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Residential Consumers' Willingness to Pay Price Premium for Renewable Heat in South Korea

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Abstract: Heat accounts for about one-third of the final energy use and it is mostly produced using fossil fuels in South Korea. Thus, heat production is an important source of greenhouse gas emissions. However, using renewable heat that is directly produced from renewable energy, such as bioenergy, geothermal, or solar heat can save energy and reduce greenhouse gas emissions, rather than transforming conventional fuel into heat. Therefore, an energy policy for renewable heat urgently needs to be established. It is such situations that this paper attempts to assess the consumers' additional willingness to pay (WTP) or the price premium for renewable heat over heat that is produced from fossil fuels for residential heating. To that end, a nationwide contingent valuation survey of 1000 households was conducted during August 2018. Employing the model allowing for zero WTP values, the mean of the additional WTP or premium for one Gcal of heat produced using renewable energy rather than fossil fuels was estimated to be KRW 3636 (USD 3.2), which is statistically meaningful at the 1% level. This value represents the price premium for renewable heat over heat that is based on fossil fuels. Given that the heat price for residential heating was approximately KRW 73,000 (USD 65.1) per Gcal at the time of the survey, the additional WTP or the price premium corresponds to about 5% of that. When considering that the cost of producing renewable heat is still significantly higher than the cost of producing fossil fuels-based heat, more efforts to lower the production costs of renewable heat as well as financial support of the government for producing and supplying renewable heat are needed to ensure residential consumers' acceptance of renewable heat.

Keywords: renewable heat; willingness to pay; consumer acceptance; contingent valuation; price premium

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1. Introduction

Much of the demand for final energy is for heat, which is mostly produced using fossil fuels. Fossil fuel use for heat production is the primary source of carbon dioxide and air pollutants emissions. According to International Energy Agency [1], heat globally accounted for 52% of final energy consumption in 2015. Renewable heat (RH) can be produced from renewable energy, such as bioenergy, geothermal, and solar heat directly, or renewable electricity indirectly. Using RH can save energy and reduce greenhouse gas emissions, rather than transforming conventional fuel into heat.

Thus, RH needs to be considered at the center of the energy transition to a less carbon-intensive and more sustainable energy system [2]. Heat accounts for about one-third of the final energy use in South Korea [3]. However, South Korea's renewable energy policy only focuses on electricity, which accounts for only 18.9% of South Korea's final energy consumption as of 2016. It is time for the government to expand its policy focusing on renewable electricity to RH. Although the focus of this research is on residential RH that is based on district heating, the shift to renewable sources of heat can also contribute to the improvement in the energy efficiency of building and industrial processes that require heat, as well as a recovery of the excess heat.

It is necessary to look into the different sources of RH. First, bioenergy is one of the most important sources of renewable heat. Bioenergy is classified into solid biomass, biogas, and biofuel. Major bioenergy technology includes fuel processing or manufacturing and energy supply. From the fuel processing or manufacturing perspective, there are pulverized timber, high pressure compression technology for solid biomass (pellet), pre-processing system (impurities elimination), methane conversion (digester) for biogas, and so on [4]. Bioenergy dominates RH consumption and it is produced from present system through boilers, cogeneration systems, and natural gas grid. Biofuel boilers—can be used directly in buildings' heat systems, in district heating systems, or used to produce industrial process heat. Biofuels (solid biomass, biodegradable wastes, liquid biofuels, or biogas) are often sourced locally, but the international trading of wood pellets is also taking place. Biofuel cogeneration systems—can produce heat for district heating systems or industrial heat needs as well as electricity. Biogas is produced from anaerobic digestion or solid biomass gasification. Once upgraded, it becomes biomethane for injection into natural gas grids [5].

Second, geothermal heat can be supplied for direct use in industry, greenhouses, and district heating, or large building, but it is location-specific. While using the heat pump as a cooling and heating system, the high indoor temperatures are stored in summer and absorbing heat from the ground can be used in winter. Geothermal energy can provide heating, cooling, and base-load power generation from high-temperature hydrothermal resources, aquifer systems with low and medium temperatures, and hot rock resources. Each geothermal source is unique in its location, temperature, and pool depth, and various geothermal technologies have been developed to the best specific resources. Flash steam, dry steam, binary, and enhanced geothermal systems are the leading geothermal technologies for power generation [5]. Geothermal utilization in Korea is primarily direct use, especially with ground-source or geothermal heat pump installations, because there are no high temperature resources that are associated with active volcanoes or tectonic activity [6].

Third, we can produce heat from solar energy. There are two main methods of converting solar energy to electricity—photovoltaics and solar thermal power, commonly known as concentrating solar power [5,7]. Concentrating solar power systems can supply solar power on-demand through the use of thermal storage, helping to address grid integration challenges that are related to the variability of solar energy and enabling solar-generated heat to be stored until electricity is needed, even after the sunsets. Solar energy can supply the energy for all of a building's needs—heating, cooling, hot water, district heating system, light, and electricity. In addition, solar applications can be used almost anywhere in the world and they are appropriate for all building types.

There has been a lot of research on the role and importance of RH [8–12]. Research has prominently featured, for example, the production and storage of heat using various renewable energy sources [8,9], public acceptability of RH [10], and the incentive schemes for expanding the use of RH [11,12]. Furthermore, information regarding residential consumers' acceptance for RH over heat that is produced from fossil fuels is required. Therefore, an energy policy for RH urgently needs to be established. It is such situations that this paper attempts to assess the consumers' additional willingness to pay (WTP) for RH over heat that is produced from fossil fuels for residential heating. It has been regarded in various sectors, including transportation, electricity, food, and industrial product [13–22]. To the best of the authors' knowledge, however, the study of measuring the price premium for RH over heat produced using fossil fuels is not found in the literature. Therefore, this study is considered to be the first empirical study that estimates the price premium for RH over heat produced using fossil fuels. The authors think that this point is an interesting feature of this article.

The acceptance of consuming a good or a service should be assessed as the WTP for the consumption. This value represents the price premium for RH over heat based on fossil fuels.

More specifically, this article aims to analyze residential consumers' additional WTP or price premium for RH over heat that is produced from fossil fuels for residential heating. The remainder of this article comprises three components. The methodology employed in the article is explained in Section 2. Section 3 deals with the data and the empirical results and then provides a discussion. The conclusions are presented in Section 4.

2. Methodology

2.1. Method: CV Approach

Arrow et al. [23] argued that reliable estimates could be gained through the CV method if several conditions are met and the results can be the basis of decision making. The CV approach can be applied to measure consumers' WTP to consume a good or service [24]. Similarly, consumers' additional WTP or premium for RH over heat from fossil fuel can be elicited through the application of the CV method [25–27]. The CV method directly asks respondents to determine their WTP contingent on a proposed situation. Moreover, Arrow et al. [23] proposed several measures to ensure the validity and accuracy of a CV study. For instance, the number of respondents should be at least 1000 and the survey should be implemented through person-to-person interviews. The CV survey should provide a detailed and persuasive explanation regarding the goods of concern. The goods, and the method of providing and paying for them, should be meaningful to people. Furthermore, they emphasized respondents' familiarity with the good to be evaluated and professional interviewing skills for the purpose of obtaining more precise results. This study was carefully designed under these conditions. Well-trained and professional enumerators should be used [28,29].

For the purpose of conducting a CV study, the current status as a starting point, the target status as a destination, and the policy measures that are necessary to reach a destination from the starting point are needed. The current status indicates a situation whereby heat is consumed from fossil fuel. The target status implies a situation in which fossil fuel is replaced with RH through some policy instruments, which contain the construction of RH facilities for the supply and storage and installation of the operation system. These were appropriately and sufficiently communicated to the respondents in the CV survey.

2.2. Dichotomous Choice Question

A dichotomous choice question is widely used for deriving the WTP response. Generally, there are three types of dichotomous choice question methods: the single-bounded, double-bounded, and one-and-one-half-bounded dichotomous choice question methods. The first method requires the respondent to select "yes" or "no" only once. It is simple and convenient, but not statistically efficient when compared with the second method. The second method is made up of two single questions. The first question is similar to the first method and the response to the first question determines the type of the second question. Thus, the second question provides the respondents with a higher bid than the first bid if they answer "yes". Otherwise, the second question asks whether they accept the lower bid. Whereas, the estimates resulting from the second method can obtain statistical efficiency, the second method may generate inconsistency due to the correlation between the first bid and the second bid [30–32] and it can cause a compliance issue [33].

The one-and-one-half-bounded dichotomous choice question method that is provided by Cooper et al. [31] is able to resolve problems, such as the inefficiency of the first method and the inconsistency of the second method. The merits of the format have promoted its application in a substantial number of previous studies [21,34–38]. Consequently, this article utilizes the question method. Two bids, of which one is higher than the other, are used in the question format. If a lower bid is presented to an interviewee first and the answer is "yes", then a higher bid is additionally offered to the interviewee. If a lower bid is presented to an interviewee first and the answer is "no", then no additional question is offered to the interviewee. When a higher bid is presented to an interviewee first and the answer is "no", a lower bid is additionally offered to the interviewee. If a higher bid is presented to an interviewee first and the answer is "yes", then no additional question is offered to the interviewee.

2.3. One-and-One-Half-Bounded Dichotomous Choice Spike Model

The following explanation is based on a utility difference approach [39]. The utility difference function takes the following form:

$$\Delta V = V(Y, I - T; D) - V(N, I; D) \geq \lambda_N - \lambda_Y \quad (1)$$

An interviewee will say "yes" to a suggested bid, T, if the following condition meets [15,39]:

$$V(Y, I - T; D) + \lambda_Y \geq V(N, I; D) + \lambda_N \quad (2)$$

where Y and N indicate the states in which RH consume and not consume, respectively, V is an indirect utility function, I is the household's income, D is the household's socio-demographic characteristics, and the λs are the error terms. If ΔV is positive, then the respondent may say "yes". Thus, the following relationship can be derived:

$$\Pr(\text{"yes"}) = \Pr(W \geq T) = 1 - F_W(T) \quad (3)$$

where W and $F_W(\cdot)$ are the interviewee's WTP and the cumulative distribution function (cdf) of W.

There are R respondents. T presented to respondent s is expressed as T_s for $s = 1, \ldots, R$. Let T_s^L and T_s^H be lower and higher bids. If T_s^L is offered to the respondent first, then "yes-yes", "yes-no", and "no" are the possible responses. When T_s^H is provided to the respondent first, "yes", "no-yes", and "no-no" are the possible answers [26]. Thus, a total of six indicator variables can emerge from the question format. Hence, E_s^{YY}, E_s^{YN}, E_s^{N}, E_s^{Y}, E_s^{NY}, and E_s^{NN} are introduced, as follows [34,35]:

$$\begin{cases} E_s^{YY} = \mathbf{1}(s\text{th interviewee's answer is "yes-yes"}) \\ E_s^{YN} = \mathbf{1}(s\text{th interviewee's answer is "yes-no"}) \\ E_s^{N} = \mathbf{1}(s\text{th interviewee's answer is "no"}) \\ E_s^{Y} = \mathbf{1}(s\text{th interviewee's answer is "yes"}) \\ E_s^{NY} = \mathbf{1}(s\text{th interviewee's answer is "no-yes"}) \\ E_s^{NN} = \mathbf{1}(s\text{th interviewee's answer is "no-no"}) \end{cases} \quad (4)$$

where $\mathbf{1}(\cdot)$ is an indicator function. It has a value of one if the proposition in the parentheses is true and a value of zero otherwise.

An interviewee who responds "no-no" to T_s^H or "no" to T_s^L is given a follow-up question asking whether she/he has the intention to pay nothing. If the response is "yes", then $0 < W_s < T_s^L$ comes into effect, and otherwise $W_s = 0$. To reflect these points, additional indicator variables are considered, as follows:

$$\begin{cases} E_s^{TY} = \mathbf{1}(s\text{th interviewee's answer to the additional question is "yes"}) \\ E_s^{TN} = \mathbf{1}(s\text{th interviewee's answer to the additional question is "no"}) \end{cases} \quad (5)$$

Thus, the log-likelihood function derived for the spike model is [40,41]:

$$\begin{aligned} \ln L = & \sum_{s=1}^{R} \{ (E_s^{YY} + E_s^{Y}) \ln[1 - F_W(T_s^U; \phi_0, \phi_1)] \\ & + (E_s^{YN} + E_s^{NY}) \ln[F_W(T_s^U; \phi_0, \phi_1) - F_W(T_s^L; \phi_0, \phi_1)] \\ & + E_s^{TY}(E_s^{N} + E_s^{NN}) \ln[F_W(T_s^L; \phi_0, \phi_1) - F_W(0; \phi_0, \phi_1)] \\ & + E_s^{TN}(E_s^{N} + E_s^{NN}) \ln F_W(0; \phi_0, \phi_1) \} \end{aligned} \quad (6)$$

In the spike model, $F_W(T;\phi_0,\phi_1)$ is assumed as:

$$F_W(T;\phi_0,\phi_1) = \begin{cases} [1+\exp(\phi_0-\phi_1 T)]^{-1} & \text{if } T>0 \\ [1+\exp(\phi_0)]^{-1} & \text{if } T=0 \\ 0 & \text{if } T<0 \end{cases} \quad (7)$$

The probability of $W_s=0$ is usually called the spike, which corresponds to $[1+\exp(\phi_0)]^{-1}$ in Equation (7) [40]. Since our main concern is to measure the mean WTP, we need to compute it from $F_W(T;\phi_0,\phi_1)$. If a well-known formula for the mean as calculated from a cdf is used, then we obtain the mean WTP as $(1/\phi_1)\ln[1+\exp(\phi_0)]$ [40,41]. If one needs to consider some covariates, ϕ_0 can be substituted with $\phi_0 + z'_s\theta$ in Equation (7), where θ is a vector of coefficients that corresponds to a vector of covariates, z_s.

3. Results

3.1. Data

1000 households were surveyed, applying the contingent valuation (CV) method, during August 2018, in order to obtain an estimate of the additional WTP or the price premium. At the time of the CV survey, there were 19,751,807 households in South Korea [42]. Thus, one can question whether a sample of 1000 households can properly represent the population of about 20 million households. The authors think that the sample represents the population well in three points. First, the Blue Ribbon Panel Report of Arrow et al. [23] mentioned that 1000 observations could properly represent the population if scientific sampling was adequately performed. In order to represent the national population well, our sampling method was satisfied with random sampling. This was conducted to be similar to the population geographical distribution within 15 strata. Our sample was allocated to the provinces in proportion to each province's population distribution rate. For example, the number of allocated and surveyed households in Seoul was 20.1% and then population distribution in nation was also 20.0%, as shown in Figure 1.

Second, Korea Development Institute, a government-funded research institute, has made guidelines regarding the application of CV in South Korea at the request of Korea Ministry of Strategy and Finance and announced them in 2012, suggesting that the size of a sample of 1000 households nationwide should be used. Given South Korea's various situations, advances in statistics, and modernized sampling techniques, it was pointed out that, if a professional survey firm conducted a CV survey of 1000 households, then the survey could fully reflect the opinions of the nation's entire. Based on this, this study employed 1000 household survey data.

Third, a professional polling company managed the entire process of the nationwide survey. In other words, the company did not perform arbitrary sampling, but it conducted scientific sampling based on the census data that were collected by the Korea National Statistical Office in 2015. Furthermore, supervisors from the company trained interviewers and conducted stratified random sampling that matched the characteristics of the population. Following Arrow et al.'s [23] recommendation, the survey was implemented through person-to-person interviews. Respondents understood the questions that were presented in the CV questionnaire well and they were provided meaningful information.

The results of a focus group interview that was administered to 100 individuals enabled us to modify and supplement the early version of the CV survey instrument. The finalized survey instrument comprises three sections. The first section presents an explanation of the aim and scope of the survey to the interviewees and questions them regarding their perceptions that are related to the RH. The second section deals with the collection of information about WTP in earnest, explaining the meaning and principle of additional payments and then asking whether they would be willing to pay the amounts that were presented. The main part of the survey questionnaire used in this study is provided in Appendix A. The third section relates to the collection of personal information regarding the respondents, asking questions about their age, income level, gender, education level, and so on. The payment vehicle of the WTP question is the residential heating cost.

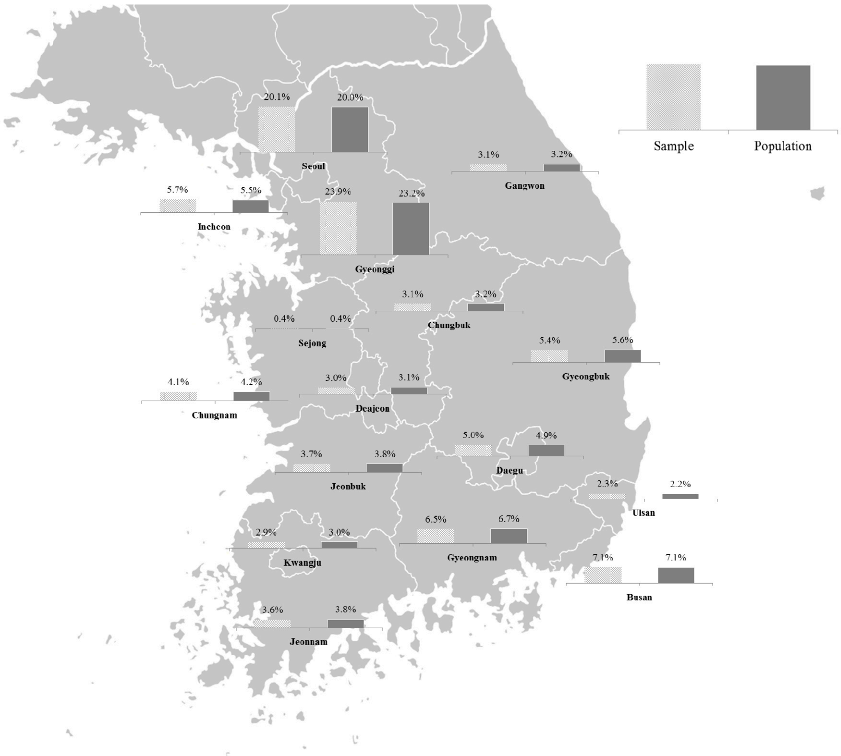

Figure 1. Summary of the proportion of populations and samples by region used in this study.

A distribution for the WTP values that were collected through open-ended questions in a pre-test of the focus group was created and then the range and number of suggested bid amounts were determined while using a trimmed distribution that cuts a percentage at each end of the WTP distribution. One of the finally determined bid amounts was randomly presented to each respondent. The sets of lower and higher bids in Korean won are the following: (2000, 3000), (3000, 4000), (4000, 6000), (6000, 8000), (8000, 10,000), (10,000, 12,000), and (12,000, 15,000). When the survey was implemented, the exchange rate was USD 1 = KRW 1121. The distribution of responses to the bid amounts that were presented to the respondents is shown in Table 1. About 46.8% of all the respondents were found to have no intention of paying only one Korean won for RH over heat that is produced from fossil fuels for residential heating. Therefore, it can be seen that applying the spike model is an appropriate strategy.

Table 1. Summary of the responses to willingness to pay questions.

Bid Amount [a]		Higher Bid is Given First (%) [b]				Lower Bid is Given First (%) [b]				Sample Size
		"yes-yes"	"yes-no"	"no-yes"	"no-no"	"yes"	"no-yes"	"no-no-yes"	"no-no-no"	
2000	3000	14 (9.8)	9 (6.3)	21 (14.7)	28 (19.6)	21 (14.7)	10 (7.0)	9 (6.3)	31 (21.7)	143 (100.0)
3000	4000	14 (9.8)	8 (5.6)	18 (12.6)	31 (21.7)	12 (8.4)	7 (4.9)	18 (12.6)	35 (24.5)	143 (100.0)
4000	6000	10 (7.0)	13 (9.1)	17 (11.9)	31 (21.7)	14 (9.8)	8 (5.6)	18 (12.6)	32 (22.4)	143 (100.0)
6000	8000	10 (7.0)	7 (4.9)	17 (12.0)	37 (26.1)	15 (10.6)	4 (2.8)	18 (12.7)	34 (23.9)	142 (100.0)
8000	10,000	9 (6.3)	6 (4.2)	18 (12.7)	38 (26.8)	11 (7.7)	6 (4.2)	23 (16.2)	31 (21.8)	142 (100.0)
10,000	12,000	11 (7.7)	4 (2.8)	19 (13.3)	38 (26.6)	12 (8.4)	9 (6.3)	22 (15.4)	28 (19.6)	143 (100.0)
12,000	15,000	9 (6.3)	2 (1.4)	21 (14.6)	40 (27.8)	7 (4.9)	5 (3.5)	26 (18.1)	34 (23.6)	144 (100.0)
Totals		77 (7.7)	49 (4.9)	131 (13.1)	243 (24.3)	98 (9.2)	44 (4.9)	134 (13.4)	225 (22.5)	1000 (100.0)

Notes: [a] The unit is Korean won. When the survey was implemented, the exchange rate was USD 1 = KRW 1121. [b] The percentage of the responses is given in parentheses next to the number of respondents.

3.2. Estimation Results

Table 2 and Figure 2 report the estimation results of the model that is given in Equation (6). All of the parameter estimates are statistically meaningful at the significance level of 1%. The estimated equation is significant when judging from the Wald statistic. In addition, the sign of the coefficient estimates meets the prior expectations. The additional WTP or the price premium for RH is KRW 3636 (USD 3.2) per Gcal. This value is statistically significant at the 1% level. At the time of the survey, the price for residential heat that is produced from fossil fuels was approximately KRW 73,000 (USD 65.1) per Gcal. Thus, the additional WTP or the price premium for RH amounts to 5% of the price for residential heat that is produced from fossil fuels.

Table 2. Estimation results of the spike model.

Variables	Coefficient Estimates (*t*-Values)
Constant	0.0889 (1.43)
Bid amount [a]	−0.2031 (−21.08) *
Spike	0.4778 (30.86) *
Mean additional willingness to pay per Gcal	KRW 3636 (USD 3.24)
t-value	18.68 *
95% confidence interval [b]	KRW 3296 to 4013 (USD 2.94 to 3.58)
99% confidence interval [b]	KRW 3198 to 4150 (USD 2.85 to 3.70)
Number of observations	1000
Log-likelihood	−1278.62
Wald statistic (*p*-value) [c]	572.82 (0.000)

Notes: [a] The unit is 1000 Korean won. When the survey was implemented, the exchange rate was USD 1 = KRW 1121. [b] The confidence intervals are computed using the method of Krinsky and Robb [43]. [c] The null hypothesis is that all the parameters are jointly zero. * denotes statistical significance at the 1% level.

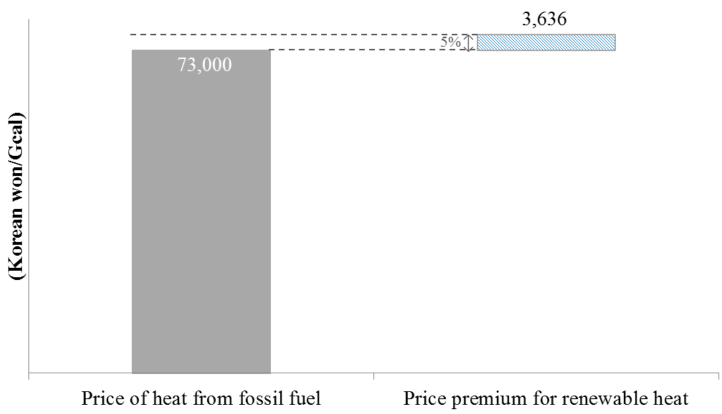

Figure 2. Consumers' additional willingness to pay for using renewable heat over heat from fossil fuel.

Rather than only presenting a point estimate of the mean additional WTP, it would be preferable to present confidence intervals for it for the purpose of explicitly reflecting the uncertainty that is associated with the mean additional WTP estimation process. The most frequently applied method of computing a confidence interval is the Monte Carlo simulation, as suggested by Krinsky and Robb [43]. This method assumes that both parameters, ϕ_0 and ϕ_1, are distributed as bivariate normal, extracts the values for ϕ_0 and ϕ_1, from the bivariate distribution randomly, calculates a series of the mean additional WTP, sorts the series, and then obtain 95% confidence interval after deleting 2.5% from both the tails and 99% confidence interval after deleting 0.5% from both of the tails. Table 2 contains the 95% and 99% confidence intervals.

3.3. Estimation Results of the Model with Covariates

As the next step, it is necessary to deal with a model including covariates that can address the effect of the socio-economic variables concerning the respondent on the probability that the respondents will answer "yes" to the proposed bid amount. Moreover, the model can be used for deciding whether the results of applying the CV method that involves the survey will ensure internal consistency or theoretical validity. For this purpose, this study employed five covariates, which are explained in Table 3. Table 4 shows the results of the model estimation.

Table 3. Description of the variables in the model.

Variables	Definitions	Mean	Standard Deviation
Heating	Dummy for the respondent's household's tending to heat a house more strongly during the winter season than other household (0 = no; 1 = yes)	0.446	0.497
Education	The respondent's education level in years	14.093	2.233
Age	Dummy for the respondent's age being more than the sample average (48)	0.482	0.500
Income	The respondent's household's monthly income before tax (unit: KRW 1.0 million = USD 892)	4.912	2.145
Environment	Dummy for the respondent's judging that the issue of environment is more critical than that of unemployment (0 = no; 1 = yes)	0.419	0.494

Table 4. Estimation results of the spike model with covariates.

Variables [a]	Coefficient Estimates	*t*-values
Constant	−2.2470	−4.97 *
Bid amount [b]	−0.2176	−22.43 *
Heating	−0.3350	−2.72 *
Education	0.1290	4.21 *
Age	−0.3547	−2.72 *
Income	0.1276	4.31 *
Environment	0.5397	4.36 *
Spike	0.4743	28.93 *
Number of observations	1000	
Log-likelihood	−1229.00	
Wald statistic (*p*-value) [c]	576.55 (0.000)	

Notes: [a] The variables are defined in Table 3. [b] The unit is 1000 Korean won. When the survey was implemented, the exchange rate was USD 1 = KRW 1121. [c] The null hypothesis is that all the parameters are jointly zero. * denotes statistical significance at the 1% level.

All of the estimated coefficients for the five covariates are statistically meaningful at the 1% level. The sign of an estimated coefficient for a particular variable is positive (negative), which means that the value of that variable has a positive (negative) relationship with the probability of responding "yes" to the proposed bid amount. The estimated coefficients concerning the Education, Income, and Environment variables have positive signs. Both the education level of the respondent and the respondent's household's income have positive correlations with the probability of reporting "yes" to an offered bid. Since RH is a normal good and thus increased income will increase the consumption of RH, it is natural that the coefficient for the Income variable is positive.

The respondents who judged that the issue of environment is more critical than that of unemployment showed a higher likelihood of saying "yes" to a given bid than others. The results imply that it is important to sufficiently explain to the public that, when the government implements a policy of expanding the provision of RH, the policy can contribute to the environment, including the reduction of greenhouse gas and air pollutants emissions. Communicating with the public regarding the eco-friendliness of RH will also enhance the public acceptance of RH. In addition, Zhang et al. [44] and Krishnamurthy and Kriström [45] found that environmental concern is a determinant of public acceptance is, which positively affects WTP.

However, the signs of the estimated coefficients for the Heating and Age variables are negative. The respondents whose households tend to heat a house more strongly during the winter season than other households are less likely to accept the payment of a provided bid than others. The results appear to be due to the burden of increasing heat charges. The respondent's age negatively affects the possibility of accepting a suggested bid.

3.4. Discussion of the Results

In the literature, a number of studies dealt with the additional WTP or price premium in the area of energy [15–22]. These studies analyzed consumers' WTP and found that consumers determine their preference in an ethical and environmentally friendly way in order to mitigate greenhouse gas and air pollutants emissions or to protect the environment. There have been many case studies where price premium has been examined for the use of renewable energy-based electricity in place of fossil fuels-based electricity, since renewable energy has been mainly used for electricity generation [15–18]. In addition, the price premium for electricity from a non-distributed generation source over that from distributed generation source [19]; the price premium for electricity that is generated without emitting thermal discharge water over that with emitting thermal discharge water [20]; the price premium for electricity from coal-fired power plant over that natural gas-fired power plant [21]; and, price premium for eco-friendly goods over conventional goods were analyzed [22] in the literature.

To the best of the authors' knowledge, there have been no studies that examining additional WTP or price premium for RH. Therefore, this study is the first one to estimate any additional WTP or price premium for RH. For this reason, the message of the study is all the more useful. It is clear that the South Korean households are willing to accept some economic burden to consume RH for residential use. However, it is necessary to look into the magnitude of the estimated mean additional WTP or the price premium for RH. In an economics sense, the economic benefits or value of consuming a good or a service should be assessed as the WTP for consumption. The WTP is defined as the sum of the consumer expenditure or the price and the additional WTP. Thus, the economic benefits or value of RH consumption is KRW 76,636 (=73,000 + 3636) per Gcal. To increase the production of heat from renewable sources and to supply the produced RH to consumers, the costs of installing, operating, and maintaining RH-producing and -supplying facilities, and RH technology development costs need to be considerably invested. Only when the costs of producing and supplying one Gcal of RH are less than KRW 76,636, the RH provider can secure the financial feasibility of providing the RH.

Although accurate analyses have not yet been performed, the costs of providing RH are estimated to be approximately twice the cost of providing heat from fossil fuel. In other words, the additional WTP or the price premium for RH over heat that is produced from fossil fuels is much lower than the additional costs of providing RH instead of heat that is produced from fossil fuels. Without the government's financial support, the provision of RH does not appear to have financial feasibility. Thus, the government should financially support the RH provision if it is necessary to increase the provision of RH. In this regard, the South Korean government considered the RH expansion policy in the Second National Basic Plan for Energy (2015–2035) that was announced in 2014. For example, the introduction of some programs, such as RH obligation, RH incentive, and feed-in-tariff for RH, was considered [12,46]. Regrettably, they were not actually introduced due to the difficulty of securing enough budget and the government's smaller interest in heat than electricity.

However, at present, the interests in RH are greater than ever [1,8]. In addition, some point out that the focus of the renewable energy policy that only focused on electricity should be shifted to RH. This is because it is much more efficient to directly produce heat from renewable energy rather than from electricity that is made from renewable energy. As of 2017, Korea Electric Power Corporation, which is a government-owned electricity transmission and distribution monopoly, purchased the fossil-fueled electricity for KRW 81 per kWh, while renewable electricity was purchased for KRW 211 per kWh and subsidized KRW 130 per kWh. Therefore, to ensure that RH has price-competitiveness, the South Korean government should establish and implement a strong support policy, such as sufficient tax support, subsidy, incentive, and so on [46].

Globally, renewable electricity has been and will be growing rapidly thanks to price-competitiveness that is caused by technological developments, governmental assistance policy, regulations to encourage the production and use of renewable electricity, and increasing public interest in renewable electricity. In particular, owing to sharp cost reductions for solar photovoltaics and wind power, the share of renewables in electricity has increased 23.9% in 2017 [2,47]. However, RH accounts for only 10.3% in 2017. Thus, the fall in costs of supplying renewable electricity and the increase in interest in RH are both expected to contribute to expanding the provision of RH worldwide. In addition, South Korea will not be an exception in this expectation, provided that the aforementioned government's support policy is adequately backed up.

4. Conclusions

The global energy systems are currently experiencing some fundamental changes that are driven by energy transition scheme. Although South Korea consumed about one-third of its final energy in the form of heat, most of the renewable energy policy focuses on electricity. The government is not drawing a comprehensive blueprint for what heat energy should be like in an era of energy transition. However, the pressure to expand the provision of RH, as well as that of renewable electricity, is growing. This is because reducing greenhouse gas emissions in the heat production sector has become an important task. One of the key concerns of RH providers and government in expanding the provision of RH is the amount of consumers' additional WTP or the price premium for RH.

Thus, this article intended to assess households' additional WTP or price premium for RH over heat form fossil fuel in the residential sector. For this purpose, a nationwide OOHB DC CV survey of 1000 households was conducted and statistical analysis using the spike model was performed to derive information regarding the additional mean WTP for RH from the collected data. The estimation results of the OOHB DC spike model possessed statistical significance at the 1% level. The respondents accepted the contingent market that was described in the CV survey and placed a significant value on RH for residential heating. As addressed above, this study was the first to empirically estimate the additional WTP or price premium for RH, rather than heat form fossil fuels. Although there are lots of previous studies highlighting the importance of RH, it is difficult to compare the findings from this study with those from other studies because there are no prior studies that estimated the additional WTP or price premium for RH in the literature.

Nevertheless, the results of this study have some uses, not only in terms of research, but also in terms of policy. From a research perspective, this study applied the CV approach, which is a well-developed economic technique. The validity and reliability of the approach have already been verified in the literature. In order to derive the price premium, in particular, the various methodological guidelines that were highlighted in the literature were well followed. In addition, when considering that, of the total 1000 consumers, 468 reported zero WTP responses, a spike model that can explicitly allowing for zero WTP values, was applied. People can give a zero WTP response because of lack of concern regarding the environment, economic difficulty, dislike of hypothetical questions, and so on. Although the 468 zero responses were composed of protest bid responses as well as true zero WTP values, for a conservative approach they were not excluded from the final analysis but were treated as zero WTP values.

From the policy perspective, the results present two important implications. First, the estimate of additional WTP or price premium for RH was statistically significant at the 1% level. If the statistical significance of the estimation results is not ensured, it is difficult to use them in the actual policy assessment and decision making. For example, based on the results, we can consider introducing a green pricing for RH. Green pricing means that consumers voluntarily pay higher rates for RH when compared to fossil fuel-based heat. Second, the estimated price premium for RH exists clearly, but is insufficient to cover additional costs of producing RH. Considering that the cost of producing RH is still significantly higher than that of fossil fuels-based heat, it is shown that more efforts to lower the production costs of RH as well as financial support of the government are needed to ensure residential consumers' acceptance of RH.

The paper concludes with suggestions for future research directions. In the case of transforming renewable electricity into heat, electric heating presents lower efficiency than heating that is used by renewables directly because of electricity generation efficiency and transmission losses. This is an important property to consider by developing and consuming renewables in aspects of energy efficiency. As a next step of the study, combining the heating method using RH can assess consumers' preference. Because households have a variety of fuel to use for heating, it is necessary to analyse each sources separately. Various types of RH can be adopted in the household or used as an extra option in addition to the main heating system [48]. It can distinguish the favorite sources from renewables and be more helpful in comparing benefits with the costs of specific project. Moreover, the amount that is used by households in the final heat consumption is small. Heat accounted for 52% of final energy consumption globally in 2015, with 60% of heat being consumed in industry (including agriculture) and 40% in buildings. A price premium for RH is required to investigate industrial and commercial sectors in order to expand RH consumption. These implications can provide fundamental information justifying the RH provision.

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Appendix A. Main Part of the Survey Questionnaire

An Illustarting Example of the Questions Asking about Willingness to Pay for Renewable Heat over Heat Produced from Fossil Fuels Where the Lower and the Upper Bids are KRW 2000 and 3000, Respectively.

Type A. Q1. Is your household willing to pay additional amount of KRW 2000 (lower bid amount) per Gcal for consuming renewable heat over heat produced from fossil fuels, supposing that the supply of renewable heat is guaranteed?

a. Yes—go to Type A. Q2.
b. No—go to Q3.

Type A. Q2. Is your household willing to pay additional amount of KRW 3000 (upper bid amount) per Gcal for consuming renewable heat over heat produced from fossil fuels, supposing that the supply of renewable heat is guaranteed?

a. Yes—finish this page.
b. No—finish this page.

Type B. Q1. Is your household willing to pay additional amount of KRW 3000 (upper bid amount) per Gcal for consuming renewable heat over heat produced from fossil fuels, supposing that the supply of renewable heat is guaranteed?

a. Yes—finish this page.
b. No—go to Type B. Q2.

Type B. Q2. Is your household willing to pay additional amount of KRW 2000 (lower bid amount) for consuming renewable heat over heat produced from fossil fuels, supposing that the supply of renewable heat is guaranteed?

a. Yes—finish this page.
b. No—go to Q3.

Q3. Then, is your household not willing to pay anything for consuming renewable heat over fossil fuel?

a. Yes, my household is willing to pay a little for the consumption.
b. No, my household is not willing to pay anything at all. In other words, my household's willingness to pay for the consumption is zero.

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