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Market Penetration and the Incentives of Residential Solar Electricity in the United States

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Abstract

This paper studies the market penetration of residential photovoltaic (PV) electricity generation in the United States. The federal government and many of the state governments of the U.S. are motivated to reduce dependence on fossil fuel technology and reduce greenhouse gas emissions. Photovoltaic systems on the commercial and residential scale have been touted as part of the solution to the problem. One obstacle to adoption, is that residential PV systems have not yet reached a *cost per installed watt of capacity* equal to that of utility power companies in the U.S. Therefore, state governments and utilities are using economic incentives to drive adoption. In this research, a survey was undertaken of available incentives and compared to available data on solar installations per state in the U.S. The result of this comparison showed a strong correlation between the states with the most generous subsidies and the highest number of residential PV systems installed per capita. It appears that economic incentives and energy costs are the two main drivers of residential PV system adoption in the U.S.

Keywords: incentives, net metering, photovoltaic, residential, solar.

1. Introduction

Grid-connected solar energy has tripled in the period of from 2000 to 2008. Solar is poised for further explosive growth due in part to falling costs, government and utility incentives and environmental concern though the technology still represents a small fraction of the total installed capacity [1,2]. Solar energy does not exist in the vacuum and the technology competes with many other forms of electrical power generation. In fact, solar accounted for only 0.22% of the electrical power generation in United States in 2013. The top three sources that year were coal at 38.44%, natural gas at 27.66% and nuclear at 19.18% [3].

The primary question a user a solar must answer is, *How much of the available electricity can be converted to electricity in my location*? Five fundamental factors have the greatest impact on PV system output and they are geographic location, shading, tilt angle and orientation, materials and technology of the PV panel and efficiency of the non-PV components [1].

1.1. *Geographic Location*

High levels of sunlight are critical to the productivity of PV systems. The further from the equator a location is, the less sunlight yearly it will receive. Data has been collected the National Renewable Energy Laboratory for the U.S. Department of Energy to determine the best locations for PV system. Figure 1 is an illustration of the results. The redder an area is, the higher the solar irradiance level is and a higher likelihood of good solar energy production. From the figure, the Southeastern and Southwestern portion of the country appear to be prime candidates for solar technology. The blue and green areas are at the lower end of the solar irradiance levels. The Northeast and Alaska fall into these areas. Solar irradiance is the amount of energy from sunlight per a given area per a given time [4]. A homeowner interested in solar unfortunately has little ability to change his or her geographic location.

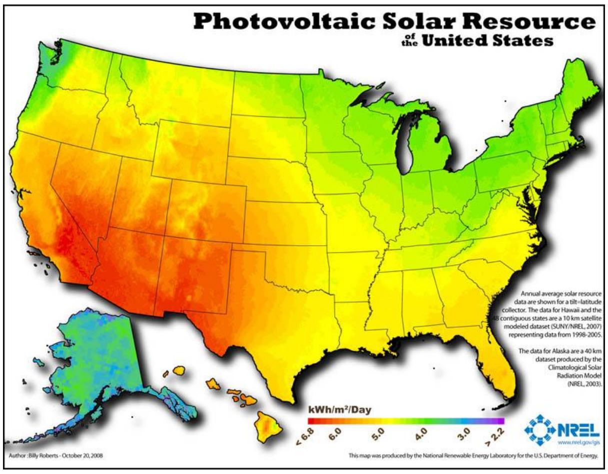

Figure 1. Photovoltaic Solar Resources of the United States [5]

1.2. *Shading, Tilt Angle and Orientation*

A PV panel output is extremely susceptible to shading. A PV panel may lose up to 80% of its output if shaded by a leafless branch. A survey of possible sources of shade should be undertaken to identify any potential sources of shade and a site selected to minimize shade on the PV panels between 9am and 3pm [6]. In the northern hemisphere, southern exposure maximizes PV output. A fixed tilt angle of 15 degrees maximizes year round output. If tilt angle is adjustable, a tilt angle of latitude minus 15 degrees with favor in summer and latitude plus 15 degrees will favor in winter. PV systems are often retrofits on existing structures and an optimum orientation and tilt angle may not be achievable [6].

2. Data Analysis

2.1. *Top Ten States for Solar Potential*

The top ten states for solar potential are listed below in Table 1. These states are known for long, sunny summers and mild winters. They are also located at the far southern regions of the United States closest to the equator. The listing was created from the same data used to create the Photovoltaic Solar Resource map previously seen in Figure 1. States with large land areas in the red to yellow range of Figure 1 are present at the top of the rankings in Table 1.

Table 1. Top Ten States of Solar Potential [7]

1. Nevada 2. Arizona 3. New Mexico 4. California 5. Colorado 6. Texas 7. Oklahoma 8. Wyoming 9. Florida 10. Kansas

2.2. *Top Ten States for Solar Installation Capacity*

The top ten states for solar installation by MW capacity are located below in Table 3. The installed capacities, commercial and residential, were totaled and the States ranked. It would be logical to assume the states with the highest potential solar capacity would also the states with the highest installed capacity. This is not the case according to the National Renewable Energy Laboratory (NREL.) In fact, many states located in the Northeastern region of the United States are present in the top ten. Each state in the Table 2 not present in Table 1 has the ranking for solar potential next to the name. Four of the top ten states in Table 2 are states that rank in the bottom half of states for solar potential. Logically, there must be factors other than potential that drives solar technology adoption.

Table 3. Top Ten States for Solar Installation Capacity [8]

1. California 2. New Jersey (Potential #41) 3. Arizona 4. Massachusetts (Potential #32) 5. Nevada 6. Texas 7. New York (Potential #34) 8. Pennsylvania (Potential #35) 9. New Mexico 10. Colorado

2.3. *Top Ten States for Capacity Installed per Capita*

Since the States are not equal in land area or equal in population, the total installed capacity is a flawed metric in understanding solar technology penetration. Dividing the total installed capacity by the population of each state created the rankings in Table 3. A majority of the states in Table 2 are present in Table 3. Five of the top ten states in Table 3 fall into the lower half of solar potential rankings. Vermont and Connecticut are notable for being nearly at the bottom of the potential rankings.

Table 3. Top Ten States Capacity Installed per Capita [9]

1. California 2. Arizona 3. New Jersey (Potential #39) 4. Nevada 5. New Mexico 6. Delaware (Potential #29) 7. Massachusetts (Potential #32) 8. Vermont (Potential #44) 9. Connecticut (Potential #41) 10. Colorado

2.4. *Top Ten States for Installations per Capita*

The total capacity per state metric includes the sum residential, commercial, industrial and utility scale installations. This makes the metric difficult to use to judge the adoption of solar technology by the residential consumer. Residential, commercial, and utility-scale solar capacity account for approximately 29% each of installed solar capacity. Industrial installations account for approximately 13% of the installed capacity. (EIA, 2012) NREL researchers have collected data on the number of solar installations per state. Making the assumption residential solar systems are installed with the fraction of capacity of commercial and utility scale projects it is assumed residential installations make a bulk of the number of installations. The ranking below in Table 4 were created by dividing the number of installations per state by the populations of the states. The rankings give a good indication of the states with the highest per capital residential installations. Once again, many states rated low for potential are located in the top ten ranking. Factors other than solar potential must be driving adoption of residential solar.

Table 4. Top Ten States Installations per Capita [8]

1. California 2. Arizona 3. Delaware 4. New Jersey (Potential #39) 5. Vermont (Potential #44) 6. Massachusetts (Potential #32) 7. Connecticut (Potential #41) 8. Wisconsin (Potential #40) 9. New Mexico 10. New Hampshire (Potential #33)

3. Incentives, Financing and Tax Credits

PV systems are incentivized by several tax credits and rebates on the federal, state and utility level. Private individuals interested in residential solar must carefully study the available rebates before committing to construction. The North Carolina Clean Energy Technology Center at North Carolina State University has developed "the most comprehensive source of information on incentives and polices that support renewable and energy efficiency in the United States [10]. This effort is financially supported by the United States Department of Energy and can be found at www.dsireusa.org.

The Federal ITC credit currently available to home PV system installations was established by the Energy Policy Act of 2005 (P.L. 109-58.) The law has undergone several revisions, extensions and tweaks but the most recent revisions for home PV systems is found in the Emergency Economic Stabilization Act of 2008 (P.L. 110-343.) Under this law, owners of home PV systems can deduct up to 30% of the cost of installations with no limits for systems installed after January 1, 2009. Homeowners subject to the alternative minimum tax (AMT) now qualify for this credit [11].

Several states offer tax credits and rebates similar to the structure of the Federal ITC. Often these programs are more limited in the dollar amount of the tax credits available and are more restrictive on who may participate. The State of New York offers 25% of installed system cost capped at $5000 and limited to 10kW or small installed systems [1]. Utility incentive programs availably vary between states. Many programs are structured as rebate programs. Utility customers receive cash up front for installation of PV systems. Other incentives programs are structures as performance based incentives (PBI) that pay rebates based on actual generation of PV electricity [1].

3.1. *Net Metering*

Net metering is defined as " a service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period" (Energy Policy Act of 2005). Net metering was first developed in the early 1980s as a way to promote the growth of privately owned renewable energy generating facilities such as solar and wind [12]. This arrangement allows the customer ***bank*** excess power generated onsite in the grid and tap the grid when generations onsite does not meet demand, thus solving the critical issue with the variable nature of power generation of wind and solar for the private customer. The customer is also compensated for electricity set back into the grid. Net metering policy is set at the state level and varies by a few key metrics.

3.2. *Established Policy*

The first metric is whether or not a state has an established statewide net metering policy. Alabama, Mississippi, South Dakota and Tennessee are the four states do not have established statewide net metering policies. Federal law requires net metering by request but in these states customers have to negotiate one-on-one with their utility [13]. States have implemented varies caps on the subscriber limit as percent of peak. West Virginia's 0.5% subscriber limit is amongst the lowest the country while many states such as Arizona and Colorado have no such limits. When a subscriber cap is reached, no new residential solar customers will be able to register for net metering. Since net metering is an integral component to the economic viability to residential solar, caps may ultimately put the halt to further installation of PV systems [14].

3.3. *Power Limit, Monthly Rollover and Annual Compensation*

States have also elected to place limits on the installed capacity allowed per customer. Arizona limits customer capacity to 125% of connected load while Connecticut limits capacity to 2000kW. Colorado and Connecticut are two of group of states with no set limit. Capacity limits can also vary by utility type, customer type, technology, and system type. For instance, Georgia limits residential solar systems to 10kW while commercial systems are limited to 100kW [15]. Many customers are able to generate a net positive amount of electricity in a given monthly billing cycle. Customers receive billing credits for this excess power and nearly all states allow customers to "rollover" bill credits from one month to the next. North Dakota is a lone exception to this policy and reconciles credits at the end of each billing cycle. Credits are awarded at either the retail rate of electricity or the avoided-cost rate. Avoided-cost is the wholesale or cost of electricity to the utility. States vary if credits are allowed to rollover indefinitely or are reconciled at the end of each billing year. Customers of some states, such as Colorado, are given to choice to rollover indefinitely or to receive a check from the utility for unused credits at the end of each year. Policies can vary between utilities within each state so research is necessary when calculating economic benefits of PV systems [14].

3.4. *Financing/Leasing*

The Federal Government has historically utilized Fannie Mae and Freddie Mac to allow homebuyers to roll into home mortgages to cost of residential PV systems [16]. Today, private financing is growing rapidly in popularity to amongst residential customers to make PV systems more affordable. Two popular forms of third party financing exist: power purchasing agreements (PPAs) and solar leases. In the PPA arrangement, a third party installs a PV system on the residences and the installing company retains ownership of the PV system. Power is sold at an agreed rate (often lower than the utility) to the residential customer. This business arrangement requires no outlay of capital from the homeowners [17]. Twenty-four states allow for third-party PPAs but five have banned their use [18]. Home customers can also enter into leasing arrangements with PV system installers. In this arrangement, a homeowner owes a monthly lease payment to the installation company. Little or no upfront cost to the homeowner can be negotiated [17]. Ideally, the benefit of the solar energy generated and any tax credits will be greater than the monthly lease payment.

3.5. *Non-Financial Motivations*

It is often cited that concern for the environment and reducing greenhouse gas emissions is a common reason for installing solar panels. (CITE 1st Light) President Obama in 2015 ordered cuts in Federal greenhouse gas emissions by 40% partly increasing the use of renewable energy by 40% from sources such a solar and wind [19]. Researchers at Yale and University of Connecticut have found a different motivation for residential solar customers: green envy. The researchers claim that a new installation on a home of a PV system 6 months prior will increase the average installations by 0.44 in a one half mile radius. Within a one-mile and a one to four mile radius installations will increase by 0.39 and 0.12 respectively. Researchers also failed to find nearly as much influence from other socioeconomic and demographic factors such as income, political party registration and the unemployment rate [20,21].

3.6. *Breakeven Analysis*

The key economic metrics to the prospective residential PV system owner is the price per installed watt of capacity that the system will break even in a 30-year system life. Any cost per watt below this price will equal a net positive benefit for the residential customer. NREL, using their System Advisor Model (SAM), has computed this per watt dollar value for Q4 of 2012. Figure 2 below is the graphical representation of the results. It should be noted the reported cost per watt for residential PV systems competed in 2013 was \$4.69/W (\$4.62/W 2012.) [22].

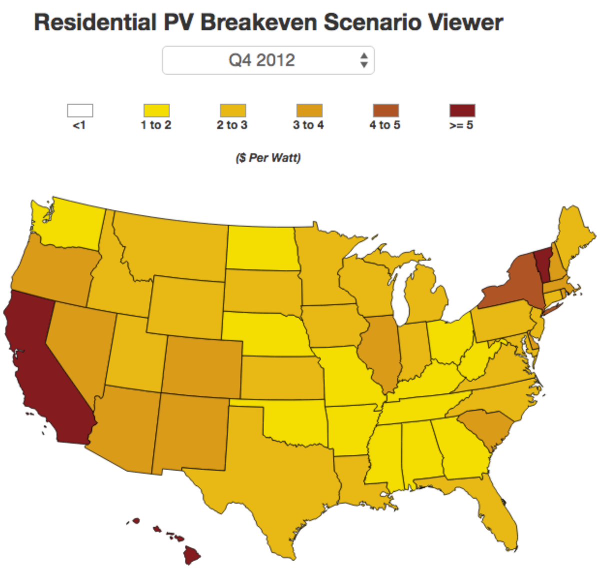

Figure 2 Residential PV Breakeven Scenario Viewer [23]

The 10 most expensive states for electricity are included in Table 5 for comparison to earlier tables. Many of the same states that rank at the top of PV system installs are states with the most expensive electricity.

Table 5. Top Ten States for Most Expensive Electricity per kWh [24]

1. New York 2. Connecticut 3. New Hampshire 4. New Jersey 5. Vermont 6. Maine 7. California 8. Rhode Island 9. Massachusetts 10. Delaware

4. Conclusion and Future Research

It appears that economic incentives and energy costs are the two main drivers of residential PV system adoption in the U.S. States with high potential for solar generation have either ignored or, in some cases, purposefully hampered adoption. Conservative and liberal groups in Florida have joined forces to roll back state laws and regulations they have seen as hampering solar deployment [25]. Future research is warranted to determine the economic effectiveness and efficiency of incentives in driving residential PV system adoption. Government money is not unlimited and it would behoove those governments to implement the most effective dollar-for-dollar incentives.

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