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INTEGRATING CONSUMER ADOPTION MODELING IN RENEWABLE ENERGY EXPANSION PLANNING

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ABSTRACT

The electricity market in the U.S. is changing rapidly from a utility-scale centralized generation-distribution model to a more distributed and customer-sited energy model. Residential energy consumers in the U.S. have shown increased interest in solar-based electricity at home, resulting in increased adoption of distributed solar on the rooftops of owner-occupied residences (known as rooftop PV). However, increased rooftop PV adoption has led to equity concerns among policymakers, as well as dissatisfaction among utilities due to falling revenues. In this research, a bottom-up simulation-based expansion planning approach through consumer adoption modeling has been proposed to help utilities satisfy consumer demand for distributed solar while also addressing the issues that have arisen from increased rooftop PV adoption.

1 INTRODUCTION

In the face of climate change, solar power is emerging as a viable technology to meet future global energy needs. In contrast to traditional large-scale and centralized power plants, solar technology supports a distributed model of energy generation and enables consumers to produce their own energy. Residential energy consumers in the U.S. have demonstrated an increased interest in solar power for a variety of reasons, including energy bill savings, the desire to own and control the energy infrastructure, interest in investing in a new and innovative technology, concern for the environment, and peer influence. As a result, adoption of rooftop PV on owner-occupied residences in the U.S. has steadily increased over the past several years.

However, there are significant challenges associated with rooftop PV. Though federal and state incentives have helped to reduce the high up-front cost of rooftop PV installation, adoption still tends to be restricted to higher-income households. Further, in the U.S. only about 25% of all rooftop area is suitable for installation of PV panels due to structural, shading, and/or ownership issues. Limited access has raised equity concerns among policymakers, particularly because publically-funded rebates are only being distributed to a small number of U.S. households.

Moreover, as the number of consumers who generate their own energy using rooftop PV increases, utilities' revenues decline. Because rooftop PV consumers do not pay their fair share of the cost of maintaining and upgrading the existing electricity infrastructure, the utilities are forced to increase electricity tariffs. This creates an unfair financial burden on consumers who do not have the resources to install rooftop PV. As a result, many utilities in the U.S. are changing their policies to discourage rooftop PV adoption, such as charging interconnection fees and reducing net metering rates.

Alternative renewable energy models, such as community solar and green pricing programs, offer a potential solution to these challenges. These models involve both consumers and utilities as stakeholders. For example, community solar enables a customer to subscribe to a portion of a shared renewable energy facility (much like a resident may invest in a community garden) located elsewhere in the community. The subscriber's financial benefit is proportional to the size of his/her investment. Utilities, mandated by federal and state policies to increase renewable sources in their energy mix, should consider adopting these alternative models to increase their customers' buy-in as investors in creating new energy infrastructure.

However, utilities must be strategic about the structure (e.g., capacity, ownership) of the alternative renewable energy models that they decide to offer. It is important for them to understand how heterogeneous individual customers would respond and what the impacts of these individual decisions would be on the long-term success of the overall system. In particular, while consumer energy choices are driven by perceived benefits such as financial savings and increased convenience, they are also often socially motivated. Conventional methods for expansion planning (i.e., mathematical modeling) assume aggregate consumer behavior based on extrapolations of historical data and do not account for consumers' social behaviors, such as diffusion of innovation and social learning within spatial and social networks.

2 PROPOSED RESEARCH PLAN

Agent-based modeling (ABM) is a technique that is well-suited to studying the effects of energy consumers' heterogeneous behaviors, boundedly rational decision processes, and social interactions on the adoption of energy technology over space and time. The nonlinear interactions arising from consumers' decisions could result in an overall system-wide behavior that emerges over time. ABM has been previously used as a tool to study the consumer adoption of various energy technologies. For example, several ABMs have been developed to study the effects of different policies on rooftop PV adoption among residential energy consumers. However, the existing work does not aim to help utilities make decisions about how to effectively structure alternative renewable energy models to address the issues associated with increased rooftop PV adoption. The objective of this research is to develop a validated ABM that can serve as a decision support tool to assist utilities with their expansion planning decisions. The model will allow them to test different alternative energy model structures to determine how well they satisfy customer demand for solar-based electricity, address equity concerns by increasing consumer participation, and maintain utility revenues.

A preliminary version of this model has been developed (Mittal and Krejci 2017). In this model, consumer agents in an urban neighborhood decide in each time-step whether they will adopt solar power, based on their own heterogeneous preferences and their interactions with other agents. Using this model as a baseline, a new ABM was developed to incorporate various financial, attitudinal, and demographic factors that are known to influence consumers' decisions to adopt solar power (Mittal, Huang, and Krejci 2017). Additionally, the effect of social influence on consumers' adoption decisions was represented via two types of agent interactions: visual interactions (i.e., observing other agents' rooftop PV installations) and interactions via a social network. Simulation results demonstrate the usefulness of this modeling approach to guide utilities' decisions about when and how much to invest to satisfy consumer energy demand, maximize consumer participation, meet renewable energy portfolio requirements, and maximize profits.

Future research will build on these two models. In particular, there are several behavioral theories (e.g., theory of planned behavior, value-based norm theory, diffusion of innovation) and social network structures (e.g., community structure, small-world) that map to factors that are known to affect consumers' solar adoption decisions. These will be used to develop agent architectures for different types of consumer and utility company agents, which will provide a foundation for an ABM that can be validated using empirical data from a region that has introduced an alternative renewable energy model.

REFERENCES

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