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Structuring financial incentives for residential solar electric systems

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ABSTRACT

This paper introduces a simple methodology to aid in the decision of how to distribute financial incentive funding for residential solar electric systems in order to maximize demand. Incentive funding can be used more effectively if adjusted according to the decrease in price and the increase in demand of solar electric systems. The decision of how to reduce these incentives due to changing annual funds, while increasing or even maintaining the growth of solar electric system demand, is of great interest to policymakers and public benefit funded program administrators. In order to aid in this process, a three step methodology is described in this paper. The first step uses the concept of learning-by-doing to determine the relationship between historic pricing and demand. The second step employs discrete choice modeling with spatial analysis to determine the relationship between market, financial, and social factors with historic demand. The final step uses nonlinear programming to forecast incentive structuring for maximizing demand. Finally in order to validate the model the study uses solar market data from Portland, Oregon. The results show a decrease in incentives over the period of study from 2014 until 2020, except for 2017 and 2018 when federal and state tax credits expire respectively.

1. Introduction

The adoption of residential solar electric systems has increased drastically over recent years. The decrease in the price of solar energy, the availability of incentives, and the increase in active and passive peer effects have had a positive impact on the rate of adoption of solar electric systems. A question that policymakers and public benefit funded program administrators commonly have is how to adjust incentives in order to maximize adoption. In order to answer this question, it would be beneficial to first understand what impact these incentives have previously had on consumers. However, there is limited research on the understanding of solar adopters and most of the focus has been on aggregated economic and social factors. In order to understand how incentives impact adoption of solar electric systems, it would be beneficial to understand how heterogeneous consumers respond to change. Without extensive field research and with the lack of available data on solar electric system adoption beyond general location, price, and incentives, the possibility of understanding the heterogeneity of consumers is limited. This study therefore only considers the relationship between census data and adoption on a zip code basis to gain a basic understanding of consumer adoption of solar electric energy.

This study first reviews the current solar photovoltaic (PV) policies, actors, industry, market, and issues in order to bring them together into one conceptual model of positive and negative effects. Research on solar electric systems discusses different aspects of the impact of increasing solar adoption, but very few, if any, discuss them together. This study then reviews different technologies and diffusion models.

The overall objective of this study is to determine what incentives to offer in order to maximize demand of solar electric systems, while remaining within a public benefit funded program administrator's predefined budget. The methodology followed in this study consists of three steps. The first step uses the concept of learning-by-doing to determine the relationship between historic pricing and demand. The second step uses discrete choice modeling with spatial analysis to determine the relationship between economic and social factors with historic demand. The final step uses nonlinear programming to forecast incentive structuring for maximizing demand.

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2. Solar market, industry, and policies

2.1. U.S. Solar market

Residential solar electric system adoption in the U.S. has continued to grow, with cumulative residential installations reaching 360,000 by the end of the third quarter of 2013. The size of the installations also continues to increase, up to an average of 6.0 kW, while the price per watt continues to decline [1]. In the first quarter of 2014, more than a third of all residential installations came online without any state incentives [2]. Even with California transitioning away from state-level incentives, growth continues to occur. California constitutes a majority of the national installations, reaching 55% of all installation in the third quarter of 2013 [1]. Third-party ownership has also increases substantially over the last couple of years, reaching as high as 90% of new residential installations in some states. The main risks associated with the residential market continues to be the uncertainty associated with net metering and potential electricity rate structure reforms [2].

Even with these successes in residential solar adoption, there is significantly more potential that has been left untapped. The National Renewable Energy Laboratory (NREL) conducted a study on the technical potential of renewable energy in the U.S. [3]. The technical potential is an upper-boundary estimate of development potential, by taking into account topographic, system, environmental, and land-use constraints. This gives an idea of what can be achieved, however it may not always be economically feasible and/or practical. It was estimated that there was a potential capacity of 664 GW for residential and commercial rooftop PV installations. This is substantially more than the total installed capacity of all PV in the U.S. of close to 13.4 GW by the first quarter of 2014.

2.2. Market structure

In more developed markets such as Arizona, California, and New Jersey, solar PV systems are mainly adopted in middle-class neighborhoods with median annual incomes ranging from $40,000 to $90,000 [4]. Developing markets such as New York and Massachusetts are following a similar trend, except for Maryland which has a larger percentage of installations in the higher income range of $90,000+ [5].

An important factor that influences the adoption of any technology is peer effects (i.e. social interaction). Noll et al. [6] specified two types of peer effects that exist in the solar market. Active peer effects are group incentives, market information, workshops, and other initiatives aimed at increasing the adoption of solar energy. Passive peer effects are observed consumer behavior and indirect peer influences. As part of the study, the authors examined the impact of Solar Community Organizations (SCOs) on the residential solar market (active peer effect). They found that successful SCOs leveraged trust networks with key members of the community and created complete information and financial tool packages for consumers. Solarize is an example of an SCO, which is a volunteer driven initiative for the collective purchasing of residential solar systems [7].

2.3. Solar policies in the U.S.

Fig. 1 illustrates the interaction between the important actors in the solar industry, created by using information from the Database

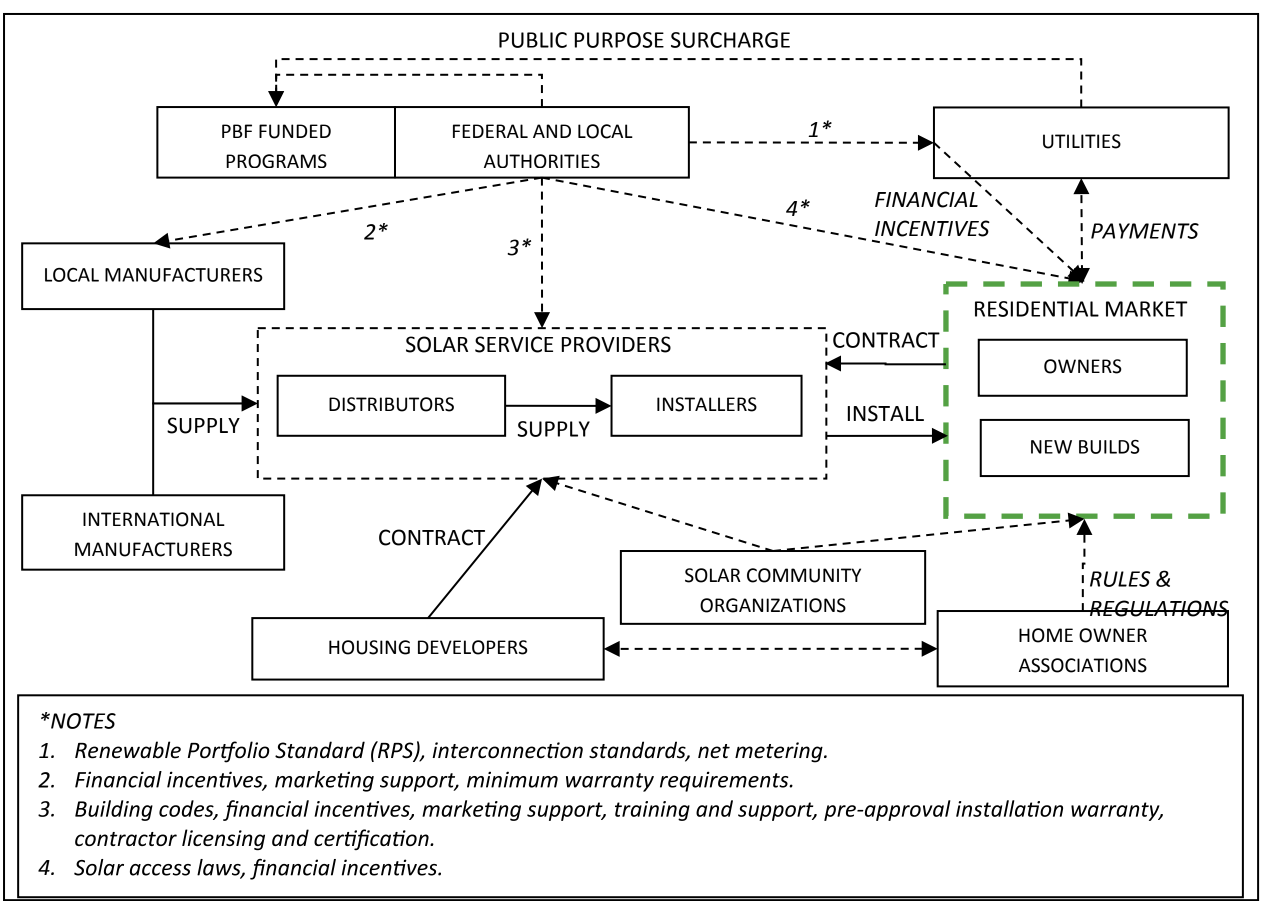

Fig. 1. Solar market structure with current policies.