Impacts of public acceptance and willingness to pay on achieving target of renewable energy resources in Japan

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The aim of this study is to analyze and assess the impacts of the citizens' public acceptance and willingness to pay on achieving target of renewable energy resources in Japan. Electricity production by renewable energy resources such as solar photovoltaic and wind power is an effective measure to mitigate climate change by reducing carbon dioxide emissions as well as to avoid depletion of fossil-fuel resources. Although its higher capital cost than facilities and system those used conventional fossil-fuel resource, there is a movement to defray the additional cost of electricity generated in environmental-friendly renewable energy resources due to the increasing public concern for global environmental problems, especially climate change. For the purpose, we have developed series of models to simulate the willingness to pay and the corresponding acceptability of renewable energy resources under three renewable energy development scenarios and two economic growth cases to 2030, allowing the further evaluation of the necessary investment subsidies of adopting renewable energy resources to meet national targets and its future potential in each prefecture of Japan. As the result, the median value of willingness to pay is estimated to approximately increase from 1,200 to 2,200 JPY per month per household over the period. For the necessary investment subsidies to meet renewable energy target in the future, overall, it is assessed to decrease sharply considering the willingness to pay of consumers. In particular, for prefectures with higher willingness to pay such as Tokyo, the investment required could be covered only by consumer's willingness to pay and no subsidy is needed.

Key Words : *willingness to pay, renewable energy, investment subsidy*

1. INTRODUCTION

Global warming is already impacting on many physical and biological systems. Continued warming increases the risks of floods, sea level rise, deaths from heat waves and other extreme weather conditions[1)]. The potential dangers of global warming have led some countries to implement policy reforms to reduce risks by reducing GHG emissions.

One measure to mitigate climate change is shifting to renewable energy. IEA[2)] suggested that by 2050, the largest contribution to reducing emissions will come from renewable energy. To promote renewable energy, many countries are planning to expand renewable energy capacity. For example in Japan, the Fourth Strategic Energy Plan[3)] set the renewable share goal to 22% to 24% by 2030. A 100% renewable energy target in Japan by 2050 has been proposed[4)]. The generation cost of renewable energy being usually much higher than that of conventional energy could be a main barrier to expanding the penetration of renewable energy in the future.

Despite the higher generation cost of renewable energy than those for conventional fossil-fuel energy resources, several studies have indicated that consumers are willing to pay the additional cost of renewable electricity due to the increasing public concern about global environmental problems, especially climate change[5),6)]. Nomura[7)] employed stated preference surveys to elicit respondents' willingness to pay (WTP) for increasing renewable energy resources in Japan, in which the results indicated the median WTP value for renewable energy per household in Japan was around 2,000 JPY per month. Yoo et al. evaluated the monthly mean willingness to pay for green electricity in Korea was 1.8 USD[8)]. Guo et al. pointed an average WTP for renewable electricity ranges from 2.7 to 3.3 US$ monthly in Beijing, China[9)]. These various aforementioned studies used all kinds of methods to analyze the willingness to pay for renewable energy over different counties, which would be much valuable for achieving the corresponding energy target. Neverthless, WTP itself may have a significant impact on the penetration of renewable energies[10], which thus further assist the policy-makers in setting the eligible energy polices. Unfortunately, to the best of our knowledge, there is still no extensive study of this assessment along the impact of WTP on renewable energy development in Japan.

The purpose of this paper is to analyze and assess the impacts of the citizens' public acceptance and WTP on penetration of renewable energy in Japan. We develop two types of models to simulate the willingness to pay and the corresponding acceptability of renewable energy resources (Section 3). In section 4, the generation cost and WTP for renewable energy are simulated under three renewable energy development scenarios and two economic growth cases to 2030. Based on these projections, the necessary investment subsidies of adopting renewable energy resources to meet national targets and its future potential in each prefecture of Japan are evaluated.

2. METHODLOGY

(1) Description of data

In this study, we applied meta-analysis involving a set of statistical methods for the collection of previous research studies in a given topic. An extensive search for the primary studies related to WTP for renewable energy was collected from Web of Science, Google Scholar and CiNii Articles. The search spanned from the 2000 to 2018 using the phrase "willingness to pay", "Japan" and "Contingent Valuation Method" in combination with the following renewable energy related words: renewable energy, green, electricity, power, wind, solar, photovoltaic and hydro. These studies both included the English related studies and Japanese related studies. We collected 22 primary studies by using this research terms. Among the 22 studies, 14 studies which included the value of WTP for meta-regression analysis were selected. The median value of WTP for increasing the renewable energy in current electricity mix was used as dependent variable and the WTP for nuclear power is not included due to the negative preference for this kind of energy source[11]. For the purpose of comparison, WTP values was converted in Japanese Yen (JPY) per household per month. Our observed data are summarized in Table 1 and the average of WTP was 1,388 JPY/(household·month). The highest value of WTP (5,410 JPY/(household·month)) was found in Tokyo[12]. The lowest value of WTP (238 JPY/(household·month)) was reported for using biomass in Kagoshima[13].

Table 1 Studies relating to WTP for renewable energy

Author	Year	Coverage	WTP
Nomura and Akai[14]	2000	National	1956.1
Nomura[7]	2000	National	1895.5
Teraoka[13]	2001	Local	1199.2
Baba and Tagashira[15]	2001	Local	238.5
Takahashi and Nakagome[16]	2002	Local	1445
Fukae[17]	2002	Local	278.5
Ise[12]	2005	Local	5410
Ito et al.[18]	2005	National	1310.9
Tagashira and Baba[19]	2005	National	276.7
Goto and Ariu[20]	2009	National	725.7
Matsuoka[21]	2012	Local	421.0
Murakami et al.[11]	2013	National	3036.5
Hironaka and Hondo[22]	2015	Local	644.8
Nakamura[5]	2015	Local	576.3

For the meta-regession analysis, socioeconomic data was employed to identify critical factor of WTP, which included age, population, income and education level. For studies that did not provide those information, data for each target area was compiled from e-Stat which is a portal site for Japanese Government Statistics and Agency for Natural Resources and Energy. All cost figures quoted in this paper are given in 2005 prices, calculated based on the Consumer Price Index (CPI) in Japan.

Socioeconomic data for future simulations with our models were assembled. For the simulation parameters of population and number of household in Japan, the data provided by National Institute of Population and Social, were used, covering the future period of 2015–2030. The income was taken from Cabinet Office (2018). For each prefecture, we assum their growth speed of income are as same as Japan. All these cost figures are also given in 2005 prices, calculated based on the Consumer Price Index (CPI) in Japan.

(2) Willingness to pay model by meta-regression

In this study, the effect of various factors on the WTP for the increase of renewable energy share in the electricity mix was investigated. Based on a review of previous study, the WTP was initially assumed potentially to correlate with four numerical variables (Age, Gender, Income and Education). The rationale for selection of these variables is as follows. In general, Age is frequently selected as an impact factor and older people seem to have a higher WTP[24]. Gender is also expected to affect the WTP and the male trended to pay more for renewable energy than female. As the different economic level will impact on the expenditure, Income is expected to effect the WTP[14]. Finally, a number of studies report the concern about environment which correlated with education level indicated a positive impact on the WTP[11].

Follow the literatures, education level is also selected. We seek to develop a WTP function with above variables and the function is estimated by an ordinary least squares method, as follows:

$$WTP_{med} = f\,(Age, Gender, Income, Education\ level) \quad (1)$$

Where *Age* is the average for target area, *Gender* is the percentage of female share within total population (%), *Income* is the annual average household income (JPY) and *Education level* is the percentage of the adult population held a university degree (%).

(3) Acceptability model

As the WTP value increase, the acceptability rates for renewable energy will decrease. This relationship usually indicates by Weibull distribution, as follows:

$$F_{\text{base}}(X) = Y = \exp\left(-\exp\left(\frac{\ln X - a}{b}\right)\right) \quad (2)$$

In this specification, $F_{\text{base}}(X)$ is the base acceptability function which is estimated by pervious studies. Y is acceptability rates, X is WTP in JPY/(household·month). The value of a and b have been estimated by several studies, and in this work they are assumed to 6.505 and 1.065 respectively, which are the mean value for previouse studies[15),22)].

In present study, it should be noted that the median value of WTP is used as observed data, which is estimated by determine factor. Theoretically, the WTP of the same acceptability rate of renewable energy is changing for consumers when median value of WTP is changed. This implies a shift in acceptability curve. Based on equation (1) and (2), the acceptability model can be defined as follows:

$$F(X) = \exp\left(-\exp\left(\frac{\ln(X_t - \alpha) - a}{b}\right)\right) \quad (3)$$

$$\alpha = X_{t,50\%} - X_{\text{base}} \quad (4)$$

$$X_{t,50\%} = WTP_{\text{med}} \quad (5)$$

$$X_{\text{base}} = \exp(a + b\ln(-\ln(Y_{50\%}))) \quad (6)$$

Where, *F(X)* is the acceptability function, $Y_{50\%}$ is acceptability rates in 50%, X is WTP in JPY/(household·month), t is the year.

(4) Annual cost for renewable energy

Based on the installed capacity and price for renewable, the total cost can be calculated. Regarding the former, the annual amortized cost can be determined by multiplying the total cost with an annuity factor, basing on the following equation:

$$AC_t = (IC_{j,t} \times Cost_{j,t} + IC_{j,t+1} \times Cost_{j,t+1}) \times \frac{i \times (1+i)^n}{(1+i)^n - 1} \quad (7)$$

Where AC is annual cost in JPY/year, IC is the increased installed capacity for renewable, kW. *Cost* is the capital cost for renewable energy, j is the type of energy, t is the period. i and n indicate the annual discount rates and payback year, respectively.We use a discount rate of 3% and 20-year payback year.

3. SET FUTURE VISION IN 2030

As shown above, the WTP and Acceptability models was developed by history data. Next, these two models are used to project the future WTP and acceptability in different prefectures, assuming that the trends observed over the modeling period (2000-2014) will continue for the next several decades (2015-2030). Attention is focused on the following:

(1) Socioeconomic condition

Income was forecast by Cabinet Office (2018) based on past performance and the current economic trend. The projection depicts two possible future condition.

- **Economic Growth Achieved Case**: This case offers a projection in which the policies of Abenomics for overcoming deflation and attaining economic revitalization show solid results at a more feasible pace.
- **Baseline Case**: This Case offers a projection in which the economy will grow approximately at the rate of current potential growth

(2) Installed capacity for renewable energy

MOEJ[25)] and RIST[4)]estimated the growth rate for renewable energy and indicate three conditions. We assumed the growth rate for renewable energy in each prefecture is same.

- **100% renewable energy scenario**: This scenario assumes that in 2050, all of Japan's energy is supplied by renewable energy.
- **Bridge scenario**: This scenario assumes that the goverments official target of an 80% reduction in greenhouse gas emissions by the year 2050 is achieved.
- **BAU scenario**: This case is consistent with the development patterns for renewable energy that have been observed over the past century.

(3) Policy scenario

In order to clarify the effect of decrease production cost and payment by consumer to reduce the subsidy from government, three future scenarios are established.

- **Scenario 1**: Only the reduction of production cost is taken into account. The price change for renewable energy are taken from MOEJ[25)], JWPA[26)] and METI[27)].
- **Scenario 2**: Both the reduction of production cost and WTP by consumer are considered. Moreover, WTP is estimated under the baseline case.
- **Scenario 3**: Both the reduction of production cost and WTP by consumer are considered. While, WTP is estimated under the economic growth achieved case.

4. RESULT

(1) Willingness to pay model by meta-regreation

Table 2 presents the meta-regression results for WTP. Based on the regression results of model-1 to model-4, Gender and Income are the most statistically signification variable in WTP estimation. For the Gender, the results suggest that WTP would decrease with an increase in the percent of women in total population. This indicate the male have a positive environment attitude than females and the results is consistent with previous studies[14),24)]. Moreover, the person with higher income are likely to pay more for environment protection. In terms of the quantitative function of capital cost, those variables that result in an improvement in the model fit after their addition are deemed an integral part of the WTP. We use Akaike's information criterion (AIC) to check the model accuracy, and model 3 is considered to be the best model due to the lowest AIC value. The WTP function can be defined as follows:

$$WTP = 3153 - 7.51\times10^{3}\times Gender + 6.3\times10^{-4}\times Income \quad (8)$$

t-statistic: (1.8) (-3.4) (2.6)

where, *WTP* is in JPY/kWh, *Gender* is the percentage of female share within total population in each area, and *Income* is in JPY. The t-statistics show that *Gender* is significant at the 99% level, and *Income* is significant at the 90% level. Furtherly, R^2 values is 0.77 and this result suggest a satisfactory performance for developed WTP functions.

Table 2 Results of meta-regression analysis

Variable	Model 1	Model 2	Model 3	Model 4
Constant	6864***	5292*	3153*	4210
Gender	-10800***	-9937**	-7507**	-7256*
Age		24.1		
Income			6.3E-04*	7.1E-04
Education				3970
AIC	231.2	233.3	227	229.5
R^2	0.66	0.63	0.77	0.74

***, ** and *indicate significance at 99%, 95% and 90% levels, respectively

(2) Prediction of the medium value of WTP

Based on the above result, the medium value of WTP can be forecast. Fig.1 shows the projected the medium value of WTP for each prefecture in 2015-2030. As expected, the WTP is higher in Tokyo, Aichi, Tochigi which do have a higher income. Moreover, based on the simulation results to 2030, the projected medium value of WTP for all studied prefecture increase markedly compared with the 2015 figures. In baseline case, the increase is less than that in the economic growth achieved case and this is primarily attributable to the higher growth of income under the latter case.

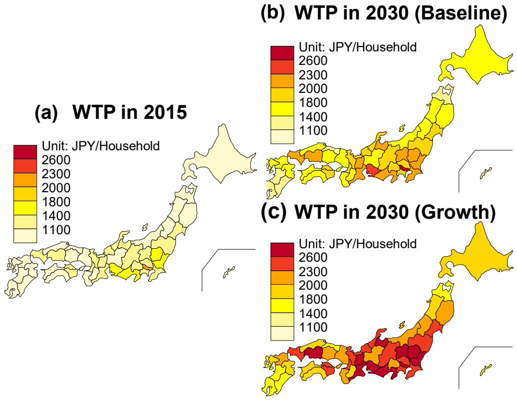

Fig.1 A map of the projected medium value of WTP for different area in 2015 and 2030 under the economic growth achieved case and baseline case

(3) Prediction of WTP under different acceptability rate with Future Simulation

This section focuses on the projection of WTP per household under different acceptability rate, within economic growth achieved case and baseline case. Fig.2 shows the projected WTP, and acceptability rate for Tokyo and Nagasaki in 2015–2030. Overall, the WTP showed a decreasing trend caused by the increase of acceptability rate. From 2015-2030, the acceptability function was upward shift which can be explained primarily by the income growth. In baseline case, the difference of acceptability function between each year was less than that in the economic growth achieved case which was primarily attributed

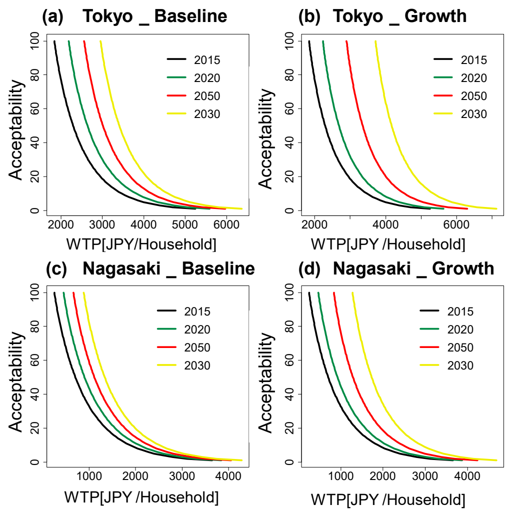

Fig.2 Prediction of WTP by different acceptability rate from 2015-2030 under the economic growth achieved case and baseline case.

to a slower growth rate of income in baseline case. Furtherly, comparting the median value of WTP between Tokyo and Nagasaki for each scenario, the value in Tokyo was higher than Nagasaki due to the higher average value of income.

(4) Prediction of total WTP

After completing the projection of WTP per household, the next concern was owned to the projection of total WTP in 47 prefectures over the period 2015–2030. Fig.3(a) shows the total WTP in Nagasaki from 2015-2030 under baseline case. On the temporal-scale, as shown in Fig.3(a), the maximum value of WTP is increasing from 194 to 442 Million JPY/month over the study period in Nagasaki under baseline case. On the spatial-scale, a complete illustration of the projected maximum value of WTP in each prefecture was shown in Fig.3(b)-(d) by a map. For all scenarios in 2030, the projected maximum value of WTP in different prefecture would extensively increase compared to the 2015 figures, though at different levels. In our data, the total maximum value of WTP increase from 2015 to 2030, to 84 and 110 billion JPY/month under the Economic Baseline and Economic Growth Achieved Case, respectively. The increase of the value could be primarily explained by growth of income and population in each prefecture.

(5) Prediction of necessary investment for renewable energy with Future Simulation

In this section, we focus on the annual cost for the renewable energy. Fig.4 shows the Prediction of annual cost for renewable under BAU, Bridge and 100% scenario in 2030. Overall, the annual cost for increasing the installed renewable energy capacity to 90~326 million kW, are expected to be within 1.3×10^3~6.7×10^3 billion JPY/year. Moreover, these costs will decrease to 1.0×10^3~4.8×10^3 billion JPY/year, attributing to the reducing of production cost.

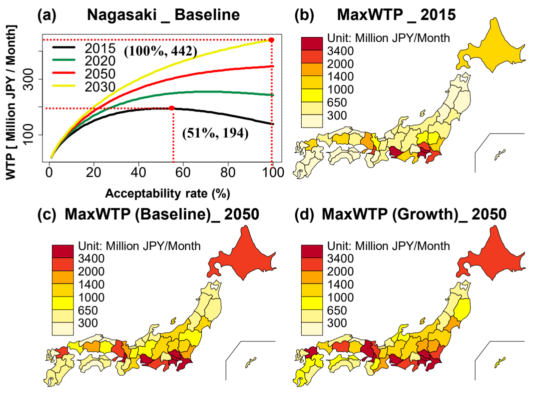

Fig.3 Prediction of WTP from 2015-2030, (a) under baseline case in Nagasaki by different acceptability rate, (b)-(d) the maximum value of WTP for different prefectures in the year 2015 and 2030 under economic growth achieved case and baseline case.

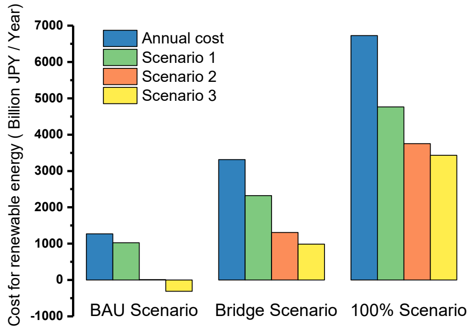

Fig.4 Prediction of annual cost for renewable under BAU, Bridge and 100% scenario in 2030.

Furtherly, both considering the reduced production cost and WTP by consumer these costs will continued decrease to -0.3×10^3~3.8×10^3 billion JPY/year. To concern the difference between each prefecture, the annual cost for renewable energy, which consider the reduced production cost and WTP, in 2030 under different condition are show in Fig.5 (a)-(d). As expected, the annual production cost is higher in Kagoshima, Aomori and Hokkaido, caused by their relatively lower income and rapidly increased installed renewable capacity. Since the WTP could be amounted to the maximum value paid by consumer, other subsidies should be considered for these regions in the case of their insufficient affordability for the huge annual production cost to renewable energy. By contrast, for Tokyo, Kanagawa and Osaka, additional investment subsidy for renewable energy is unnecessary since the higher income in these regions. In the scenario 3, the number of the area which require subsidies are higher than that in scenario 2, which is primarily attributable to the higher income under a rapidly economic growth, as the latter leads to a higher WTP by consumer. Furtherly, in the case of 100% scenario, the number of the regions which require subsidies are less than that in other scenarios, ascribing to the increased installed renewable capacity in such scenario.

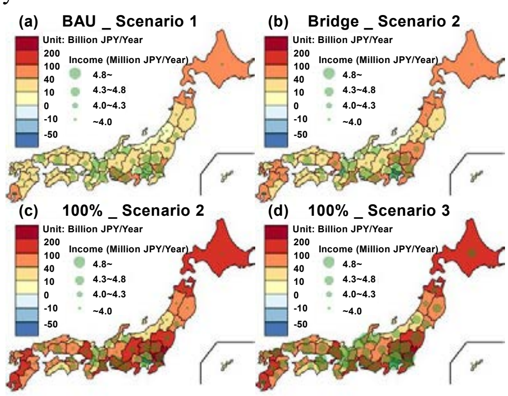

Fig.5 Prediction of annual cost for renewable under different scenario in 2030.

5. CONCLUSION

This paper proposes a method for simulation the willingness to pay and the corresponding acceptability of renewable energy resources in Japan during 2015-2030. Subsequently, the necessary investment subsidies of adopting renewable energy resources to meet national targets and its future potential in each prefecture of Japan are evaluated by using the simulated WTP.

In this study, several major findings were obtained. First, the WTP is positively correlated to the household income, suggesting rich households value renewable energy expansions more than poor ones. Moreover, basing on the simulated WTP at different acceptability rate, the maximum value of WTP is estimated. The results suggest that maximum value of WTP would increase, especially under the Economic Growth Achieved Case. The corresponding total maximum value of WTP will increase by 2.3-fold in 2030 compared to the present (from 0.46×10^3 in 2015 to 1.1×10^3 billion JPY/year). Lastly, WTP would contribution on the reduction of necessary investment subsidies to meet renewbale energy target in Japan. In particular, for prefectures with higher willingness to pay such as Tokyo, investment cost for renewable energy is unnecessary due to its complete cover by consumer's WTP.

Above all, in dealing with the increasing carbon emission, one of the most effective strategies is to use renewable energy. Although its higher capital cost than fossil-fuel resource, there is a movement to pay for it by consumer. The present study is an attempt to evaluate the impact of WTP on achieving renewable energy target in Japan. The method developed is simple but designed to function with the currently available knowledge base and technology. For the furute work, we would like to incorperate our WTP function into energy use model to discuss the optimal energy use pathway under consumer preference.

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