_{nit} = \int L_{nit}(\beta_n) f(\beta_n) d\beta_n. \tag{4}$$

Accordingly, we demonstrate variety in the parameters at the individual level using the maximum simulated likelihood (MSL) method for estimation with a set of 100 Halton draws.[11] We estimate formula (2) and derive WTP values for each attribute using this formula. Each respondent completed eight questions in the choice experiment, the data formed a panel, and we applied a standard random effect estimation.

A total differentiation of formula (2) gives:

$$dV_{nit} = \frac{\partial V_{nit}}{\partial x_{kit}} dx_{kit} + dm_{it}\ , \tag{5}$$

[11] Louviere et al. (2000) suggested that 100 replications are sufficient for a typical problem involving five alternatives, 1000 observations, and up to 10 attributes (see also Revelt and Train, 1998). The adoption of the Halton sequence draw is an important issue (Halton, 1960). Bhat (2001) found that 100 Halton sequence draws are efficient for simulating an ML model with over 1000 random draws.

Table 5
Respondents' perception.

Region[a]	California (2012)	Michigan (2012)	New York (2012)	Texas (2012)	Japan (2013)[b]
Number of samples	1022	1070	1021	1089	4000
Respondents' interest in GHG emissions reductions					
"The government should aggressively work on reducing the emission of greenhouse gases to mitigate climate change."					
—*Totally agree, Somewhat agree* (GHG = 1 in Table 10 estimation model)	68.2%	59.1%	69.0%	60.7%	59.3%
—*Neither* (GHG = 0 in Table 10 estimation model)	19.6%	25.5%	21.2%	22.7%	32.8%
—*Totally disagree, Somewhat disagree* (GHG = 0 in Table 10 estimation model)	12.2%	15.4%	9.9%	16.6%	8.0%
Respondents' awareness after Fukushima crisis					
"My perception toward nuclear power has changed since the nuclear accident at the Fukushima nuclear power plants in Japan on March 11, 2011."					
—*Totally agree, Somewhat agree* (Change = 1 in Table 10 estimation model)	39.9%	34.2%	40.4%	34.0%	64.6%
—*Neither* (Change = 0 in Table 10 estimation model)	34.1%	38.3%	34.4%	35.9%	25.7%
—*Totally disagree, Somewhat disagree* (Change = 0 in Table 10 estimation model)	26.0%	27.5%	25.3%	30.1%	9.7%
Respondents' view on the future of nuclear power in their country					
—*New plants should be built as part of an aggressive program of expansion.*	15.4%	10.1%	12.2%	12.7%	2.6%
—*New plants should be built, but cautiously.*	35.2%	39.6%	36.1%	40.6%	10.6%
—*The current situation should be maintained.*	17.0%	20.0%	17.5%	17.0%	16.9%
—*Current nuclear power plants should be demolished in the future.*	8.8%	5.6%	9.1%	6.1%	46.3%
—*Current nuclear power plants should be immediately demolished.*	4.9%	2.1%	4.8%	4.4%	16.7%
—*No idea.*	18.7%	22.5%	20.2%	19.3%	7.0%
The ratio of the respondents who think the following renewable sources should be widely implemented in the future.[c]					
—*Solar power generation at home* (Placing a solar panel on the roof of a house)	85.1%	75.1%	80.1%	79.2%	78.2%
—*Mega-solar power generation* (Setting large-scale solar panels in open country)	76.9%	69.0%	72.9%	73.0%	77.6%
—*Wind power generation*	76.6%	79.2%	79.5%	78.8%	70.4%
—*Geothermal power generation*	68.0%	64.3%	66.1%	65.2%	78.8%

[a] US survey was conducted in 2012. All states surveyed have nuclear plants.
[b] The survey in Japan was conducted in 2013, a year after the US survey.
[c] The sum of the ratio of respondents who replied "totally agree" to those who replied "somewhat agree."

where subscript *ki* denotes attribute *k* of alternative *i*. When the utility level does not change ($dV = 0$) and attributes other than the said attribute are invariable ($dx_{kit} = 0$ *for all* $k \neq l$), the following marginal WTP is obtained.

$$\mathrm{MWTP}_l = dm_{it}/dx_{lit} = -\beta_l/\gamma \,. \quad (6)$$

4. Results and discussion

4.1. Respondents' perceptions

Table 5 shows respondents' perceptions with respect to electricity. We asked the respondents to rate their interest in GHG emissions reduction. A total of 60% to 70% of the respondents show a positive preference for government action to mitigate the risk of global warming. The percentage of respondents interested in GHG emissions reduction is 10% higher in California and New York than in the other jurisdictions.

The respondents were asked whether their perception of nuclear power had changed since the March 11, 2011 accident at the Fukushima nuclear power plant in Japan. Table 5 shows that 65% of the Japanese respondents and 30% to 40% of the US respondents had altered their perceptions since the incident. Table 5 further describes respondent preferences for nuclear plants. Only 13% of Japanese respondents supported the construction of new nuclear power plants. Contrastingly, one out of two respondents in each of the four states favored building nuclear power plants.[12]

Finally, a large majority in the four US states and the Japanese respondents endorsed renewable energy sources. Solar power is preferred by the respondents from both countries (approximately 80% in both countries), and wind power is the second most preferred source of energy in the US. This finding is consistent with previous US social surveys (Borchers et al., 2007; Greenberg, 2009). Geothermal power is the second most preferred source of power among the Japanese respondents.

4.2. Estimation results

Table 6 displays the estimation results for the four US states and Japan. The number of observations in California, Michigan, New York,

[12] Although Table 5 mentions that a number of respondents had altered their perceptions since the incident, the directions of the changes were not specified. There can be both positive and negative alterations in theory. The questionnaire cannot clearly show the direction of the changes; however, the following facts imply that there is a tendency among the respondents to change their perceptions to negative. First, among the respondents who prefer to demolish nuclear power plants, the percentages of those who had changed their perception are 61.4% (California), 59% (Michigan), 66.2% (New York), 64.9% (Texas), and 78.6% (Japan): the majority. Additionally, among those who prefer to build new nuclear power plants, the percentages of the respondents who had changed their perception are 37.5% (California), 29.3% (Michigan), 32.8% (New York), 27.1% (Texas), and 39.7% (Japan): the minority. Furthermore, these tendencies are confirmed by the results displayed in Table 10, in which the estimates of the interaction term "nuclear change" are significantly negative in all areas. This implies that the respondents had changed their perception to negative *on average*.

Table 6
Estimation result: Four US states and Japan.

	US respondents												Japan		
	California			Michigan			New York			Texas					
	Coeff.	s.e.	WTP ($)	Coeff.	s.e.	WTP ($)	Coeff.	s.e.	WTP ($)	Coeff.	s.e.	WTP ($)	Coeff.	s.e.	WTP ($)[a]
Mean of fixed parameter															
Monthly bill (US$)	−0.047***	0.002		−0.057***	0.002		−0.045***	0.002		−0.050***	0.002		−0.073***	0.001	
Mean of random parameter															
GHG emissions reduction (%)	0.015***	0.001	0.32	0.015***	0.001	0.27	0.015***	0.001	0.34	0.015***	0.001	0.31	0.019***	0.001	0.26
Nuclear (%)	−0.005***	0.002	−0.11	−0.001	0.002	−0.02	−0.009***	0.002	−0.19	−0.005**	0.002	−0.09	−0.053***	0.002	−0.72
Renewable (%)	0.034***	0.002	0.72	0.039***	0.002	0.69	0.033***	0.002	0.74	0.034***	0.002	0.69	0.023***	0.001	0.31
Standard deviation of random parameters															
GHG emission reduction (%)	0.008***	0.003		0.000	0.003		0.000	0.003		0.001	0.004		0.005**	0.002	
Nuclear (%)	0.041***	0.003		0.039***	0.002		0.045***	0.003		0.046***	0.003		0.075***	0.002	
Renewable (%)	0.031***	0.003		0.037***	0.003		0.030***	0.003		0.035***	0.003		0.000	0.003	
Number of observations	8176			8560			8168			8712			32,000		
McFadden Psedo R-squared	0.1523			0.1911			0.1489			0.1632			0.2441		
Log likelihood function	−4803.8			−4799.6			−4818.5			−5053.1			−16,765.7		

*** denotes 1% significance, and ** denotes 5% significance.
[a] 1USD = 100 JPY.

Texas, and Japan is 8176, 8560, 8168, 8712, and 32,000 (number of respondents × 8 questions), respectively. The McFadden R^2 values are 0.15 (California), 0.19 (Michigan), 0.15 (New York), 0.16 (Texas), and 0.24 (Japan), all of which are sufficiently high for a discrete choice model. We assume that the parameters are distributed normally and the mean and standard deviation values are reported, except for a monthly electricity bill that is set as a numeraire.

First, the parameters of a monthly electricity bill are negative and statistically significant in every area. All random parameters, except for nuclear power in Michigan, are statistically significant. For the California, New York, Texas, and Japanese respondents, the statistical estimates of mean represent monthly electricity bill (−), GHG emissions reduction (+), nuclear (−), and renewable energy (+). Note that the symbols in the parentheses are the signs for each estimate. Over half of the standard deviations of random parameters are highly significant, which means that it is appropriate to consider that the parameters are random.

The parameters for a decrease in GHG emissions are positive. Therefore, the US and Japanese respondents have a positive preference for GHG emissions reduction. The parameters for an increase in the proportion of nuclear power in the fuel mix are negative, which implies that the average respondent has a negative preference for an increase in nuclear power. Similarly, the average respondent has a positive preference for an increase in renewable power.

Table 6 also summarizes the WTP values, which are derived from subtracting the parameter of the attribute divided by that of the monthly electricity bill as shown in formula (6). The results show that US respondents would be willing to pay an additional $0.27 to $0.34 on a monthly basis for the service with a 1% emissions reduction. They would also be willing to pay an additional $0.69 to $0.74 per month for a 1% increase in renewable power. With respect to nuclear power in the fuel mix, the WTP for a 1% decrease in nuclear power is $0.19 per month in New York and approximately $0.10 per month in California and Texas, whereas Michigan respondents have no WTP for a change in nuclear power.

In comparison with US respondents, the Japanese respondents would be willing to pay an additional $0.26 on a monthly basis for the service with a 1% emissions reduction, which is slightly lower than the result for the US. They would also be willing to pay an additional $0.31 per month for a 1% increase in renewable power, which is approximately half of the WTP in the US. Moreover, the Japanese WTP for a 1% decrease in nuclear power is $0.72 per month, which is substantially larger than that of the US. This fact implies that the Japanese are strongly opposed to nuclear power (see Table 5).

Table 7 presents average WTP for a change in fuel mix and lowered emissions and the result of Roe et al. (2001). For example, interpreting the top-left value in Table 7, the US average respondent is willing to pay an additional $0.31 on a monthly basis for a 1% decrease in GHG emissions. Similarly, they would be willing to pay $0.71 per month for a 1% increase in renewable fuel accompanied by a 1% decrease in fossil fuels and $0.11 per month for a 1% decrease in nuclear fuel accompanied by a 1% increase in fossil fuels. Comparing the four US states, these WTP values are consistent with the US household income levels shown in Table 1. That is, the higher the income level, the higher the WTP they exhibit. Because the average monthly electricity bill in each area is $101 (California), $105 (Michigan), $118 (New York), $141 (Texas), and $96 (Japan), as shown in Table 1, the WTP values for a 1% decrease in GHG emissions reported in Table 7 are modest, amounting to approximately 0.2% to 0.3% of the monthly electricity bill. Roe et al. (2001), who surveyed US consumers' WTP a decade ago, reported that the WTP for a 1% decrease in GHG emissions is $0.26 per month. Therefore, US consumer preference for GHG emissions reduction may have increased modestly.

Roe et al. (2001) also reported the WTP values for a 1% decrease in GHG emissions with a 1% increase in renewable fuels and a 1% decrease in GHG emissions with a 1% increase in nuclear fuels. For a comparison with the results of Roe et al. (2001), we calculate the same WTP values using the estimates in this study. The values shown in the right two columns of Table 7 are obtained by simply summing the related values. We assume that interaction among marginal preferences for variations, such as an increase in renewable power and GHG emissions reduction, is at or close to zero within a limited extent. The values show that the average US respondent would be willing to pay $12.21 per year for a 1% decrease in GHG emissions with a 1% increase in renewable fuels and $2.43 per year for a 1% decrease in GHG emissions with a 1% increase in nuclear fuels. The previous study reported that the average US respondent would be willing to pay $0.11 to $14.22 for a 1% decrease in GHG emissions with a 1% increase in renewable fuels, and $1.03 to $14.43 for a 1% decrease in GHG emissions with a 1% increase in nuclear fuels. The recent declining WTP for emissions reduction using nuclear power represents a significant difference in preferences for renewable energy and nuclear power. Japanese respondents would be willing to pay $6.90 per year for a 1% decrease in GHG emissions with a 1% increase in renewable fuels, which is lower than the result in the US, and −$5.48 per year for a 1% decrease in GHG emissions with a 1% increase in nuclear fuels, which is opposite in sign to the US. This latter finding implies that Japanese consumers are willing to resist an increase in the proportion of nuclear power although a certain amount of GHG emissions could be reduced.

Table 7
Average willingness to pay for changed fuel mix and lowered emission.

	For 1% decrease in GHG emissions ($/month)	For 1% increase in renewable fuel and 1% decrease in fossil fuels ($/month)	For 1% increase in nuclear fuel and 1% decrease in fossil fuels ($/month)	1% decrease in GHG emission 1% increase in renewable fuel 1% decrease in fossil fuels[c] ($/year)	1% decrease in GHG emissions 1% increase in nuclear fuel 1% decrease in fossil fuels[c] ($/year)
United States[a] *this study 2012	0.31	0.71	−0.11	12.21	2.43
—California	0.32	0.72	−0.11	12.48	2.45
—Michigan	0.27	0.69	−0.02	11.43	2.93
—New York	0.34	0.74	−0.19	12.97	1.78
—Texas	0.31	0.69	−0.09	11.98	2.55
Japan *this study 2013	0.26	0.31	−0.72	6.90	−5.48
United States[b] *Roe et al., 2001	0.03–0.47			0.11–14.22	1.03–14.43

[a] The US average values of the four states.
[b] Roe et al. (2001) found significant differences across regions, different segments, such as income level and education, and environmental organization affiliation. The range of results is shown here.
[c] This WTP value is obtained by summing related values, assuming that interaction among marginal preferences for variations, such as increase in renewable power and GHG emission reduction are zero or little different from zero, within a limited extent.

Previous studies concerning the WTP for renewable energy and green electricity in the US and Japan are listed in Table 8 (for consistency, all figures have been converted to show the monthly value of a 1% increase in renewables). Many of these studies have analyzed consumer WTP for renewable energy using contingent valuation (CV) methods, which is a method often used to estimate the economic value of non-market goods and services (e.g., Champ and Bishop, 2001; Hite et al., 2008; Mozumder et al., 2011; Nomura and Akai, 2004; Whitehead and Cherry, 2007). Recent studies have used a choice experiment method, which is currently the most advanced methodology, and these studies analyze preference heterogeneity (Borchers et al., 2007; Yoo and Ready, 2014). The first four studies in Table 8 did not specify the percent increase in renewable energy. Respondents evaluated a general investment program promoting green energy with accompanying improvements in air quality, visibility, natural resources, and human health. Thus, US consumers' monthly average willingness to pay for green energy promotion ranges from $1 to $12.62. In recent decades, several studies estimated WTP for an increase in renewable energy. According to these studies, the monthly WTP for a 1% increase in renewable energy has ranged from $0.58 to $5.02, similar to the result of $0.71 in our study. Table 8 shows that US consumer preference for renewable energy has not changed significantly over the past decade. Although Japanese consumers' WTP is not within the US WTP range, it is similar to the previous results in Japan that ranged from $0.03 to $0.54. Additionally, according to the previous papers, the WTP for renewable energy correlates with consumer income, environmental concerns, and other perceptions.

5. Further discussions

5.1. Differences in respondent characteristics

To determine differences in WTP by income, residential area, and environmental awareness we estimate an additional model, in which the utility function can be written as follows.

$$V_{nit} = \beta_n{}' x_{it} + \gamma' m_{it} + \delta' x_{it} D_n + \omega' m_{it} H_n. \tag{7}$$

The third and fourth are additional interaction terms. D_n and H_n denote individual dummy variables as shown in Table 9, and δ and ω denote fixed parameters as mean–shift parameters. Table 10 displays the estimation results using an RPL model with interaction terms between respondent characteristics and attribute levels that show average differences by respondents' perceptions. The McFadden R^2 values are 0.16 (California), 0.19 (Michigan), 0.16 (New York), 0.17 (Texas), and 0.24 (Japan), all of which are sufficiently high for a discrete choice model.

The interaction terms that we added in this model are as follows. First, the interaction term “high-income interaction” allows for shifting the mean of the monthly bill parameter for high-income households by

Table 8
Recent studies on WTP for general renewable energy in the US and Japan.

Survey time	WTP (US$/month)	Survey area	Object analyzed	Author
N.A.	4.91–8.42	Wisconsin	WTP for wind-generated electricity[a]	Champ and Bishop (2001)
1999	1.00	Texas	WTP for supporting utility investments in renewables[a]	Zarnikau (2003)
2002	4.24–12.62	North Carolina	WTP for green energy program[a]	Whitehead and Cherry (2007)
2000	17.00	Japan	WTP for promoting green electricity[a]	Nomura and Akai (2004)
2005	0.65	Alabama	WTP for 1% of electric from biopower[b]	Hite et al. (2008)
2006	0.58–1.33	Delaware	WTP for 1% increase in general renewable energy[b,c]	Borchers et al. (2007)
2010	0.58–0.93	New Mexico	WTP for an energy program providing 1% share of general renewable energy[b]	Mozumder et al. (2011)
2011	4.61–5.02	Pennsylvania	WTP for a program promoting renewable electricity production[d]	Yoo and Ready (2014)
2012	0.71	United States (4 states)	WTP for 1% increase in renewable fuel and 1% decrease in fossil fuels	*This study*
2000	0.19	Japan	WTP for 1% of green electricity[e]	Nomura (2009)
2005	0.03–0.13	Japan	WTP for 1% of green electricity[e]	ANRE (2005)
2005	0.54	Japan	WTP for 1% of green electricity[e]	Ise (2006)
2013	0.31	Japan	WTP for 1% increase in renewable fuel and 1% decrease in fossil fuels	*This study*

N.A. = not available.
[a] Percent increase in renewable energy was not specified. Respondents evaluated a general investment program promoting green energy with accompanying improvements in air quality, visibility, natural resources, and human health. The value in the table represents monthly WTP for this program.
[b] The monthly value of a 10% increase in renewables was estimated. In the table, the original value has been converted to show the monthly value of a 1% increase for consistency.
[c] We calculate an average value of WTP for general green energy, solar, wind, farm methane, and biomass using the original results.
[d] We calculate an average value of WTP for solar, wind, biomass, and other renewables using the original results.
[e] The monthly value of a 100% of green electricity was estimated. In the table, the original value has been converted to show the monthly value of a 1% increase for consistency.

multiplying using a high-income dummy. This parameter indicates the difference in preference between respondents with an income level higher than the national median and respondents with an income level lower than the national median. Second, the interaction term "GHG interaction" is for shifting the mean of the GHG emissions reduction parameter by multiplying using a GHG interest dummy. This parameter indicates that the difference in preference between the respondents who think GHG emissions should be reduced aggressively from the respondents who think otherwise. Third, the interaction term "region interaction" shifts the mean of the nuclear parameter by multiplying by a region dummy. This term, extracting the difference caused by residential area, is added only to the Japanese model because 13 out of 47 prefectures in Japan have an active nuclear plant at this time. We consider the differences from the presence of a nuclear power plant in the neighborhood. The fourth and fifth interaction terms, "nuclear change" and "renewable change," shift the mean of the nuclear and renewable energy parameters. These parameters indicate the difference in preferences of the respondents whose perception concerning nuclear energy has changed following the Fukushima crisis from the respondents whose perceptions have not changed.

The statistically significant estimates of interaction terms are GHG interaction (+) and nuclear-change (−) in all areas. This indicates that the respondents who consider that GHG emissions should be substantially reduced have a greater positive preference for emissions reductions than the respondents who consider otherwise. Additionally, for the respondents who changed their perceptions concerning nuclear energy after the Fukushima crisis, the parameters of the increase in the proportion of nuclear power are lower. Renewable change (−) is also statistically significant in California and Japan, which implies that the change in the respondents' perception of nuclear energy after the crisis reduced the parameters of an increase in the proportion of renewable power in California and Japan. For Japanese respondents only, high-income interaction (+) is statistically significant, whereas the effects of higher income are not statistically significant for US respondents. Therefore, a higher income mitigates disutility because of decreased Japanese household income. Finally, regional interaction is not statistically significant, which implies no significant differences among residential areas in Japan. Because this result is counterintuitive, we may consider a specific regional area such as the municipal level.

Table 11 shows the average WTP for changed fuel mix and lowered emissions according to several respondent characteristics. The left two columns show the respondents who have a positive preference for government action to mitigate the risk of global warming. These respondents exhibit approximately 1.3 to two times greater WTP for emissions reductions without altering the fuel mix than other respondents. For example, the WTP values for 1% GHG reduction among respondents who consider that GHG emissions should be reduced is \$0.35 per month, which is 1.4 times higher than respondents who consider otherwise; \$0.25 in California.

The WTP values concerning an increase in nuclear fuels are particularly interesting. For the respondents who changed their perceptions concerning nuclear energy after the Fukushima crisis, the WTP values for an increase in the proportion of nuclear power are −\$0.37 (California), −\$0.13 (Michigan), −\$0.59 (New York), −\$0.48 (Texas), and −\$0.93 (Japan), which are negatively dominant. This result applies to both the US and Japan and implies stronger opposition for increases in nuclear power. However, for those who have *not* changed their perception of nuclear energy, remarkable differences are observed among US and Japanese households. The WTP for an increase in the proportion of nuclear power is not significant or is slightly positive for the US respondents who have not changed their perception after the crisis, whereas the WTP remains negative in Japan at a value of −\$0.29.

Table 9
The definitions of each dummy variable.

Variable	Definition
H	High income dummy. H = 1 if the respondents' income level is higher than the national median.
D_1	GHG interest dummy. $D_1 = 1$ if the respondents think GHG emissions should be reduced aggressively. See Table 5.
D_2	Region dummy. $D_2 = 1$ if the respondents live in the prefecture that has active nuclear power plants.
D_3	Change dummy. $D_3 = 1$ if the respondents' perception for nuclear energy has changed after the Fukushima crisis. See Table 5.

5.2. Expected acceptability for scenario variations

We calculate household acceptability with respect to four different scenarios of electricity service using our estimation results. We determine the baseline scenario with reference to the current US status. Table 12 presents the baseline scenario denoted by a combination of monthly bill, GHG emissions reduction, nuclear, renewable, hydroelectric, and fossil fuels: \$100, 4%, 19%, 5%, 10%, and 66%, respectively. According to the electricity projection for 2040 in the Annual Energy Outlook (AEO) 2014, we devise scenario 1 (\$100, 4%, 16%, 6%, 10%, and 68%) as a future standard. Comparing scenario 1, which projects a future standard energy service, with the baseline scenario, which is the current status, acceptability rates (explained below) are approximately equal with slight variance because of differences in both services. Hereafter, we consider scenario 1 as a standard and compare the acceptability rates of three other scenarios.

The US government calls for an 80% clean energy target that raises the proportion of clean energy from the current 40% to 80% by 2035. Clean energy includes nuclear, renewables, and natural gas and clean coal, which are categorized as fossil fuels. Because consumers stated their different preferences for each energy source in this study, it is reasonable to expect acceptability variations of clean energy standards (CES) by accelerated energy sources. First, we devise scenario 2 (\$120, 20% emissions reduction, 16%, 6%, 10%, 68%), which meets CES goals by promoting natural gas and clean coal energy, assuming rising costs from \$100 to \$120 per month for accelerating clean energy. Similarly, scenario 3 (\$120, 20% emissions reduction, 36%, 6%, 10%, 48%) meets CES goals with a 20% increase in nuclear energy. Scenario 4 (\$120, 20% emissions reduction, 16%, 26%, 10%, 48%) meets CES goals with a 20% increase in renewable energy.

We define acceptability rates as the ratio of choice probabilities, which are the normal logit formulas shown in earlier estimations. Given the above chosen attribute levels of each scenario, acceptability rates can be derived by calculating:

$$\begin{aligned} &\mathit{Acceptability\,rate}_i \\ &= \frac{\exp(V_i(\beta))}{\exp(V_0(\beta)) + \exp(V_i(\beta))} \Big/ \frac{\exp(V_1(\beta))}{\exp(V_0(\beta)) + \exp(V_1(\beta))}, \end{aligned} \tag{8}$$

where $i = 0, \ldots, 4$ are scenario numbers. We obtain each acceptability rate by calculating the percentage change of choice probabilities based on the future standard scenario 1.

The results are presented in Fig. 1. There are no remarkable differences among the acceptability rates of the US four states. This implies that the average US consumer has a similar preference for energy mix. Assuming 100% acceptability in the case of the standard scenario 1, acceptability rates are 58.6% to 69.3% for scenario 2, 57.5% to 62.2% for scenario 3, and 94.4% to 100.5% for scenario 4. A comparison of the three different scenarios, all of which are accompanied by an identical rise in electricity cost, shows that the acceptability rates for scenario 4 are relatively high and maintain the same levels as scenario 1, which requires no additional cost. Therefore, US consumers prefer to meet CES goals through accelerated renewable sources rather than through fossil fuel and nuclear energy use.

Table 10
Estimation result: Interaction model.

	US respondents								Japanese respondents	
	California		Michigan		New York		Texas			
	Coeff.	s.e.	Coeff.	s.e.	Coeff.	s.e.	Coeff.	s.e.	Coeff.	s.e.
Mean of parameters										
Monthly bill (US$)	−0.048***	0.002	−0.058***	0.002	−0.045***	0.002	−0.049***	0.002	−0.075***	0.001
GHG emissions reduction (%)	0.012***	0.002	0.011***	0.001	0.010***	0.002	0.013***	0.001	0.012***	0.001
Nuclear (%)	0.003	0.002	0.002	0.002	0.003	0.002	0.005**	0.002	−0.022***	0.002
Renewable (%)	0.039***	0.003	0.038***	0.003	0.034***	0.002	0.033***	0.002	0.026***	0.001
Mean of shift parameters—additional interaction term										
Monthly bill_*high income* (>median)[a]	0.001	0.003	0.002	0.004	0.000	0.003	−0.003	0.003	0.006***	0.002
GHG emissions reduction (%) _*GHG*[b]	0.005**	0.002	0.008***	0.002	0.007***	0.002	0.004**	0.004	0.012***	0.001
Nuclear (%) _*Region*[c]	–		–		–		–		0.001	0.004
Nuclear (%) _*Change*[d]	−0.020***	0.004	−0.009**	0.004	−0.030***	0.004	−0.028***	0.004	−0.048***	0.003
Renewable (%) _*Change*[d]	−0.012***	0.004	0.003	0.004	−0.003	0.004	0.005	0.004	−0.005***	0.002
S.D. of random parameters										
GHG emissions reduction (%)	0.008***	0.003	0.000	0.003	0.000	0.003	0.001	0.004	0.002	0.005
Nuclear (%)	0.040***	0.003	0.039***	0.002	0.043***	0.002	0.045***	0.002	0.071***	0.002
Renewable (%)	0.030***	0.003	0.037***	0.003	0.030***	0.003	0.035***	0.003	0.000	0.003
Number observations	8176		8560		8168		8712		32,000	
McFadden Psedo R-squared	0.1561		0.1931		0.1551		0.1677		0.2533	
Log likelihood function	−4782.5		−4787.4		−4783.8		−5026.2		−16,563.1	

*** denotes 1% significance, ** denotes 5% significance, and * denotes 10% significance.
[a] Interaction term for shifting the mean of parameter of monthly bill by multiplying by high income dummy. *High income* = 1 if the respondents' income level is higher than the national median. See Table 5.
[b] Interaction term for shifting the mean of parameter of GHG emissions reduction by multiplying by GHG interest dummy. *GHG* = 1 if the respondents think GHG emissions should be reduced aggressively. See Table 5.
[c] Interaction term for shifting the mean of parameter of nuclear by multiplying by region dummy. *Region* = 1 if the respondents live in the prefecture that has active nuclear power plants. The four US states all have active nuclear power plants.
[d] Interaction term for shifting the mean of parameter of nuclear and renewable energy by multiplying by change dummy. *Change* = 1 if the respondents' perception for nuclear energy has changed after the Fukushima crisis. See Table 5.

Table 11
Willingness to pay for changed fuel mix and lowered emission: By segments.

	Respondents' interest in GHG emission reduction		Respondents' awareness after Fukushima crisis	
	For 1% decrease in GHG emissions ($/month)		For 1% increase in nuclear fuel and 1% decrease in fossil fuels ($/month)	
	Low interest in GHG[a]	High interest in GHG[b]	No change in attitudes[c]	Change in attitudes[d]
California	0.25	0.35	0.00	−0.37
Michigan	0.19	0.32	0.00	−0.13
New York	0.23	0.39	0.00	−0.59
Texas	0.27	0.34	0.10	−0.48
Japan	0.16	0.32	−0.29	−0.93

[a] The WTP estimates for the respondents who *do not think* GHG emissions should be reduced aggressively.
[b] The WTP estimates for the respondents who *think* GHG emissions should be reduced aggressively.
[c] The WTP estimates for the respondents whose perception of nuclear energy has *not changed* since the Fukushima crisis.
[d] The WTP estimates for the respondents whose perception of nuclear energy has *changed* since the Fukushima crisis.

With respect to Japanese consumers, the acceptability rates for each scenario are 50.1%, 21.3%, and 68.5%. Scenario 4 is the most preferable, which is the case in the US. Although there are no remarkable differences between the acceptability rates for scenarios 2 and 3 in the US, Japanese consumers have a strong resistance to scenario 3 and exhibit less than half the acceptability rate of the US for scenario 3. This fact reflects the sensitivity to nuclear energy sources in Japan.

5.3. Policy implications

This study focused on consumer preferences, the demand side of the market for renewable and nuclear energy. We found that consumers in four US states and in Japan are willing to pay modestly higher bills to reduce fossil fuel use and have more of their current energy consumption provided through clean renewable power. We have also found that the consumers are not willing to pay more (and in Japan, might require lower bills) for current energy consumption to be provided through additional nuclear generation (although this would also reduce fossil fuel use and GHG emissions). While this helps to establish that consumers perceive a "benefit" from an increase in renewables, policy should depend on whether the benefits exceed the costs. A cost analysis is beyond the scope of this study, but we can offer some observations that draw relationships from findings similar to those in this study to public policies concerning new generating sources for electricity.

Two common policies used to promote renewable energy are the feed-in tariff (FIT) and the renewable portfolio standard (RPS).[13] The FIT is a system in which the purchasers of generated electricity are required to purchase the output of a FIT generator at a specified price for a specified period. In Japan, for example, a FIT was established in 2012 and, during the year 2014, new contracts for photovoltaic generation for residential customers promised PV generation for 37 yen/kWh

[13] For a recent review of these policies, see Schmalensee (2012).

Table 12
Scenario variations.

	Baseline (Scenario 0) Current US status[c]	Scenario 1 2040 projection[d]	Scenario 2 Meets CES[e] using accelerated fossil fuels	Scenario 3 Meets CES[e] using accelerated nuclear (20% increase in nuclear)	Scenario 4 Meets CES[e] by accelerated renewables (20% increase in renewables)
Monthly bill	100 US$	100 US$	120 US$	120 US$	120 US$
GHG emissions reduction	4%	4%	20%	20%	20%
Nuclear	19%	16%	16%	36%	16%
Renewable[a]	5%	6%	6%	6%	26%
Hydroelectric	10%	10%	10%	10%	10%
Fossil fuels[b]	66%	68%	68%	48%	48%

[a] Without hydroelectric energy.
[b] Fossil fuels include *Natural gas* and *Clean coal*, both of which are clean energy.
[c] US Energy Information Administration "State electricity profile" (EIA, 2014a).
[d] US Energy Information Administration "Annual Energy Outlook 2014," Early Release Overview, Fig. 13 (EIA, 2014b).
[e] Clean Energy Standards. Clean Energy includes *Nuclear*, *Renewable*, *Natural gas*, and *Clean coal*.

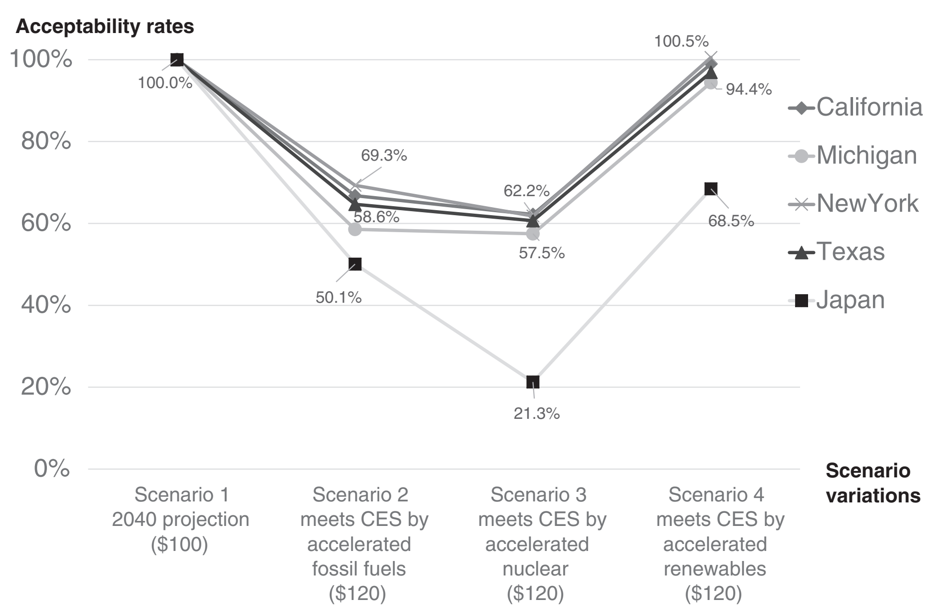

Fig. 1. Acceptability rates of energy services by accelerated source.

(or $0.37/kWh) for 10 years. Work that is similar to that in this study could be useful in helping to determine such FIT prices.

For example, we have shown that the average Japanese consumer in the sample would pay $6.90 extra per year for a 1% emission reduction by renewable power. Recall that the average monthly Japanese bill in our sample is $96 or $1152 annually. Given that the 2012 average household consumption in Japan was 4432 kWh, the 1% implies a purchase of 44.32 kWh of new renewable generation (instead of fossil-fueled generation).[14] At $6.90, the WTP per kWh is approximately $0.16 above the average price per kWh of $0.26 or $0.42. Not all of this $0.42/kWh can be used as a FIT payment to the extent that even households with PV would be required to contribute to transmission and distribution expenses. The actual FIT payment seems to be close to the amount that could be justified by our estimate.

FIT policies, if considered as policies for which the government sets the price and the market response determines quantity, are the opposite to RPS policies: the government sets a quantity renewables target and the market response determines the price paid for those renewables. The RPS is used in many of the US states, including the four in our sample. Generally, RPS mandates a percentage goal for renewable generation in the entire state. California, for example, has a target of 33% renewable generation by 2020. Then, either the regulator or the legislature may set interim, year-by-year goals until the target year is reached and the target goal accomplished. Typically, each electricity retailer in the state is assigned a share commensurate with the share of total state electricity that it provides to its customers. Competitive bidding allows the market to select the least-cost set of renewable generators within the state that will achieve the target quantity from among all qualifying sources (e.g. wind, PV, geothermal).[15]

A key issue with RPS policies is how ambitious the target goal should be, and again, studies such as this can be helpful to making or revising this quantity decision. The four states in our sample have quite different

[14] The Japanese Ministry of Economy Trade and Industry (METI) reports average Japanese household energy consumption for 2012 at 4432 kWh (http://www.enecho.meti.go.jp/category/saving_and_new/saving/general/actual/). We use this as the average consumption for our Japanese sample, which implies, at the annual sample bill of $1152, an average price of $0.2599 per kWh. This is consistent with residential electricity prices in Japan.

[15] Schmalensee (2012) is critical of many independent state-level RPS policies because a program that allows trading across the states could achieve the same amount of renewables at a lower total cost.

goals.[16] California's 33% by 2020 is the most ambitious. New York has a 30% goal by 2015, but this includes substantial hydropower (around 19%) not counted as a renewable in California. Texas has a relatively modest goal of less than 10% by 2025, but it had already exceeded this goal in 2009 largely through its extensive wind power. Michigan has a 10% target for 2015. As with FIT policies, both benefits and costs should be considered in setting these targets, and states' costs of providing renewable generation can vary greatly (e.g., some states have substantial year-round sunshine, some have substantial wind, some have adequate access to geothermal sources). Our work only speaks to the benefit side and indicates that the average household in each of the four states is willing to pay an additional $12 to annual bills that average from $1212 (California) to $1692 (Texas) for a 1% increase in renewables. For a state like Texas that has already met its RPS goal, this suggests that its electricity customers will support a strengthening of this goal. For the other three states, we can say that customers support the progress made at the time of our survey and would support further progress (how much depends upon costs).

6. Conclusion

This study conducted a choice experiment based on a web questionnaire survey. We investigated US and Japanese consumer preferences for two alternative fuels, nuclear and renewable sources, as energy sources that have potential to reduce GHG emissions. Additionally, the study discusses the differences in preferences according to respondents' characteristics.

The primary findings of this paper are as follows. First, the results for the US are similar across the four states concerning consumers' WTP for the reduction of air emissions. People are willing to pay approximately $0.30 per month for a 1% decrease in GHG emissions. Second, the average consumer expresses a negative preference for increases in nuclear power in the fuel mix in both countries. In comparison with the US results from the last decade, WTP for emissions reduction with the use of nuclear power has been decreasing, which has caused a greater trade-off between renewable energy and nuclear power. Additionally, Japanese consumers have a stronger aversion to nuclear energy than US consumers. Third, US and Japanese consumers have a higher acceptance for emissions reduction with the use of renewable sources. Moreover, WTP varies depending on consumer characteristics such as interest and awareness. For example, the US and Japanese consumers who changed their perceptions concerning the use of nuclear energy after the Fukushima crisis have a higher opposition to nuclear energy in both countries. Approximately 60% of the US respondents did not change their perception subsequent to the crisis and have no preference for variation in nuclear power. Conversely, Japanese consumers oppose an increase in nuclear power in the fuel mix regardless of whether or not their perceptions have changed. The result of scenario analysis indicates that US and Japanese consumers prefer to meet CES goals through accelerated renewable sources rather than through fossil fuel and nuclear energy use. Finally, we have shown that results like those found in this study can be useful in helping to set parameters for renewable energy policies like FIT rates and RPS stringency.

To consider the variable characteristics of respondents, further study must analyze the data using a latent class model to quantify household preferences for different energy sources according to several classes. Cost-benefit approaches to policy discussions that would include other important factors, such as power generation cost and social welfare impacts, would also be valuable.

We acknowledge that all of these results are based on data analysis of stated preferences that would benefit from confirmation using revealed preference data. Therefore, further research should investigate whether our findings are consistent with evidence from the real energy market.

[16] The US Department of Energy sponsors the DSIRE database that tracks each state's incentives for renewables and efficiency. It is available at http://www.dsireusa.org/.

Appendix A. Population characteristics

Table A
Socio-demographic data from US and Japanese census.

Region	California	Michigan	New York	Texas	United States	Japan
Age (mean) [a]	43	45	44	43	44	49
Gender (%) [a]						
Male	49.2	48.4	47.6	49.0	48.5	48.1
Female	50.8	51.6	52.4	51.0	51.5	51.9
Education (%) [a]						
High school graduate or more	80.6	87.9	84.7	79.9	85.3	80.7
Bachelor's degree or more	29.9	24.6	32.4	25.5	27.9	20.0
Annual household income (%)						
Under $25,000	20.4	25.6	23.0	23.8	23.4	11.6
Between $25,000 to $50,000	21.4	25.7	21.0	24.5	23.9	34.9
Between $50,000 to $75,000	16.9	18.4	16.6	17.8	17.9	26.2
Between $75,000 to $100,000	12.4	11.9	12.0	11.7	12.2	14.5
Between $100,000 to $150,000	14.9	11.4	14.2	12.6	12.9	9.8
Over 150,000	14.0	6.8	13.2	9.5	9.7	3.0

[a] These values are calculated based on the population 18 to 79 years.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.eneco.2015.05.002.

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