Consumer's Attitude Towards Investments in Residential Energy-Efficient Appliances: How End-User Choices Contribute to Change Future Energy Systems

By Mattia Baldini, Alessio Trivella and Jordan Wente

INTRODUCTION

The proliferation of increasingly energy-efficient (EE) appliances is a key strategy to address the impacts of rising residential electricity demand (Danish Energy Agency 2017). To this end, governments and institutions are interested in understanding the drivers of consumer choice between conventional and environmentally friendly alternatives when purchasing new household electric appliances. This study employs empirical data from a survey conducted by the Danish Energy Agency to model the decision criteria behind Danish consumer investment in energy-efficient labeled appliances. The analysis uses logistic regression over a set of socio-economic, demographic, and behavioral variables to predict purchase propensities. The findings are relevant for policy makers interested in targeting consumers in the appliance market, particularly for a relatively wealthy national context. The study concludes by integrating the predicted propensities with an energy-systems model to assess the nation-wide impact of efficient appliances' uptake in terms of electricity, emissions and economic savings.

The authors are with the Technical University of Denmark, Department of Management Engineering. Mattia Baldini and Alessio Trivella are PhD candidates at the System Analysis and Management Science divisions, respectively. Jordan Wente is a graduate from the Sustainable Energy Master program. E-Mail: mbal@dtu.dk.

METHOD

The dataset analysed is the Danish Energy Agency's bi-annual survey, "El-model Bolig" for the year 2012, sample totaling 1716. The dataset's demographic distributions are compared against national registries from Statistics Denmark, without sampling error, and are deemed representative. Socio-economic variables are chosen with the intention of predicting investment in a highest EE labeling appliance: age, quantity of inhabitants, housing type, house size, year built, income and other additional questions regarding profession and end-use behaviour for appliances. All pertinent questions related to energy savings behavior are combined into a singular composite variable: EE index. The consumer's propensity to invest in a household energy-efficient appliance is evaluated with a discrete choice model, using logistic regression. If the investment is considered as a binary outcome Y (1 = investment, 0 = no investment), the model assumes that:

$$logit\,(P(Y{=}1 \mid X_1 = x_{1,}\ldots,X_n = x_n)) = \log \frac{P(y = 1 \mid X_1 = x_{1,}\ldots,X_n = x_n)}{P(y = 1\, X_1 = x_{1,}\ldots,X_n = x_n)} = \beta_0 + \beta_1 x_1 + \cdots\cdots + \beta_n x_n$$

where X represents the vector of explanatory variables (age, job, income, type of house etc.) and β the weight vector fitted through logistic regression on the survey's data. The probability of investment (i.e., Y=1), is computed as a standard logit function:

$$\widehat{\pi} = P(Y{=}1 \mid X_1 = x_{1,}\ldots,X_n = x_n) = \frac{exp(\widehat{\beta}_0 + \widehat{\beta}_1 x_1 + \cdots\cdots + \widehat{\beta}_n x_n)}{1 + exp(\widehat{\beta}_0 + \widehat{\beta}_1 x_1 + \cdots\cdots + \widehat{\beta}_n x_n)}$$

To complete the analysis, the predicted consumer investments are embedded into the partial-equilibrium energy-systems model Balmorel (Balmorel 2015) to assess the system-wide socioeconomic impacts. The standard model, normally used for power generation dispatch, has been extended to handle investments in EE appliances (Baldini & Trivella 2017). Investment in EE appliances in a given region reduce the electricity consumption of that region, modifying consequently the optimal configuration of generation technologies and lowering the system costs.

RESULTS AND INTERPRETATION

The results of the logistic regression and the socioeconomic variables, significant in predicting EE appliance investment, are reported in the Table.

Assuming all the other variables fixed, a marginal increase in income by 100,000 DKK, for instance, results in a 1.079 (i.e. exp(0.076)) times greater odds of investment. The estimates show that the EE index is among the most important predictors, along with house type and age of the respondents. Surprisingly, the income variable is not as a strong predictor as expected.

The contribution of different behaviors to the EE index is presented in Figure 1. The heat map is presented per house type and shows that specific EE-related actions contribute more than others. For example, having EE lights (X800s), lowering indoor temperature (X580) and loading dishwasher/washing machine to at least 50% fullness (X359, X401) more often increase the value of the EE index and, consequently, the probability of investing in EE appliances.

Variable	Estimate	p-value	Significance
Intercept	-1.746	<0.001	***
Income	0.076	0.0110	*
Farmhouse	0.692	0.0024	**
Single-family house	0.555	<0.001	***
Town-SD-row	0.290	0.0924	.
Age: 30-39 years	0.746	0.0046	**
Age: 40-49 years	0.758	0.0015	**
Age: 50-59 years	0.789	0.0008	***
Age: > 60 years	0.919	0.0001	***
Qty-inhabitants	0.215	0.0009	***
EE-index	1.021	0.0011	**
Significance codes: 0.001 '***', 0.01 '**', 0.05 '*', 0.1 '.'			

To study how the predicted probabilities in EE investments change when varying the explanatory variables, we compute probability curves. Figure 2 shows the development of the expected probabilities for different levels of income (it is similar for other variables). The increasing trend suggests that the higher the respondent's income, the higher the probability that the same respondent will invest in more efficient household appliances. The curves are split by housing type to show the relevance of this factor.

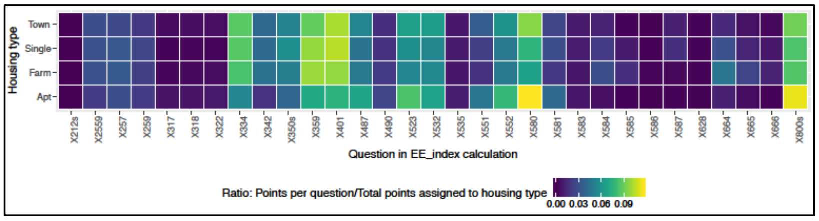

Figure 1

Integrating the estimated investment propensities with the energy-systems model Balmorel results in a larger share of EE appliances and a reduction of consumption profiles. Figure 3 illustrates the electricity demand reduction resulting from the EE investments in four representative days (one for every season) used in the simulations (year 2012). The reduction is higher for load peak hours (morning 7:00-10:00 and evening17:00-20:00) as well for winter weeks. On a yearly scale, the electricity and emissions savings amount to 125 GWh/year and 75 Kton CO_2. For the end-user, the annual net economic savings amount to 25-35 €.

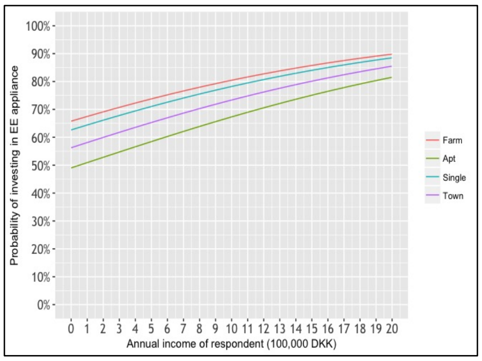

Figure 2

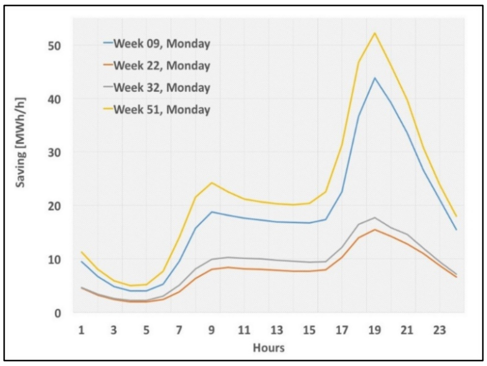

Figure 3

CONCLUSION

The reported study focused on the drivers for investments in energy efficient appliances and the estimated systems-wide consequences of this uptake. Results indicate that the housing type, quantity of inhabitants, income, age, and end-use behaviour are strong predictors for investment in energy efficient appliances. Using a logistic regression model, socioeconomic and housing characteristics were found to be highly significant when explaining investment in efficient appliances (p-value <0.05), with housing type the stronger of these predictors. Income was a positive predictor for EE investment although with much less influence on the total probability than other variables. The further implementation of the investment probabilities in Balmorel characterized quantitatively the impact of the consumer's choices within the energy system. The results lead to the conclusion that the consumers' attitude towards energy savings has an impact on the whole energy system. In total, annual energy and environmental savings correspond to approximately 125 GWh/year and 75 Kton CO_2.

References

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