Electricity Simulations on the Distribution Edge: Developing a Granular Representation of End-User Electric Load Preferences using Smart Meter Data

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Introduction

The electric distribution grid is transitioning toward a model in which customers can themselves provide a variety of services to the grid by investing in distributed energy resources (DERs) such as distributed solar generation, programmable appliances, and energy storage. However, customers' incentives to make these investments depend on how they are being charged for electric service. Specifically, the way the electric distribution company allocates the cost of service into the different elements of the rate (tariff) design, such as volumetric or demand charges and time-variant or flat charges, determines the returns on investment for different types of DERs. The rate design will also be a main factor in determining how, when, and where DERs are deployed and used, and whether DERs will contribute to improving system reliability and reducing electric system costs.

Despite the topic's importance for the electric distribution system of the future, the body of literature on the impact of electric rate design on the proliferation of DERs is still limited, see e.g., Darghouth et al. (2016), Hledik and Greenstein (2016), Schittekatte et al. (2018), and Simshauser (2016). Though these studies look at important topics such as the potential for cost shifting, they all hold electricity consumption patterns constant, and, hence, do not take into account how customers' use of electricity may shift in response to new electric rate designs. As a result, their approaches are more limited in their ability to capture the impact of rate design on the return on investment for different DERs.

Our research improves upon common assumptions of fixed electric demand by incorporating microeconomic theory into an existing engineering simulation model. Typically, engineering simulations model a cost-minimization problem with an ad-hoc monetized penalty for deviations from a reference electricity use profile, and, thus, do not provide a very good representation of consumer preferences. In contrast, by including preference parameters that are calibrated to data from observed electric customers, we can more accurately represent how residential customers would respond to different electric rate designs through consumption shifting, conservation, and DER deployment.

Methods

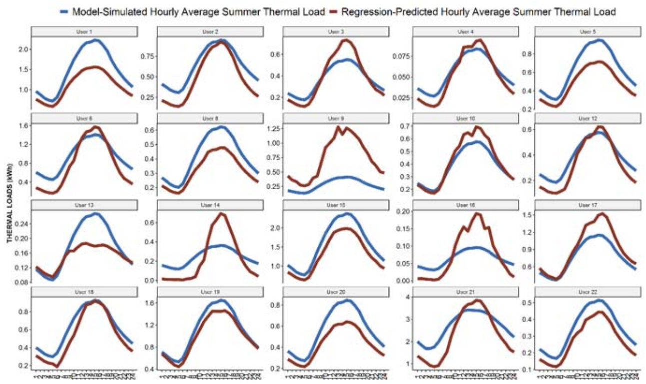
Specifically, we replace the ad-hoc penalty in an electric bill minimization model with a consumer welfare (i.e., an economic utility) constraint to represent consumer preferences for electric services. This specification allows us to separate consumer preferences related to thermal (heating and cooling) needs, which are weather-dependent, and other electricity services, which depend on individual preferences for appliance usage. We then calibrate the model using hourly AMI data for over 50,000 customers of a large US electric distribution company. The calibration methodology first conducts a regression analysis of observed loads on outdoor weather and other control variables to estimate household-specific thermal electricity loads; non-thermal loads are calculated as the difference between observed total loads and estimated thermal loads. We then calibrate the parameters of the utility constraint such that the model replicates the daily load shape of the regression-estimated non-thermal electricity loads, and adjust the parameters representing building thermal properties to replicate the regression-estimated cooling loads.

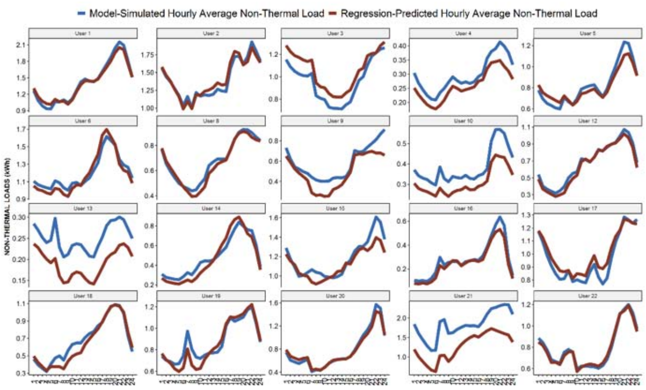
Results

The two figures on the next page illustrate the average model-generated load shapes across the hours of the day and compares them to the average load shapes estimated in our regression analysis. We plot the model-simulated and regression-estimated summer average space cooling loads in the top graph, with the respective yearly average non-thermal loads in the bottom graph. The figures show that, in general, our household-level calibrations allows the model to closely replicate both space cooling loads and non-thermal electricity loads for each household in our random sub-sample.

Conclusions

The results of this research demonstrate the capabilities of our modelling tool for creating large numbers of synthetic end-user profiles that can replicate observed household level load data, relying on a combination of econometric techniques and engineering simulation methods. In future research, we will further improve the calibrations, and then use the





resulting individually calibrated preferences to assess how end-users may respond to different electric rate designs by changing their electricity load and investing in DERs.

References

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Dual Plenary Session 3: New Business Models: Prosumers and Future Grids

SUMMARISED BY PALLAVI ROY, PHD GRADUATE, RYERSON UNIVERSITY

Plenary 3 was titled New Business Models: Prosumers and Future Grids. New technologies are evolving and challenging old business models, while also creating opportunities for new business models to flourish. The 3rd plenary tackled the topic of new business models, discussing a vast range of topics that are impacting the current grid and exploring key elements of future grids. Jorgen Bjorndalen from DNV GL chaired the session. Main speakers were Hugues Giradin, representing Canadian wind company Boralex, Marc-Andre Forget of OSSIACO, a Canadian energy services company (ESCO) and Dr. Hans Auer from Vienne University of Technology.

The main focus of the discussion was the disruption in the power sector and consumer-focused innovation. Considerable emphasis was placed on the customer and their evolving needs. New modular generation technologies are empowering consumers to become prosumers and are seeing rapid adoption in many jurisdictions such as Germany, Australia, California, among others. The need for grid flexibility was stressed upon by all panel members. New technologies such as electric vehicles, battery storage are all adding critical complexity to the power grid, which in turn is creating new opportunities. Many new ESCOs are developing services and products to cater to customers' demands while utilizing new innovative business models.

Mr. Giradin compared the power sector disruption to the once faced by the telecommunications sector in the 2000s. Telecom industry too saw a move from wired connections to wireless technology which completely modified the business model. The telecommunication sector example identifies that the winners in this disruption will be power sector organizations that explore new ideas and offer customers new services. Mr. Forget declared that "We are counting down to a global energy revolution", which is expected to see increased adoption of distributed generation technologies leading to the rise of prosumers and bi-directional exchange of energy with the grid. Dr. Auer remarked that power sector utilities need to focus on their customers more and provide a suite of services and products to meet evolving customer needs.

The unintended consequences of these developments (increasing distributed generation) such as stranded assets and impact on low-income customers were also discussed. It was agreed upon by all panel members that the evolving grid requires new policies to make a sustainable transition to a future grid. New policies are required allowing the power sector to evolve in ways that optimize new technologies, putting the consumer at the centre of new business models.