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Integration of residential PV and its implications for current and future residential electricity demand in the United States

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ABSTRACT

The authors estimate price-responsiveness of the residential customers with increasing residential PV penetration and project future electricity sales to the residential sector considering various future PV penetration scenarios. This projection is potentially useful for utilities in their resource planning and ratemaking processes as they formally incorporate the expected reduction in residential electricity demand due to increased penetration of distributed generation.

1. Introduction

After the federal government passed the Energy Policy Act in 2005, U.S. energy policy shifted towards fostering renewable energy investments. State-level policies followed, incentivizing the renewable energy technologies and electricity generation from renewable resources. For example, state renewable portfolio standards (RPS), one of the most successful state-level policies for renewable energy developments, have promoted renewable energy generation since the late 1990s by requiring states to generate a certain portion of their electricity from renewables (Wiser et al., 2007).

Wind has been one of the most widely adopted renewable resources and it currently has the highest share in the renewable energy portfolio. The wind sector is now considered to be a mature industry (Dismukes, 2012). Solar energy, however, is still an emerging technology, and could potentially lead to sustainable electricity generation across the country (Wiginton et al., 2010). Residential rooftop solar penetration in the U.S. has increased significantly over the past decade. In the last quarter of 2012, residential rooftop PV capacity installations exceeded 1.5 GW in the U.S. The projected increase in distributed generation capacity by residential solar is 9 GW by 2016 and 20 GW by 2020 (APPA, 2013).

While state RPS policies incentivized utilities to generate renewable electricity, their impact has been limited in terms of customer-based distributed solar generation (Borchers et al., 2014). Federal investment tax credits (ITC) and state net energy metering (NEM) regulations have played a more important role in the development of distributed generation. Decreasing installation costs, technological advancements, alternative financing options and state and federal incentives have contributed to increasing trends for investments in residential solar in the U.S (ICF International, 2010). For instance, solar installation costs have decreased by roughly 70 percent since 2008, and federal tax credits have reduced initial installations costs for solar by about 30 percent[1] (APPA, 2013). Third-party solar is also becoming a popular financing option; it stimulates development of residential solar by offering residential customers the opportunity to generate electricity from solar without purchasing the equipment. Third-party solar has two financing models: (1) power purchase agreement (PPA) and (2) lease. Neither models requires an initial investment cost. The PPA model offers customers an offset in their electricity bill in return to the electricity generated by the solar system. Developers typically sell that electricity to the customers for a lower rate (SEIA, 2014a). The leasing model is designed as a contract between the customer and the developer. The customer pays a fixed monthly fee for solar energy generated and does not for the solar energy portion of the electricity (SEIA, 2014a). Third-party solar financing has been an important catalyst of increasing residential solar penetration. For example, about 90 percent of residential solar in New Jersey was through third-party solar agreements as of 2013 and in states like California, Arizona, and Colorado, third-party distributed generation exceeded 60 percent (SEIA, 2014a) of total solar energy consumption.

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[1] The federal tax credit will step down to 10 percent from 30 percent in 2017.

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Distributed generation has a number of potential benefits including clean energy generation, avoided peak generation capacity, avoided or deferred transmission and distribution capacity investments reduced transmission line losses due to proximity to the generator source, and lower customer bills due to generating electricity on site (Chiradeja and Ramakumar, 2004; Pepermans et al., 2005; Darghouth et al., 2012; APPA, 2013). On the other hand, increased penetration of distributed generation creates challenges for the electric utilities as their sales decline. In a phenomenon dubbed a "death spiral" by some industry experts, as more customers adopt distributed generation, utilities' costs to maintain and operate the grid must be spread across a smaller customer base, raising customer rates and increasing the economic incentive to opt for more distributed generation (Kind, 2013; Costello and Hemphill, 2014; Darghouth et al., 2015). Utilities also argue that distributed generation creates a fairness issue with transferring the transmission, distribution and reliability costs to customers without distributed generation technologies (Raskin, 2014). More specifically, customers with distributed generation (i.e., rooftop solar) reduce the amount of electricity they purchase from the grid but still rely on the grid due to the intermittency of rooftop solar. This implies that they pay less than their fair share for the system's fixed costs while the utilities maintain their fixed costs for generation, transmission and distribution (Stanton, 2013).

Several studies have looked at the costs and benefits of distributed generation, and the role that state and federal incentives have played on accelerating renewable energy investments in the U. S. A study by Crago and Chernyakhovskiy (2014) studied the effectiveness of the state policies that incentivize solar PV adoption in the U.S. The results of their empirical analysis showed that policies (e.g., sales tax exemptions, income tax credits, loan financing programs and cash rebates) increase the rate at which solar PV capacity is installed, particularly the policies that are specifically targeting solar PV technology (Cai et al., 2013). Recent studies also showed that future residential demand from their utility is likely to decrease with the penetration of various technologies such as residential PV, combined heat and power, heat pump storage and electric vehicles, while the government continues to subsidize cleaner electricity generation (Veldman et al., 2013; Asare-Bediako et al., 2014; Darghouth et al., 2014). Their scenario analysis showed that residential PV penetration is projected to grow and that future residential load profiles, particularly summer load profiles, will be significantly affected by distributed generation. Most of the simulations in these studies have shown that residential electricity demand from the utility is reduced with the adoption of various combinations of residential PV, combined heat and power, heat pump storage, and electric vehicles technologies. Increasing integration of these technologies is expected to increase the flexibility of the electric system (Asare-Bediako et al., 2014). Further, PV has one of the highest financial returns among other technologies without even considering the impact of policy incentives on distributed generation technologies (Vahl et al., 2013). Studies in this literature focus primarily on the effectiveness of the incentives for residential solar development and the impact of distributed generation on the grid. Current research has placed much less emphasis on the impact of solar integration on the utilities.

In this article, we explore the implications of the integration of distributed generation on electricity demand on the residential sector and consider distributed generation as an endogenous factor that influences residential electricity demand. This study extends the previous work on residential electricity demand by including on-site generation into the residential demand analysis and estimating price-responsiveness of residential customers with increasing residential PV penetration. We also analyze the impact of various state specific variables (i.e., state NEM policy, state regulatory status) on residential PV capacity additions. Finally, using the estimation results, we project future electricity sales to the residential sector considering various future PV penetration scenarios. This projection is potentially useful for utilities in their resource planning and ratemaking processes as they formally incorporate the expected reduction in residential electricity demand due to increased penetration of distributed generation. Utilities may also benefit from this analysis in terms of understanding the implications of different levels of PV penetrations for their revenues and financial viability.

1.1. Policy background

Solar generation's share of U.S. generation has grown substantially, with a 41 percent growth rate over the last year, and has currently reached a total capacity of 17.5 GW in the United States (SEIA, 2014a,b). Solar installations have increased mostly due to the decline in the PV costs and state and federal incentives. The federal solar investment tax credits (SITC) program provides credits for 30 percent of the qualified investment and installation costs for the residential taxpayer who owns solar panels. The SITC policy has been in effect since 2006 and is set to expire in 2016. Sener and Fthenakis (2014) note that solar tax credits have played an important role in the growth in solar investments in the U.S. Some states have formed solar renewable energy certificate (SREC) markets as an important feature of the renewable portfolio standards, where electricity generated from PV can be traded separately from electricity as environmental attributes of renewable energy generated. A facility with 10 kW capacity is able to generate approximately 12 SRECs annually (SRECTrade, 2014).[7]

Another state program is net energy metering (NEM), in which customers have the option to pay only for the electricity that they purchase from the utility and which allows the solar electricity generated on-site behind the retail meter to be used by the household or to be sold to the grid (SEIA, 2014a). Customers are billed for their net energy purchase from the utility and, in some cases, negative net balances can be carried forward to the next month's bill (Arnette, 2013; APPA, 2013). States vary considerably in the applications and regulations of their NEM policies and states may limit their generation capacity, eligible fuel type, and total load for net metering (APPA, 2013).

Whether a state has competitive electricity supply may also indirectly influence the rate of residential PV integration. Restructured states offer retail competition, so that customers can choose to buy power from alternative electricity suppliers. In non-restructured states, customers buy power from their local utility and their electricity rates are set by the commissions. One might expect that a competitive market environment is more conducive to new distributed energy technologies to enter the market compared to a monopolized vertically integrated electricity market, and some studies support that view. Those studies have shown that there are higher adoption rates of rooftop solar in restructured states compared to the non-restructured states (Morse, 1997; Spratley, 1998; Martinot et al., 2005; Cai et al., 2013). However, retail competition may actually discourage customers from adopting distributed generation because customers in restructured states are able to choose the least expensive electricity provider. In this case, investing in distributed generation may not seem to be a cost-effective option. However, between 2000 and 2012, restructured states appear to have higher electricity prices than those in non-restructured states (Eid et al., 2014). See Appendix A,Fig. A1. It may be that higher

[7] https://www.srectrade.com/blog/srec-markets/september-2014-srec-pricing-update-and-auction-results.