Mobilizing residential electricity consumer demand response using an ICT-ecosystem with dynamic electricity price discounts

Jed Cohen, Energy Institute at Johannes Kepler University, +43-732-2468-5662, cohen@energieinstitut-linz.at
Johannes Reichl, Energy Institute at Johannes Kepler University, +43-732-2468-5652, reichl@energieinstitut-linz.at
Andrea Kollmann, Energy Institute at Johannes Kepler University, +43-732-2468-5660, kollmann@energieinstitut-linz.at
Valeria Azarova, Energy Institute at Johannes Kepler University, +43-732-2468-5679, azarova@energieinstitut-linz.at

Overview

Demand response in electricity markets refers to the potential for consumers to change electricity consumption behaviour in order to contribute to grid flexibility and balancing of electricity supply and demand. In theory, demand response could contribute substantial positive benefits to electricity markets. For example, one study compares three different scenarios that vary based on how demand response is employed in the electricity market [1]. They find that the optimal scenario uses demand response to shift electricity load from peak hours to off-peak hours, which results in total savings of 2.83% for electricity consumers in Germany. Another quantifies the financial impact of demand response and find that electricity price volatility can be significantly decreased by 7.7%, and expenditures of retailers can be decreased by 3.5% [2]. These saving have yet to be fully realized in part due to regulatory and market barriers, which are discussed and summarized in [3].

Despite the potential benefits of demand response, and the ongoing rollout of smart meter infrastructure that connects consumers to their electricity demand information, a strategy for mobilizing demand response as an effective grid flexibility tool is lacking. This paper presents the results of a field study from the European Union PEAKapp Horizon 2020 project, which developed a smart phone app to connect electricity consumers to their smart meter data and service providers. A major part of the PEAKapp ICT-environment was dedicated to demand response efforts in the form of discount alerts sent to one group of test users. The alerts suggested that the residential consumers alter their planned electricity consumption, and offered them a discounted electricity rate during a specific time period in the coming day. Such a strategy is useful in balancing the load during times of high renewable energy production, and also has the potential to contribute to peak shaving by shifting some household electricity consumption from times of high system load to times of lower system load.

A small number of recent studies have field tested price information and other forms of stimuli in efforts to shift household electricity load or change consumption behaviour. One looks into the effect of placing a visual depiction of electricity prices in consumer residences on load shift and electricity consumption [4]. Their sample consists of 24 Swedish households, half of which were treated with the price visual. They find that treated households shifted an average of 5% of their total daily electricity load from peak to off-peak times. In a larger scale field test in the city of Ontario, Canada, in-home displays of electricity consumption and current prices were installed by households. Households with the display decreased electricity consumption by 3.1% on average [5]. In a similar, yet smaller scale, study in Austria it was found that providing informational feedback via ICT reduces electricity consumption by 4.5% on average amongst households [6]. Years after this Austrian field test a follow-up study was completed that found that this decrease in electricity consumption was persistent amongst households with consumption feedback [7].

Methods

The field test presented herein also investigates a feedback mechanism, as test users were able to view consumption data in an easily digestible form using the app. It also goes above and beyond all prior field tests by providing direct monetary incentives to households in the form of bonus price discounts, incentivizing households to use electricity during off-peak times. The experimental design includes over 1,500 Austrian households from across the state of Upper Austria split into three groups: one group with access to the app and bonus price discounts, one group with access to the app with no price discounts, and one group without access to the app.

We collected 15-minute electricity consumption data from all participating households over a 15-month period. These data are analysed using panel data estimation techniques following prominent papers estimating price elasticities and treatment effects on residential electricity consumption [5], [8], [9]. Specifically, we estimate various econometric models where the dependent variable is the natural log of total household electricity consumption over a 15-minute interval and explanatory variables include electricity price, the discount treatment, the information treatment of the app, and full suites of fixed effects terms to control for unobservable temporal and household-specific factors. Price discounts were given at varying levels from 10% - 50% off of the normal full end-user price. Discounts were given at either 7am, 2pm or 7pm, with 7pm reflecting system peak time. Additionally, discount alerts were sent out accompanied by one of three possible messages: one message that suggested the discount was due to economic (market) reasons on the European grid, one message that suggested the discount was due to excess solar energy somewhere in Europe, and one message that suggested the discount was due to excess wind energy somewhere in Europe. The effect of the discount alert characteristics on changing energy behaviour is also tested.

Results

The results confirm the potential for an app-based system to enable demand response through defined price incentives during specified periods. Specifically, for a 10% price discount household electricity demand is estimated to increase by 0.5% during the discount period averaged across all discount alert types and times. This finding is statistically significant at the 1% level, and is robust to omitted variables due to the flexible fixed effects specifications employed. Of the three discount reasons, the market reason induced the greatest behavioural change with a 10% discount of this type resulting in an estimated 1% increase in electricity demand during the discount period. These results and their implications for loadshifting behaviour and the potential to utilize demand response as a grid flexibility tool are explored.

Conclusions

This paper relates the analysis and results of a large-scale field test of an app-based ICT ecosystem for forwarding energy consumption information and time-specific price discounts to residential end-users. The field test involved over 1,500 Austrian households who were given energy-relevant information and electricity price discounts via the app system. The effect of price alert discounts on electricity consumption behaviour is estimated via panel data econometric models. The results show that a price discount of 10% can elicit an increase in electricity consumption of up to 1% if the optimal discount alert characteristics are used. Such an effect could be useful for mobilizing demand response during times of high renewable energy production, and thereby decreasing the storage and transportation requirements on the grid.

References

[1] S. Feuerriegel and D. Neumann, “Integration scenarios of Demand Response into electricity markets: Load shifting, financial savings and policy implications,” *Energy Policy*, vol. 96, no. Supplement C, pp. 231–240, 2016.

[2] S. Feuerriegel and D. Neumann, “Measuring the financial impact of demand response for electricity retailers,” *Energy Policy*, vol. 65, no. Supplement C, pp. 359–368, 2014.

[3] M. Valles, J. Reneses, R. Cossent, and P. Frias, “Regulatory and market barriers to the realization of demand response in electricity distribution networks: A European perspective,” *Electric Power Systems Research*, vol. 140, no. Supplement C, pp. 689–698, 2016.

[4] A. Nilsson, P. Stoll, and N. Brandt, “Assessing the impact of real-time price visualization on residential electricity consumption, costs, and carbon emissions,” *Resources, Conservation and Recycling*, vol. 124, no. Supplement C, pp. 152–161, 2017.

[5] S. Martin and N. Rivers, “Information Provision, Market Incentives, and Household Electricity Consumption: Evidence from a Large-Scale Field Deployment,” *Journal of the Association of Environmental and Resource Economists*, vol. 5, no. 1, pp. 207–231, 2018.

[6] J. Schleich, M. Klobasa, S. Gölz, and M. Brunner, “Effects of feedback on residential electricity demand—Findings from a field trial in Austria,” *Energy Policy*, vol. 61, pp. 1097–1106, 2013.

[7] J. Schleich, C. Faure, and M. Klobasa, “Persistence of the effects of providing feedback alongside smart metering devices on household electricity demand,” *Energy Policy*, vol. 107, pp. 225–233, Aug. 2017.

[8] B. Gilbert and J. G. Zivin, “Dynamic salience with intermittent billing: Evidence from smart electricity meters,” *Journal of Economic Behavior & Organization*, vol. 107, pp. 176–190, 2014.

[9] K. Jessoe and D. Rapson, “Knowledge Is (Less) Power: Experimental Evidence from Residential Energy Use,” *American Economic Review*, vol. 104, no. 4, pp. 1417–38, Apr. 2014.