WORKING PAPER SERIES

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

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August 2014

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

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 a US consumer’s willingness to pay for a 1% decrease in greenhouse gas emissions is $0.31 per month, which is similar to results for the US a decade ago. The Japanese consumer shows a slightly lower willingness to pay of $0.23 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 respectively show a willingness to pay of $0.71 and $0.38 per month for a 1% increase in the use of renewable source energy. This study also examines WTP differences by 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.

Keywords: renewable energy, nuclear energy, choice experiment

JEL Classifications: O33, Q48, Q51

1. Introduction

Increasing awareness concerning 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 concern with the trade-offs involved in replacing fossil fuels with renewable sources and nuclear power to meet climate change goals.

Changing power sources presents 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 a decreased reliance on imported energy sources. The pursuit of renewable energy entails substantial investment costs, intermittent supply, and associated local negative externalities such as landscape change, noise, and potential harm to birds. Therefore, consumer opinion concerning the overall value of the attributes of each power source should be sought.

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 has been examined in numerous empirical studies. These studies have found that people have a preference for renewable energy (Goett et al., 2000; Menges et al., 2005; Grosche and Schoroder, 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

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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.

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 not known. The Fukushima nuclear crisis revealed evidence of change in consumer attitudes toward the electric power source mix that includes nuclear and other alternative energy (Kato et al., 2013; Stoutenborough et al., 2013; Siegrist et al., 2014; Hartmann et al., 2013; Kim 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 researchers found 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) estimated the WTP for each renewable energy source such as wind, solar, farm methane, and biomass, individually, and found 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

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[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 toward, and safety perceptions of, nuclear power plants based on public sector knowledge and information (Stoutenborough et al., 2013), and by the perception of risk and emotional fear (Siegrist et al., 2014, Hartmann et al., 2013). 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.

depending on the population segment. For certain segments only, larger premiums may be obtained for emissions reduction that is accompanied by increased reliance on renewable fuels. Recent literature, such as Komarek et al. (2011) and Cicia et al. (2012), have investigated 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 varied 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

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[3] Komarek et al. (2011) compared 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) estimated preferences for wind, solar, biomass, and nuclear energy using a latent class model in Italy. The authors utilized 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 focused on specific attributes of the renewable portfolio standard policy such as employment, length of electricity shortage, and damage to forest areas in Korea.

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 is of primary interest in this study and narrows 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 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 and the expected acceptability for several future energy services. Section 6 presents the conclusions.

2. Survey and design

Approximately one year after the Fukushima disaster, in February 2012, we randomly drew a sample from 4,202 US households from four US states (web survey)—California, Michigan, New York, and Texas. These states were chosen to reflect the diversity of circumstances and attitudes that exist across the US. The selected states each differ from one another and from other areas of the country and use different electricity management systems[5]. However, the survey responses were similar in each of the four

[5] 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.

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 4,000 Japanese households one year later, in February 2013 (approximately two years after Fukushima). 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.

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 are 55% to 67% (US) and 44%, (Japan), respectively. Additionally, there is a greater number of respondents with lower household income and no college degree 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 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 house owners is high in Michigan, New York, and Texas.

＜Insert Table 1 here＞

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[6].

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[6] Current electricity generation by fuel is denoted as the following combination of

＜Insert Table 2 here＞

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 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.

＜Insert Table 3 here＞

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nuclear, renewables without hydroelectric, hydroelectric, and fossil fuels: 19.0%, 5.4%, 6.7%, 68.9% in the US, respectively; 9.3%, 15.0%, 13.7%, 62.0% in California; 25.9%, 3.5%, 0.4%, 70.2% in Michigan; 30.0%, 3.8%, 17.9%, 48.3% in New York; and 8.9%, 7.9%, 0.1%, 83.0% 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).

＜Insert Table 4 here＞

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:

$$U_i = V_i(x_i,\ m_i) + \varepsilon_i, \qquad (1)$$

where x_i is an attribute vector of a 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.

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

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 $f(\beta_n)$ (Train 2003, Louviere et al., 2000), the model specification allows for repeat choices by each respondent, such that the coefficients vary according to 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

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

which is the product of normal logit formulas, given parameter β_n, the observable portion of utility function V_{nit} and alternatives $\mathrm{j} = 1, \ldots, \mathrm{J}$ $(\mathrm{J} = 2\ in\ this\ study)$ in choice situations $\mathrm{t} = 1, \ldots, T$ $(T = 8\ in\ this\ study)$. 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 can be written as

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

Accordingly, we can 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[7]. We estimated formula (2) and derived 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:

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

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.

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

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 have a positive preference for government action to mitigate the risk of

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[7] Louviere et al. (2000, p. 201) suggested that 100 replications are sufficient for a typical problem involving five alternatives, 1,000 observations, and up to 10 attributes (also see 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 1,000 random draws.

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 also 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.

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 (Borthers et al., 2007; Greenberg, 2009). Geothermal power is the second most preferred source of power among the Japanese respondents.

＜Insert Table 5 here＞

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, Texas, and Japan is 8,176, 8,560, 8,168, 8,712, 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, except for a monthly electricity bill that is set as a numeraire, are distributed normally and the mean and standard deviation values are reported.

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 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. It is found 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 \$0.23 on a monthly basis for the service with a 1% emissions reduction, which is slightly lower than the result for the US. They also would be willing to pay an additional \$0.38 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 \$0.64 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).

＜Insert Table 6 here＞

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), $141 (Texas), $105 (Michigan), $118 (New York), 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 2% to 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 related values. We assume that interaction among marginal preferences for variations, such as an increase in renewable power and GHG emissions reduction, are 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 $7.37 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 -$4.89 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 fact implies that Japanese consumers are willing to resist an increase in the proportion of nuclear power even though a certain amount of GHG emissions could be reduced.

＜Insert Table 7 here＞

Previous studies concerning the WTP for renewable energy and green electricity in the US 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; Whitehead and Cherry, 2007; Hite et al., 2008; Mozumder et al., 2011). Recent studies have used a choice experiment method, which is currently the most advanced methodology, and these studies analyzed preference heterogeneity (Borchers et al., 2007; Yoo and Ready, 2014). The first three 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. Japanese consumers' WTP is not within the US WTP range. Additionally, according to the previous papers, the WTP for renewable energy is correlated with consumer income, environmental concerns, and other perceptions.

＜Insert Table 8 here＞

5. Further discussions

5.1. Differences in respondent characteristics

To determine differences in WTP by income, residential area, and environmental awareness we estimate the additional model. Table 9 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 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 by a GHG interest dummy. This parameter indicates 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" is for shifting 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 for 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 10 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 higher 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 is 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 for 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 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.

＜Insert Table 9 here＞

＜Insert Table 10 here＞

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 11 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 Electricity 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:

$$Acceptability\ rate_i = \frac{\exp\left(V_i(\beta)\right)}{\exp\left(V_0(\beta)\right) + \exp\left(V_i(\beta)\right)} \Big/ \frac{\exp\left(V_1(\beta)\right)}{\exp\left(V_0(\beta)\right) + \exp\left(V_1(\beta)\right)}, \quad (7)$$

where $i = 0, \dots, 4$ 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 Figure 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.

With respect to Japanese consumers, the acceptability rates for each scenario are 56.3%, 31.0%, and 75.8%. 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 approximately half the acceptability rate of the US for scenario 3. This fact reflects the sensitivity to nuclear energy sources in Japan.

＜Insert Table 11 here＞

＜Insert Figure 1 here＞

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 $0.3 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 through 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 through 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 basically oppose an increase in nuclear power in the fuel mix regardless of whether or not their perceptions have changed. Finally, 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.

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.

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Table 1. Summary statistics of sample respondents

Region	California	Michigan	New York	Texas	Japan
Number of participants in sample	1,022	1,070	1,021	1,089	4,000
Female	55%	67%	62%	63%	44%
Age (mean)	44	48	49	50	46
Annual income (mean)[a]	\$60,000-\$65,000	\$50,000-\$55,000	\$65,000-\$70,000	\$55,000-\$60,000	\$60,000-\$65,000
With a college degree	59%	47%	59%	52%	60%
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	19
3: Married or single parent and unmarried child	35	42	39	38	43
4: Two adult generations under one roof	9	8	8	8	10
5: Three adult generations under one roof	2	2	2	2	8
6: Other	3	1	2	1	5
Residential type (%)					
1: Owned house	53	73	65	70	51
2: Owned townhouse, condominium, or apartment	7	5	9	2	16
3: Leased house	9	6	4	8	4
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] 1USD = 100 JPY

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

Attribute		**Levels**
Monthly bill[a]		\$90, \$100, \$110, \$120 for US respondents 7000JPY, 8000JPY, 9000JPY, 10000JPY 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, and geothermal etc.)	0%, 10%, 20%, 30%
	Hydroelectric	(10%, fixed)[d]

[a] With advisory note for respondents "*Monthly bill is for a consumer using 1,000 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 to \$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).

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 are produced as waste.*

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

		Electricity 1	**Electricity 2**
Monthly bill[ab]		\$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, and geothermal etc.)	30%	10%
	Hydroelectric	10%	10%

[a]Monthly bill is for a consumer using 1,000 kilowatt hours (kWh) per month. Actual bill varies according to how much electricity is used.

[b]Minimum contract length: 2 years.

Table 5. Respondents' perception

Region[a]	California (2012)	Michigan (2012)	New York (2012)	Texas (2012)	Japan (2013)[b]
Number of sample	1,022	1,070	1,021	1,089	4,000
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 9 estimation model)	68.2%	59.1%	69.0%	60.7%	59.3%
-Neither (GHG = 0 in Table 9 estimation model)	19.6%	25.5%	21.2%	22.7%	32.8%
-Totally disagree, Somewhat disagree (GHG = 0 in Table 9 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 9 estimation model)	39.9%	34.2%	40.4%	34.0%	64.6%
-Neither (Change = 0 in Table 9 estimation model)	34.1%	38.3%	34.4%	35.9%	25.7%
-Totally disagree, Somewhat disagree (Change = 0 in Table 9 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."

Table 6. Estimation result: Four US states and Japan

	US respondents												Japan		
	California			Michigan			New York			Texas					
	Coeff.	s.e.[b]	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 ***		-0.060	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	0.014	0.001 ***	0.23
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	-0.039	0.001 ***	-0.64
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 ***	0.38
Standard deviation of random pa															
GHG emission reduction (%)	0.008	0.003 ***		0.000	0.003		0.000	0.003		0.001	0.004		0.001	0.001	
Nuclear (%)	0.041	0.003 ***		0.039	0.002 ***		0.045	0.003 ***		0.046	0.003 ***		0.051	0.002 ***	
Renewable (%)	0.031	0.003 ***		0.037	0.003 ***		0.030	0.003 ***		0.035	0.003 ***		0.002	0.003	
Number of observations	8,176			8,560			8,168			8,712			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			-16765.7		

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

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 ($/month)	1% decrease in GHG emission 1% increase in renewable fuel 1% decrease in fossil fuels[c] ($/yr)	1% decrease in GHG emissions 1% increase in nuclear fuel 1% decrease in fossil fuels[c] ($/yr)
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	0.23	0.38	-0.64	7.37	-4.89
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 are 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.

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

Survey time	WTP (US$/month)	Survey area	Object analyzed	Author
N.A.	4.91-8.42	Wisconsin	WTP for a 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
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[bc]	Borcher et al. 2007
2010	0.58-0.93	New Mexico	WTP for a energy program providing 1% share of general renewable energy[b]	Mozumder et al. 2011
2011	4.61-5.02	Pennsylvania	WTP for a programs 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
2013	0.38	Japan	WTP for 1% increase in renewable fuel and 1% decrease in fossil fuels	This study

[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.

N.A.= not available

Table 9. 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* [a]	0.005	0.002	**	0.008	0.002	***	0.007	0.002	***	0.004	0.004	**	0.012	0.001	***
Nuclear (%) _*Regionc*	-			-			-			-			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	8,176			8,560			8,168			8,712			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			-16563.1		

[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.

[e] *** denotes 1% significance, ** denotes 5% significance, and * denotes 10% significance.

Table10. 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)	
	L*ow* interest in GHG[a]	H*igh* interest in GHG[b]	N*o change* in attitudes[c]	C*hange* 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.

Table 11. 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 (US$)	100	100	120	120	120
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."

[d] US Energy Information Administration "Annual Energy Outlook 2014," Early Release Overview, Fig.13.

[e] Clean Energy Standards. Clean Energy includes *Nuclear, Renewable, Natural gas,* and *Clean coal*.

Figure 1. Acceptability rates of energy services by accelerated source