# CONSUMERS' ENVIRONMENTAL INTEREST AND EVALUATION OF HEMS

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## Overview

The home energy management system (HEMS) is crucial for energy saving and energy efficiency. HEMS is an important tool for promoting energy conservation in the household sector that can also contribute to $CO_2$ reduction from the sector. However, it is raised a question on whether consumers want to pay initial cost for HEMS. The basic assumption of this study is that the consumers have high environmental interest, and properly assess the benefit of HEMS, which therefore leads to the introduction of HEMS. To investigate the assumption, we classified HEMS into three functions, and consumers who responded to the survey were asked to assess the benefit of each function. The three functions of HEMS are the visualization function, the monitoring function, and the electricity peak shift function.

The purpose of this study is to clarify consumers' willingness to pay (WTP) for each HEMS function and discuss desirable policy that will encourage diffusion of the system among households. To this end, we conducted a survey of Japanese consumers. The survey yielded 1,406 responses from original 1,946 target consumers, which results in the recovery rate with 72.3%. After the data cleansing, this study obtained 1,278 valid responses.

This paper is organized as follows: Section 1 gives a brief overview of this study from a perspective of energy efficiency policy and promotion of HEMS in Japan. Section 2 summarizes the function of HEMS, as well as previous research on this topic (Alberiniab & Towec (2015), Lynham et al. (2016), and Gölza & Hahnelb(2016)). Section 3 describes the questionnaire survey data, and empirical methods for the analysis of this study. Section 4 provides results of the simple tabulation of WTP and the logistic regression estimation. Section 5 discusses diffusion policy of HEMS in Japan and concludes this study.

## Methods

The questionnaire survey of this study asks consumers whether they incur the initial costs for each function of HEMS. The logistic regression analysis was performed using binomial variable that takes one for those who pay the initial cost and zero for those who do not. The empirical model for the logistic regression analysis is described as follows:

$$Y = \alpha + \sum_{i=1}^{n} \beta_i X_i + \varepsilon,$$

where $Y$ is a binary variable and $X_i$ ($i$=1,…, $n$) is the $i$-th explanatory variable. The explanatory variables are various consumer attitudes that are associated with environment protection consciousness, information seeking behavior, and degree of energy reduction effort. These variables are summarized into important factors using principal component analysis and applied to the regression model. The logistic regression is performed for each function of HEMS under the control of various attributes such as sex, age, and household annual incomes. That is, this study examines three models, in which same explanatory variables are used.

Dependent variable for each model is a binary variable that captures whether the consumer chooses either to pay or not for each function of the HEMS. Concretely, in Model 1, the dependent variable is to pay or not for the visualization function. In Model 2, it is for the monitoring function and in Model 3, it is for the electricity peak shift function.

## Results

The average price that consumers paid for the three functions was almost same among the functions. However, different characteristics were observed in the regression analyses for the three functions: The visualization function was rated higher by information-oriented consumers who had a higher score of information seeking. The electricity peak shift function was rated higher by environment-oriented consumers who had a higher degree of environmental interest. The monitoring and the electricity peak shift functions have common influential factors, which are "Gender

dummy" and "Household annual income" with positive sign, and "Age" and "Non-married dummy" with negative sign.

Further, the estimation results indicated that consumers who were characterized by efforts to reduce energy usage and higher knowledge on environmental labels provided positive evaluation for each function of HEMS. They answered positively about paying the initial costs for each function of HEMS. On the other hand, "Treatment dummy" and "Intervention dummy" did not show statistically significant estimates. The experience of consumers and the amount of information did not change consumers' attitudes for WTP of HEMS.

Table 1: Estimation Resutls

| | Visualization function | | | | Monitoring function | | | | Electricity peak shift function | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | Standard Error | Wald | Exp(B) | B | Standard Error | Wald | Exp(B) | B | Standard Error | Wald | Exp(B) |
| Gender dummy | 0.269 | 0.230 | 1.367 | 1.309 | 0.410 ** | 0.229 | 3.211 | 1.507 | 0.684 *** | 0.252 | 7.354 | 1.982 |
| Age | −0.016 | 0.011 | 2.206 | 0.984 | −0.035 *** | 0.011 | 9.916 | 0.966 | −0.024 ** | 0.012 | 4.259 | 0.976 |
| Electricity bill | 0.000 | 0.000 | 0.724 | 1.000 | 0.000 | 0.000 | 0.035 | 1.000 | 0.000 | 0.000 | 0.343 | 1.000 |
| Number of families | 0.125 | 0.118 | 1.127 | 1.133 | −0.205 | 0.128 | 2.588 | 0.814 | −0.096 | 0.133 | 0.522 | 0.908 |
| Years lived in the housing | −0.003 | 0.011 | 0.075 | 0.997 | −0.008 | 0.012 | 0.500 | 0.992 | −0.007 | 0.012 | 0.346 | 0.993 |
| Housing area | 0.000 | 0.003 | 0.001 | 1.000 | 0.003 | 0.003 | 1.001 | 1.003 | 0.002 | 0.003 | 0.486 | 1.002 |
| Time of staying house on weekdays | −0.007 | 0.021 | 0.103 | 0.993 | −0.023 | 0.021 | 1.297 | 0.977 | −0.004 | 0.022 | 0.039 | 0.996 |
| Child less than 18 years old dummy | 0.464 | 0.307 | 2.293 | 1.591 | 0.325 | 0.310 | 1.101 | 1.384 | 0.077 | 0.335 | 0.053 | 1.080 |
| Non-married dummy | −0.301 | 0.296 | 1.032 | 0.740 | −0.836 *** | 0.299 | 7.798 | 0.433 | −0.550 * | 0.314 | 3.069 | 0.577 |
| Household annual income | 0.002 | 0.062 | 0.001 | 1.002 | 0.128 ** | 0.060 | 4.554 | 1.137 | 0.181 *** | 0.063 | 8.190 | 1.198 |
| Treatment dummy | −0.585 *** | 0.213 | 7.526 | 0.557 | −0.082 | 0.207 | 0.156 | 0.922 | −0.291 | 0.222 | 1.729 | 0.747 |
| Intervention dummy | | | | | | | | | −0.307 | 0.212 | 2.105 | 0.736 |
| Environmental interest degree | 0.034 | 0.032 | 1.088 | 1.034 | 0.006 | 0.032 | 0.040 | 1.007 | 0.059 * | 0.034 | 2.971 | 1.060 |
| Level of effort saving energy | 0.056 ** | 0.030 | 3.373 | 1.057 | 0.076 ** | 0.030 | 6.411 | 1.079 | 0.057 * | 0.032 | 3.200 | 1.058 |
| Environmental Label recognition | 0.098 *** | 0.026 | 14.525 | 1.103 | 0.097 *** | 0.026 | 14.326 | 1.102 | 0.077 *** | 0.027 | 8.317 | 1.080 |
| Score of sought information | 0.187 ** | 0.113 | 2.744 | 1.206 | 0.180 | 0.112 | 2.607 | 1.198 | 0.106 | 0.118 | 0.810 | 1.112 |
| Registrants of visualization dummy | −0.044 | 0.206 | 0.046 | 0.957 | −0.173 | 0.203 | 0.729 | 0.841 | 0.014 | 0.220 | 0.004 | 1.014 |
| Level to pay renewable energy cost | 0.218 | 0.235 | 0.860 | 1.244 | 0.329 | 0.233 | 1.986 | 1.389 | −0.075 | 0.249 | 0.092 | 0.927 |
| Level of desire for comfort | 0.148 | 0.233 | 0.405 | 1.160 | 0.170 | 0.235 | 0.519 | 1.185 | 0.101 | 0.243 | 0.172 | 1.106 |
| constant | −1.934 | 0.718 | 7.258 | 0.145 | −0.340 | 0.694 | 0.239 | 0.712 | −1.962 | 0.751 | 6.821 | 0.141 |

Note: ***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

## Conclusions

The results indicate that consumers have different assessments of and preferences for each function of the HEMS. The implication is that a variety of HEMS functions significantly influence consumers' attitudes to install the HEMS, so that they are important means to diffuse and develope the use of HEMS. However, even if consumers are informed about electricity peak shift function, they seem not to pay for this HEMS function. This implies that more explanation about the function and information supplement is necessary for the adoption by consumers.

The results of this study indicate that consumers characterized by efforts to reduce energy usage and greater knowledge of environmental labels positively evaluate each function of HEMS. However, the results also revealed that the general price that consumers would expect for HEMS was zero, meaning that most consumers were unwilling to buy it. Moreover, even consumers who were willing to pay for HEMS indicated less amounts than the actual initial cost of it. Extended policy discussions would be necessary for these issues.

## References


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