The Effect of State Policy Suites on the Development of Solar Markets

D. Steward and E. Doris
National Renewable Energy Laboratory

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Technical Report
NREL/TP- 7A40-62506
November 2014

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List of Acronyms

ACEEE	American Council for an Energy Efficient Economy
CC	Correlation Coefficient
DG	distributed generation
DSIRE	Database of State Incentives for Renewable Energy and Energy Efficiency
FTG	Freeing the Grid
IC	interconnection
IREC	Interstate Renewable Energy Council
LBNL	Lawrence Berkeley National Laboratory
MW	megawatt
NM	net metering
NNEC	Network for New Energy Choices
NREL	National Renewable Energy Laboratory
PPA	power purchase agreement
PV	photovoltaic
RPS	renewable portfolio standard
TPO	third party ownership

Executive Summary

Many states and local governments have undertaken a variety of policy initiatives with the goal of encouraging private investment and building robust solar photovoltaic (PV) markets. While some states have seen many-fold increases in solar PV installations over the last decade, many other states, some with similar policies, have been less successful. The perceived lack of a clear relationship between implementation of specific policies and increases in solar installations has been challenging to policymakers seeking to support solar markets within their jurisdictions.

This paper builds on recent work that has aimed to clarify the relationships between policy implementation and successful solar PV markets. In 2012, Doris and Krasko (2012) investigated the effect of two variables: the order in which policies are implemented (referred to as "policy stacking") and the presence of low-cost enabling policies, such as interconnection standards and net metering. That work was expanded in 2013 to investigate the influence of non-policy factors, such as solar resource and household income, on the effectiveness of policy initiatives (Steward, Doris et al. 2014). Non-policy factors that might influence the effectiveness of state PV policy were evaluated to develop state "typologies" or "contexts" that can be used to guide policy strategies in similar states.

Statistical analysis and detailed case studies of policy effectiveness in the context of state typologies confirmed earlier findings and shed light on the relationship between state context and policy effectiveness. This work confirmed that solar-related policy, especially solar set-asides within renewable portfolio standards (RPS set-asides), have a quantifiable effect on installed capacity. We also showed that non-policy factors influence the effectiveness of policy, especially in cases where the non-policy factor (such as competing electricity price) is extreme. Having a suite of best practice policies in place was also found to be correlated with increased solar PV installations.

The analysis in this current paper elaborates on the strategy of evaluating the effectiveness of policy in light of the state's demographic and economic background. Here we have focused on how states have developed policies over time and why some policy implementation strategies are more successful than others. Three primary aspects of policy development were selected:

1. The length of time policies have been in place
2. The composition of the state's suite of policies and how this changes over time
3. The influence of non-policy economic and demographic factors on policy effectiveness.

The analysis reveals some general rules-of-thumb for implementation of effective policy:

- States in all contexts experienced more robust markets with the implementation of interconnection and net metering. Although these policies alone are not usually sufficient to spur solar markets, they are foundational for distributed generation market growth. Most states that implement set-asides or TPO policy after having best practice net metering and an interconnection policy in place for a few years, see rapid increases in solar markets. States that did not implement best practice net metering and interconnection policies initially have not seen as rapid growth in solar markets.

- States with higher-than-average lifetime revenue potential[1] from solar installations and best-practice "foundational" policies had higher per capita distributed solar when they also had policies that allowed for third-party ownership (TPO).
- An initial investigation indicates that falling costs for installed distributed generation solar have had an uneven impact on installed capacity in states, with some states benefiting more than others. This result indicates that the effect that falling costs have on solar development depends, at least to some extent, on other policy and contextual factors within the state. Further investigation is necessary to better understand this phenomenon and establish effective strategies for solar development in different state contexts.
- RPS solar set-asides that build upon strong net metering and interconnection standards are valuable for successful solar markets, especially in states with less favorable demographic and economic backgrounds. However, good foundational policies are still needed. Although limited, the experience in the District of Columbia indicates that the effectiveness of the District's small solar set-aside was enhanced by the addition of best-practice net metering and interconnection standards.
- Unlike net metering and interconnection policies, the effectiveness of TPO policy is much more dependent on the state context. A favorable economic climate (i.e., high competing electricity prices and good solar resource) is needed for favorable TPO structures to be connected with higher penetration. There is also evidence that high consumer interest in energy efficiency and renewable energy is a valuable contributor to the success of TPO policy.

Detailed evaluation of "outliers"—states that do not fit the general pattern—reinforces the conclusion from earlier work that the most effective policies for a state are ones that are tailored to its specific context.

[1] The lifetime revenue potential is the total lifetime revenue for the owner of a behind-the-meter solar system that receives the typical amount of sunshine and is net metered at the current retail electricity rate in each state. The values for lifetime revenue potential are presented in terms of $/watt of installed capacity

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1 Introduction

Many states have undertaken various policy initiatives with the goal of encouraging private investment in and building robust solar photovoltaic (PV) markets. While many states have thriving solar markets, other states have been less successful. The perceived lack of a clear relationship between implementation of specific policies and increases in solar installations has been challenging to policymakers seeking the most effective strategy for supporting solar markets in their state.

This paper is third in a series of analyses that attempt to determine the relationship between demographic and economic contexts, state policies, and distributed solar installed capacity (see summary in Table 1).

Table 1. Summary of State Policy Stacking Work to Date

Paper	Question	Findings
Distributed PV Policies: Can Low Cost (to Government) Policies Have a Market Impact? (Krasko and Doris 2012)	Can low cost (to government) policies drive solar market development?	Yes. Nonfinancial incentive policies and population can explain 70% of PV capacity growth. The four policies driving development are: • Best practice interconnection • Best practice net metering • Renewable portfolio standards with a set-aside • Third-party ownership allowed.
The Effectiveness of State-Level Policies on Solar Market Development in Different State Contexts (Steward et al. 2014)	Do non-policy factors drive state-level distributed PV capacity development?	Yes. Extreme values of non-policy factors—personal economic context, solar resource, competing electricity prices, and interest in sustainability—drive solar installations.
Current effort (this paper)	How do policies and economic/demographic contexts combine to support solar markets?	• All demographic and economic contexts can achieve installed capacity growth. • Policies beyond best practice interconnection and net metering are essential for successful markets, but which ones are best depend on specific state contexts. • TPO policies can trigger rapid growth in states with both best practice interconnection and net metering AND economically and demographically favorable environments.

In 2012, our team (Krasko and Doris 2012) investigated the effect that the order in which policies are implemented (referred to as “policy stacking”) and the presence of low-cost enabling policies can have on the success of states in promoting PV markets. In 2013, we investigated four non-policy factors that might influence the effectiveness of PV policy. The four characteristics selected for the analysis were:

- Personal economic context represented by median household income (U.S. Census 2010)
- The physical characteristics of homes and how sunny it is in a given area represented by the solar rooftop potential (Denholm and Margolis 2008, Lopez and Roberts et al. 2012)
- The cost of competing grid electricity represented by a three-year average residential retail electricity price (EIA 2012)
- General community interest in energy conservation and renewable energy represented by the American Council for an Energy Efficient Economy (ACEEE) Energy Efficiency Scorecard score (Foster et al 2012).

Selecting states based on these economic and demographic factors resulted in four groups of states: Expected Leader, Rooftop Rich, Motivated Buyers, and Mixed. Each group shared a set of characteristics that combined formed a “typology”, or economic and demographic context, which might be favorable or unfavorable for solar PV markets.

The analysis focused on quantitative evaluation of the influence of the state’s non-policy background, as defined by the typology groups, on the success of several categories of state-level policy. Policy effectiveness was measured as the number of watts/person of installed capacity of behind-the-meter solar PV for each state. Four policies were evaluated; solar set-aside within the state’s renewable portfolio standard (RPS set-aside), interconnection (IC), standards net metering (NM), and third-party ownership (TPO) policy. The effect of having a combination of policies in a “policy suite” was also investigated.

Statistical analysis and detailed case studies of policy effectiveness, in the context of state typologies, confirmed earlier findings and shed light on the relationship between state context and policy effectiveness. The 2013 work confirmed that solar-related policy, especially RPS set-asides, have a quantifiable effect on installed capacity. The analysis also showed that non-policy factors influence the effectiveness of policy, especially in cases where the non-policy factor (such as competing electricity price) is extreme. Having a suite of best practice compliant policies in place was also found to correlate with increased solar PV installations. Findings from the quantitative analysis and the case histories indicated that there may be a minimum threshold of policy scope and quality that is necessary to spur solar PV markets. If confirmed and expanded, this finding could provide insights into the most effective policy development strategies for each state context, and provide actionable strategies for individual states.

The strategy of evaluating the effectiveness of policy in light of the state's demographic and economic background is elaborated here through analysis of how states have developed policies over time and why some policy implementation strategies are more successful than others. Three primary aspects of policy development were selected:

1. The length of time policies have been in place

2. The composition of the state's suite of policies and how this changes over time
3. The influence of non-policy economic and demographic factors on policy effectiveness.

The analysis of relationships between policy implementation and solar market development added depth to the understanding of trends observed in previous work, as well as revealed new insights into why state contexts matter. Detailed evaluation of "outliers"—states that do not fit the general pattern—reinforced the conclusion from earlier work that the most effective policies for a state are ones that are tailored to its specific context. The following section discusses observations of the general trends in how the age and composition of states' suites of solar policies impacts their success. The last section discusses how these general trends are reinforced or weakened by the demographic and economic contexts of individual states.

2 Methodology

We evaluated the time-dependent relationships between policy implementation and the success of solar markets using historical data for installed capacity of behind-the-meter solar PV (Sherwood 2013) and policy development from 2007 to 2012. We used a straightforward methodology to assign an age to each policy in each year and, from this information, calculated an average age of the state's "suite of policies" in each year.[2] Comparing this simple measure of the development of policy over time to the concurrent changes in installed capacity for each state reveals some general trends and their implications for development of effective policy.[3]

The year 2007 was selected as the basis for the analysis because it was the first year in which quantifiable data were collected for all of the policies. Many states had various policies in place prior to 2007, but the maximum value for the age of any one policy is set at 6 years (in 2012) to avoid weighting policies for which more information is available. Charts and graphics are plotted beginning in 2008, which is the first year with at least one full year of prior data.

2.1 Policies

In keeping with previous work, the policies selected for analysis are foundational policies: net metering (NM) and interconnection (IC), and market creation/enabling policies; solar set-asides within renewable portfolio standards (RPS set-aside) and third-party ownership (TPO) policy.

- **RPS set-aside**: Previous analyses found that both RPS age and solar set-aside age were correlated with increased solar installed capacity (Krasko and Doris 2012). This analysis builds on that work by investigating the relationship between RPS and solar set-aside age and other policy development within the state in the context of the state's non-policy environment. For this analysis, the age of the solar set-aside (if available) is calculated as the number of years prior to and including the current year in which the set-aside had a megawatt-hour requirement. States that have an RPS but no solar set-aside were given a value of 0, and states with no RPS were given a value of -1. Inclusion of negative values in the calculation of the age of the state's suite of policies has the effect of reducing the

[2] The analysis includes the 48 contiguous states and the District of Columbia. The average age is calculated as the age of each policy divided by four (the maximum total number of policies).
[3] Installed capacity includes residential and small commercial, behind-the-meter PV installations in W_{DC} installed/person (Sherwood 2014)

average age. Data for the six years covered by the analysis were derived from Barbose (Barbose 2013).

- **TPO Policy**: This analysis evaluates the relationship between TPO policy, non-policy economic and resource factors, and solar PV installations. The age assigned to favorable TPO policy is the age from the year in which the policy was enacted, including that year. For example, for legislation effective in September 2011, the policy was assumed to be 1 year old at the end of 2011 and two years old at the end of 2012. States that restrict or prohibit TPO received a score (age) of -1 in all years, and states that are silent with regard to TPO receive a score of 0. The DSIRE database provided the primary source of information for evaluating the age of TPO policy for each state over the analysis period.[4] References provided in the database were consulted to arrive at effective dates for TPO policy in cases where the DSIRE database did not provide these dates.

- **Net Metering and Interconnection**: Freeing the Grid (FTG) scores for the years 2007 – 2012 (Dworkin 2007; Rose, Webber et al. 2008; Rose, Chapman et al. 2009; Rose 2010; Weidman, Culley et al. 2011; Wiedman, Culley et al. 2012) are used to assess NM and IC standards. A higher FTG score has been shown to indicate policy more likely to effectively support distributed generation markets (Krasko and Doris 2013). Therefore, the "age" of net metering and interconnection policy refers to the number of years in which the state has had best-practice, meaningful policy in place. Any year in which the state's NM or IC policy FTG score ranked at or above the national average FTG score for that year was included in the age of the policy. Changes in FTG's methodology and criteria from year to year and the evolving definition of "best practice" policy are accounted for by assigning a policy age based on the state's ranking relative to other states in a given year. This means that there are a few instances in which a state's NM or IC "age" remained the same over several years because the state's policy did not keep current with evolving best practices for a period of time.

2.2 State Economic and Demographic Contexts

One of the key observations resulting from grouping the states based on their contextual backgrounds was that analysis of a relevant subset of states provided insights into policy effectiveness that were obscured in statistical analyses of all states together (Krasko and Doris 2013, Steward, Doris et al, 2014). Therefore, while the particular groupings of states used in previous work has not been used here, the same set of non-policy state background factors have been retained and used to form ad hoc groups of states for analysis.

As in previous analyses, a single state-wide data metric was used as an indicator for each of four broad categories of background contextual factors. These high-level factors proved to be good indicators of the non-policy characteristics of states that play a role in determining the effectiveness of policy in supporting solar markets. The categories selected are:

- Personal economic context represented by median household income (U.S. Census 2010)

[4] DSIRE. "3rd Party Solar PV Power Purchase Agreements (PPAs)." Accessed July 9, 2013: www.dsireusa.org/documents/summarymaps/3rd_Party_PPA_map.pdf.

- The physical characteristics of homes and how sunny it is in a given area represented by the solar rooftop potential (Denholm and Margolis 2008, Lopez and Roberts et al. 2012)[5]
- The cost of competing grid electricity represented by a three-year average residential electricity price (DOE 2013)
- General community interest in energy conservation and renewable energy represented by the American Council for an Energy Efficient Economy (ACEEE) Energy Efficiency Scorecard Score (Foster et al. 2012).

2.3 A Note on Costs

During the time period covered by this analysis there was a dramatic drop in the cost of solar installations in the United States (Barbose, Darghouth et al. 2012; Barbose 2014). Between 2007 and 2012, the installed cost of behind-the-meter 5 – 10 kW residential and commercial solar PV installations fell by almost 43 percent from \$8.87/W_{DC}[6] to \$5.09/W_{DC} (2012 dollars). The number of states that experienced large capacity increases of more than one W/person (red line in Figure 1) jumped from only four states (California, Hawaii, Nevada, and New Jersey) in the period 2006 to 2007 to 27 states in the period 2011 to 2012. The decrease in PV system costs is likely to have played a role in the success of these states. However, many states experienced only modest increases of one or less W/person each year (blue line in Figure 1), and 12 states experienced almost no additional installations (0.25 W/person or less) each year throughout the time period covered. If cost were the only major driver for PV capacity increases, all states should benefit, at least to some extent. This does not appear to be the case. While we have focused on non-cost drivers for solar installations and their varying impacts in different state contexts for this analysis, costs may play a major role in capacity increases in many, but not all, states. The interplay between PV system costs and capacity increases in different state contexts will be explored further in future work.

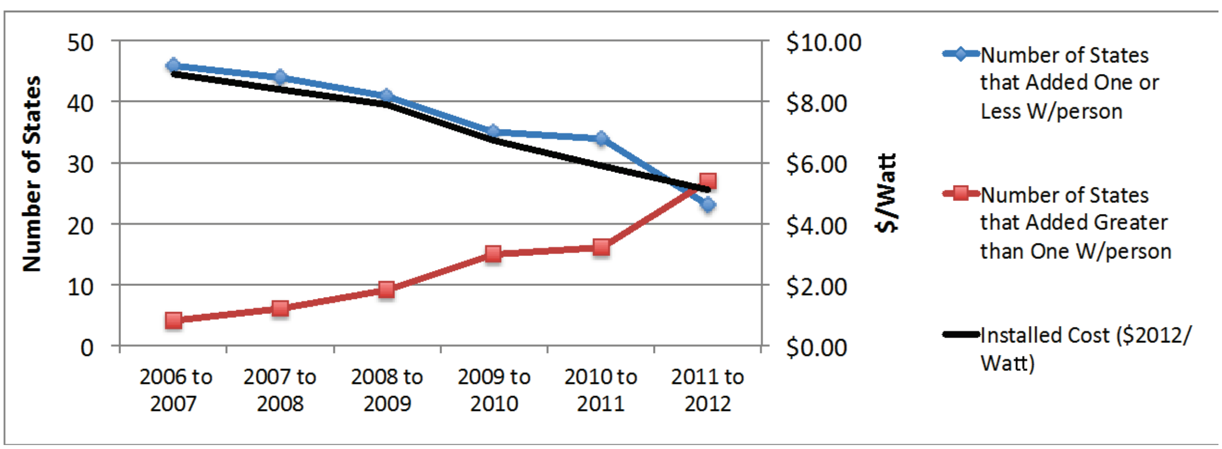


Figure 1. Changes in PV system cost and installations over the 6-year analysis period

[5] Lopez and Roberts et al. (2012) did not include rooftop solar technical potential values for Alaska and Hawaii. Therefore, these states were not included in the groupings of states.
[6] The 2007 value from Barbose, Darghouth et al. 2012 was adjusted to 2012 dollars using the GDP index (Table 10.1, http://www.whitehouse.gov/omb/budget/HISTORICALS).

3 Discussion

The total installed capacity in 2012 is plotted against the average age of each state's suite of policies in Figure 2. The color-coding used in this chart has been used throughout the analysis to indicate the composition of the state's suite of policies.

Blue diamonds represent states that do not have best practice IC standards or NM policies in the correlating year, although those states may have one of the other two policies (TPO or RPS set-aside) or may have had best practice NM policy or IC standards in the past.

Purple circles represent states that have best practice net metering and/or interconnection standards in the charted year, but do not have any other policies in place. These states do not generally have significant installed capacity, even though they may have had good NM and IC policy in place for a number of years.

Orange squares represent states that have NM and/or IC and either an RPS set-aside or a favorable TPO policy in place in the plotted year, but not both. Some of these states have significant installed capacity, but some do not. The potential drivers for these differences will be explored in the following sections.

Red triangles represent states that have NM and/or IC and both an RPS set-aside and favorable TPO policy in place in the plotted year. Almost all of these states have significant installed capacity.

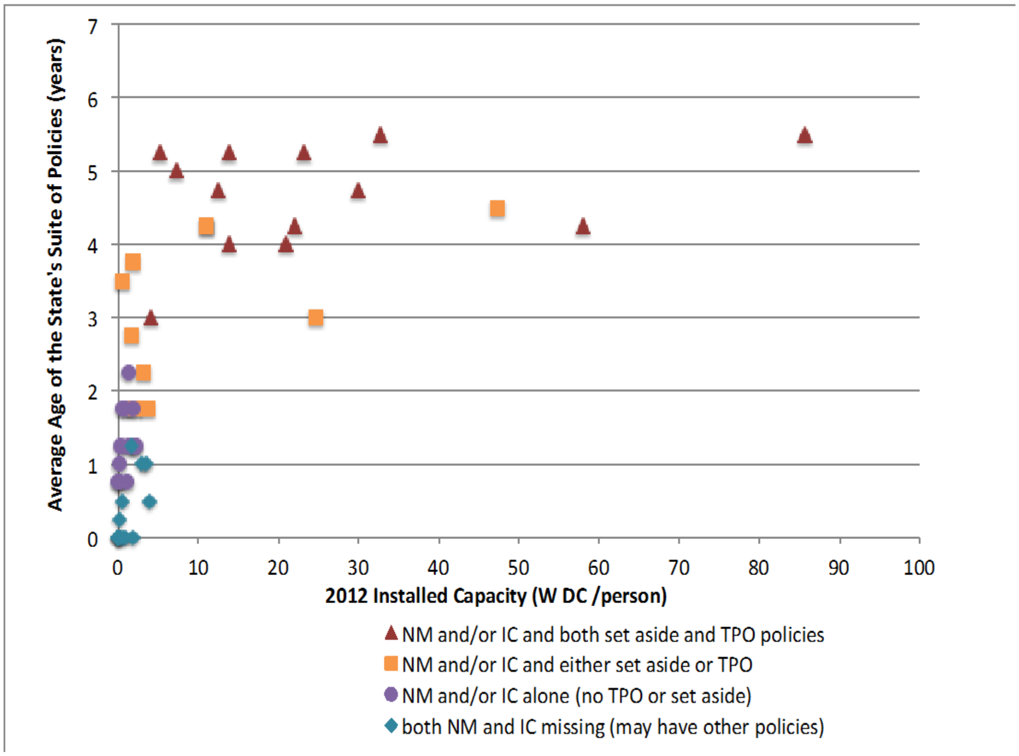


Figure 2. 2012 Installed capacity (W_{DC}/person) and the average age of states' suites of policies at the end of the 6-year analysis period.

3.1 The Evolution of States' Suites of Policies

The changes in solar installations and the composition of states' suites of policies over the period 2008 to 2012 are charted in Figure 3. Several noteworthy characteristics of the evolution of states' policies over time are evident in these charts.

> Policymaker takeaway: States with long-standing best practice interconnection and net metering policies tend to see increases in capacity when layering RPS and/or TPO on top of those policies. States without the foundational policies do not typically see such increases (Note the example of the District of Columbia discussed later in this section).

- States tend to add interconnection and net metering first.
- States that did not maintain high quality NM and IC policy relative to other states (blue diamond symbols in Figure 3) do not have as much installed capacity as states that first added and then maintained leadership in net metering and interconnection policy.
- States with only NM and/or IC without market creation/enabling policies (purple circles in Figure 3) do not have thriving solar markets, or lag (in time) in development of markets.
- Once states add a market creation/enabling policy (RPS set-aside and/or TPO) to their already established foundational policies (NM and/or IC), installed capacity generally increases rapidly (orange and red symbols in Figure 3).

The scatter plots illustrate the development of solar markets over time. The suite age tends to increase for a number of years with little change in capacity before PV markets start to take off. There appears to be a threshold age of 1-2 years for the policy suite, and states that have not reached this threshold age have little installed capacity. The average age of the suite of policies is a good indicator of the likelihood that a state will have a robust solar market because the suite age includes a measure of the length of time policy has been in place, as well as the number of best practice policies in the suite. The age of the suite of policies is the sum of the ages of individual policies divided by 4. Therefore, states that have only one or two policies, have a lower average suite age, even though they may have had these policies in place for a number of years. These states tend to have lower installed capacity. States that have added a third or fourth best practice policy (i.e., RPS set-aside or TPO) have a higher average suite age. The combination of these factors leads to the observed trend; states begin to develop robust solar markets only after market creation and/or enabling policies have been added to established foundational policies and the whole suite of policies has been in place for a year or two.

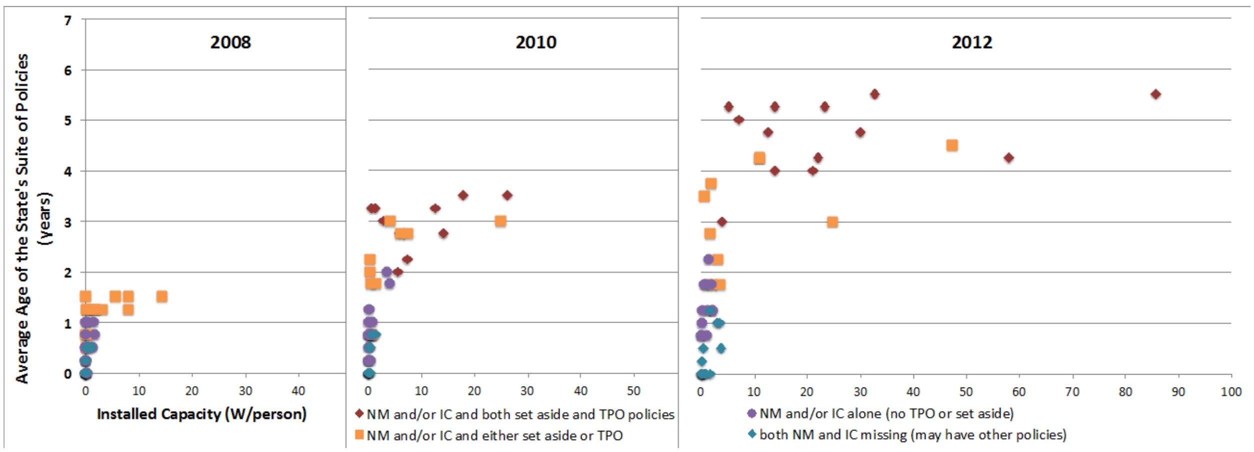


Figure 3. Histogram plot of solar policy and solar market development 2008 to 2012.

Blue diamonds represent states that do not have best practice interconnection standards or net metering policies in that year, although they may have one of the other two policies (TPO or RPS set-aside), or may have had best practice NM policy or IC standards in the past. Blue states that have a suite age greater than zero almost exclusively fall into the latter category (i.e., sometime in the past, they had net metering or interconnection FTG scores greater than the national average for the year, but later fell behind). One exception to this trend is the District of Columbia, which had an RPS set-aside beginning in 2007, but did not implement best practice NM and IC policy until 2009. The noticeable jump in installed capacity after 2009 is evident in the data plotted for DC in Figure 4. It is probable that addition of high quality foundational policies contributed to the District's success in spurring solar markets.

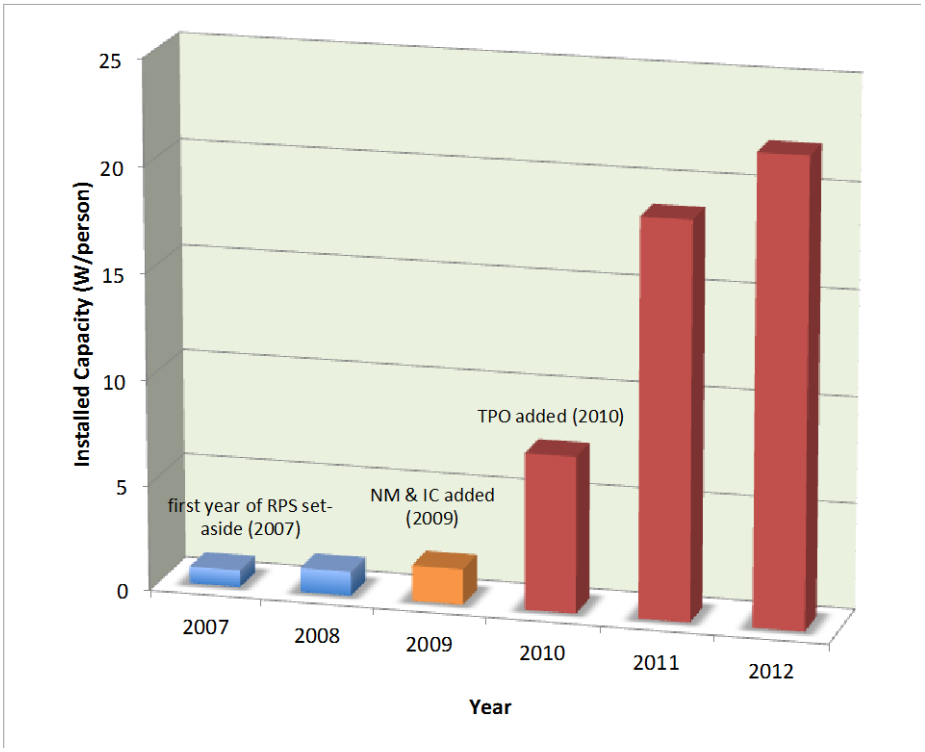


Figure 4. Installed capacity (W/person) in the District of Columbia from 2007 to 2012

3.2 TPO Policy and Lifetime Revenue Potential from Net Metering

The business case for third-party ownership in a given state depends on the cost to the business of installing PV at the client's location and the revenue that the business might expect over the life of the system. While acknowledging that system cost, including the availability of state and federal incentives, is an important consideration, we have focused on evaluating the impact of states' economic and demographic contexts on the business case for TPO. We used a simple discounted cash flow analysis to assess the impact of the state's economic background and physical environment on the revenue a third-party business might obtain from net metering over the lifetime of the PV system.

Policymaker takeaway: TPO policies are particularly effective when combined with best practice IC and NM in areas with favorable economic conditions (e.g., high competing electricity costs and solar resource) and strong community interest in energy sustainability issues. Policies are far less effective in spurring market development when even one factor is missing.

The result of the cash flow analysis is a value for the lifetime revenue potential from net metering expressed as $/watt (W) of installed capacity, which provides a straightforward numerical measure of one aspect of the economic attractiveness of TPO for each state. We then evaluated states' success in fostering solar markets in light of each state's lifetime revenue potential and policies regarding TPO.

Net-metering revenue depends on a variety of factors including the amount of solar resource available at a particular site (measured as the solar capacity factor[7]), the characteristics of the PV system (its efficiency and degradation over time), and the price that the owner of the system might expect to receive for the electricity produced. Because of the number of variables involved, the lifetime revenue potential of net metering is not immediately apparent. Therefore, we used a simple discounted cash flow model to calculate the potential lifetime revenue for net metering for each state. Inputs to the model included population-weighted solar resource data, PV system performance assumptions, electricity prices projected to 2030 for each state, and common financial assumptions. Details of the analysis are presented in the Appendix. This analysis did not consider existing net-metering policies in the various states. Rather, common assumptions were used to perform an "apples-to-apples" calculation of the lifetime revenue potential for the owner of a behind-the-meter solar system that is net metered at the current retail electricity rate in each state. Results are presented in terms of $/watt of installed capacity. Values for each state are listed in the Appendix.

Of the states included in the analysis,[8] the highest value of lifetime revenue potential is for California at $3.67/W because of its sunny climate and high electricity prices. The lowest value is for Washington State at $0.85/W due primarily to the state's very low electricity prices. The average calculated value of lifetime revenue potential for all states in the analysis is $2.35/W; about one half the average system capital cost of residential PV in the United States.[9]

Figures 5 and 6 plot 2012 installed capacity against the lifetime revenue potential for two groups of states.

The first group (Figure 5) consists of all states that had favorable TPO policy in place for at least one year in 2012, regardless of revenue potential. States with both TPO and an RPS set-aside (purple circles in Figure 5) are distinguished from states with only TPO policy (green triangles in Figure 5) to highlight the effect TPO policy has on capacity. States with higher lifetime revenue potential tend to have more installed capacity. This is an expected result because third-party owners should be more likely to pursue projects in areas where they are able to make a better business case. The relationship is more pronounced for states that do not also have an RPS set-aside (green triangles in Figure 5) because TPO may be the sole policy driver for solar installations in these states. In contrast, an RPS set-aside drives some of the capacity increases in states that have a set-aside and may be the primary driver in states with lower lifetime revenue potential. Notably, there is a strong correlation between installed capacity and the ACEEE Scorecard score and potential revenue from net metering (CC = 0.74 and CC = 0.60 respectively) for the states with only favorable TPO policy (green triangles), but only a weak correlation with median household income (CC = 0.26). For all the states plotted in Figure 5, there is only a very weak correlation (CC = 0.18) between the ACEEE scorecard score and installed capacity and a weak correlation with income and potential revenue from net metering (CC = 0.25 and CC = 0.35 respectively). In summary, good revenue potential and strong community interest in energy efficiency and renewable energy are closely associated with more successful solar markets for

[7] Solar capacity factor = (actual kWh/year ÷ kWh/year at rated output for all 8,760 hours/year)
[8] The 48 contiguous states.
[9] "In the residential sector, the majority of the states that are tracked by GTM Research have average installed costs of about $5.00/W." Kann, S., S. Mehta, et al. (2012). U.S. Solar Market Insight Report 3Q 2012 Full Report. S. E. I. Association.

states with favorable TPO policy but no solar set-aside. For states that also have a solar set-aside, favorable economics and community interest are not as important.

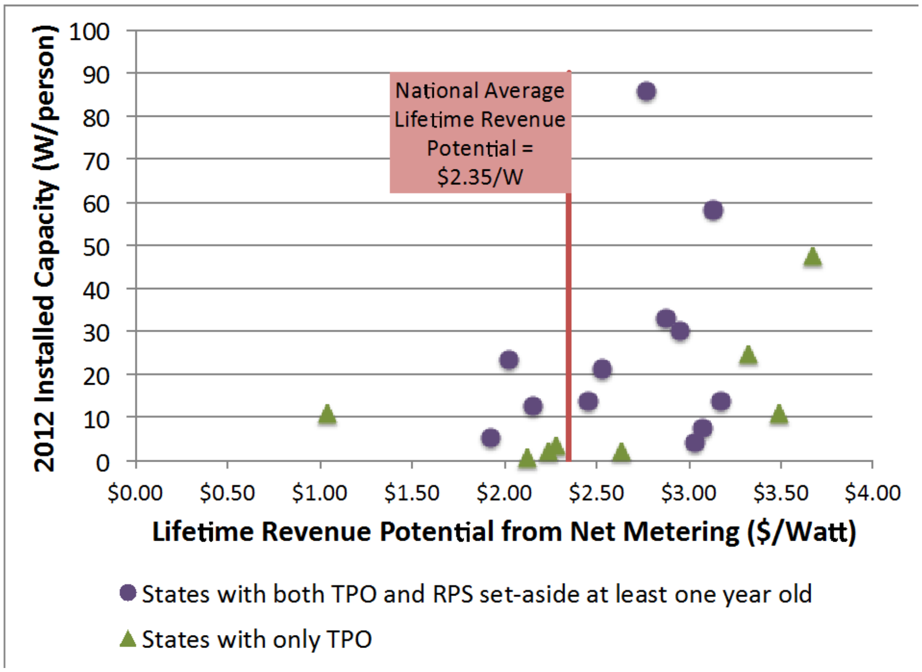


Figure 5. Installed capacity (W/person) in 2012 for states with favorable TPO policy at least one year old.

Figure 6 plots the installed capacity against lifetime revenue potential for the subset of states from Figure 5 that have greater than the national average lifetime revenue potential (all states to the right of the vertical line). States that have greater than the national average lifetime revenue potential, but lack TPO policy or prohibit TPO are added (blue squares). Thirteen states have favorable TPO policy and a lifetime revenue potential greater than the national average of $2.35 per Watt. Most of these states (9) also have a solar set-aside. Texas and New Hampshire are the only two states in this group that do not have significant installed capacity. Both states added favorable TPO policy relatively recently (2012, and 2011 respectively) and may see benefits in the near future[10]. There are seven states that have good revenue potential but do not have favorable TPO policy (blue squares in Figure 6). Only one of these states, Wisconsin (3.6 Watts/person in 2012), has an installed capacity greater than the national median value of 2 Watts/person. The solar market that does exist for these states is fairly strongly correlated with household income and ACEEE Scorecard scores (CC of 0.48 and 0.56 respectively). Non-policy drivers have influenced solar markets in these states, but the solar markets are still very small. Favorable TPO policy is needed for states to realize the benefits of good economic conditions and strong community interest in energy sustainability issues.

[10] See footnote 4

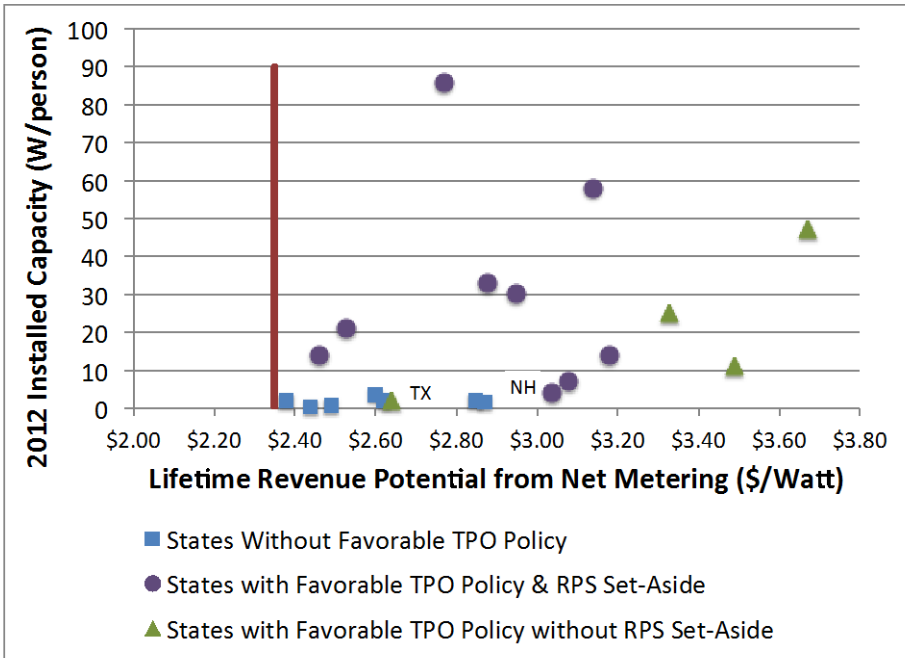


Figure 6. Installed capacity (W/person) in 2012 for states with greater than the national average lifetime revenue potential from net metering (red vertical bar at the national average lifetime revenue potential in both charts)

3.3 The Value of Tailored Policy

Generally, states that have implemented three or four best practice policies that include high quality foundational policies have been successful in creating robust solar markets. However, some states are lagging behind peers with similar best practice policies. For example, Michigan, Rhode Island, and Illinois (Figure 7) have less than the national median value of installed capacity (~2 W/person) even though they have good foundational policy and market creation or enabling policy that has been in place for some time. This indicates that age and composition of policy suites are important – but other factors must also be influential.

Policymaker takeaways:
Matching policy to context is important:

- California and Illinois have different contexts, so Illinois may best support markets by taking a mandate (RPS with a set aside) based approach similar to Pennsylvania rather than the current strategy of following the California model.
- Rhode Island and California have similar contexts, so RI may benefit from TPO policy (as California has).

Contrasting one of these states with a state that has similar policies, but greater success in fostering solar markets, reveals how policy effectiveness is influenced by background contextual factors (Figure 8a). Illinois and California have similar policy suites of similar age (Table 2).

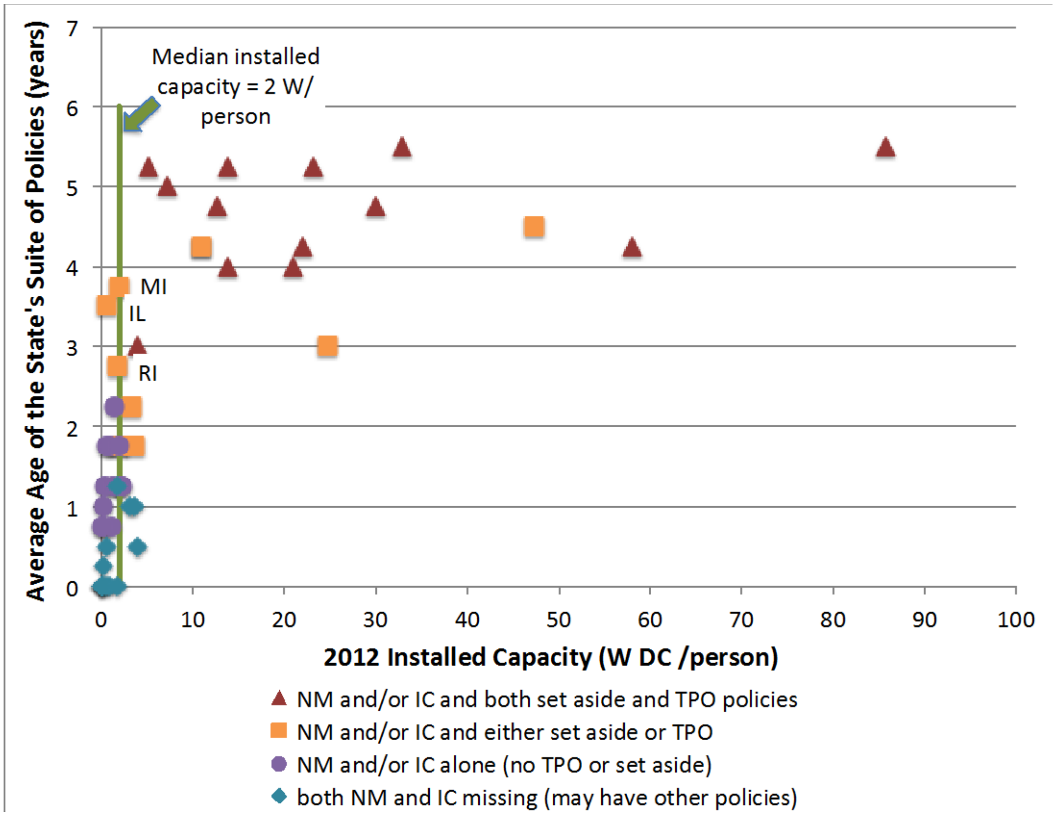
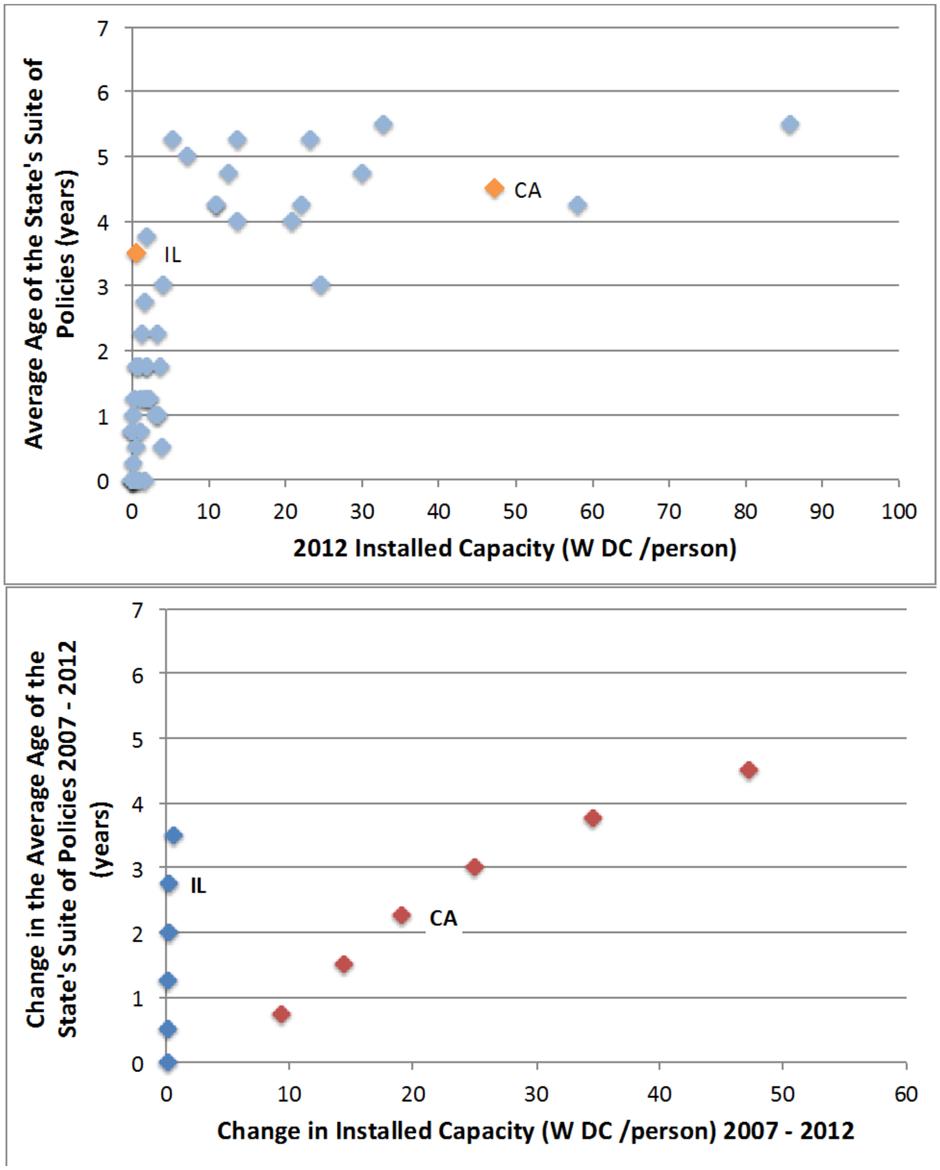


Figure 7. Some states lag behind peers with similar policy suites



Figures 8a and 8b. Development of solar markets over time in Illinois and California

Table 2. Details of Policy Suites and Demographic Factors in Illinois and California

Policy Age at the End of 2012 (y)	Illinois	California
TPO	5	6
RPS Solar Set-Aside Age	0	0
FTG Net Metering	5	6
FTG Interconnection	4	6

State Economic and Demographic Factors		
Three-year average retail electricity price: 2010 - 2012 ($/kWh)	$0.11	$0.15
Technical Potential for Rooftop PV (GWh/year)	30,086	106,411
Lifetime Revenue Potential ($/W)	$2.13	$3.67
ACEEE 2012 Scorecard Score	25	40.5

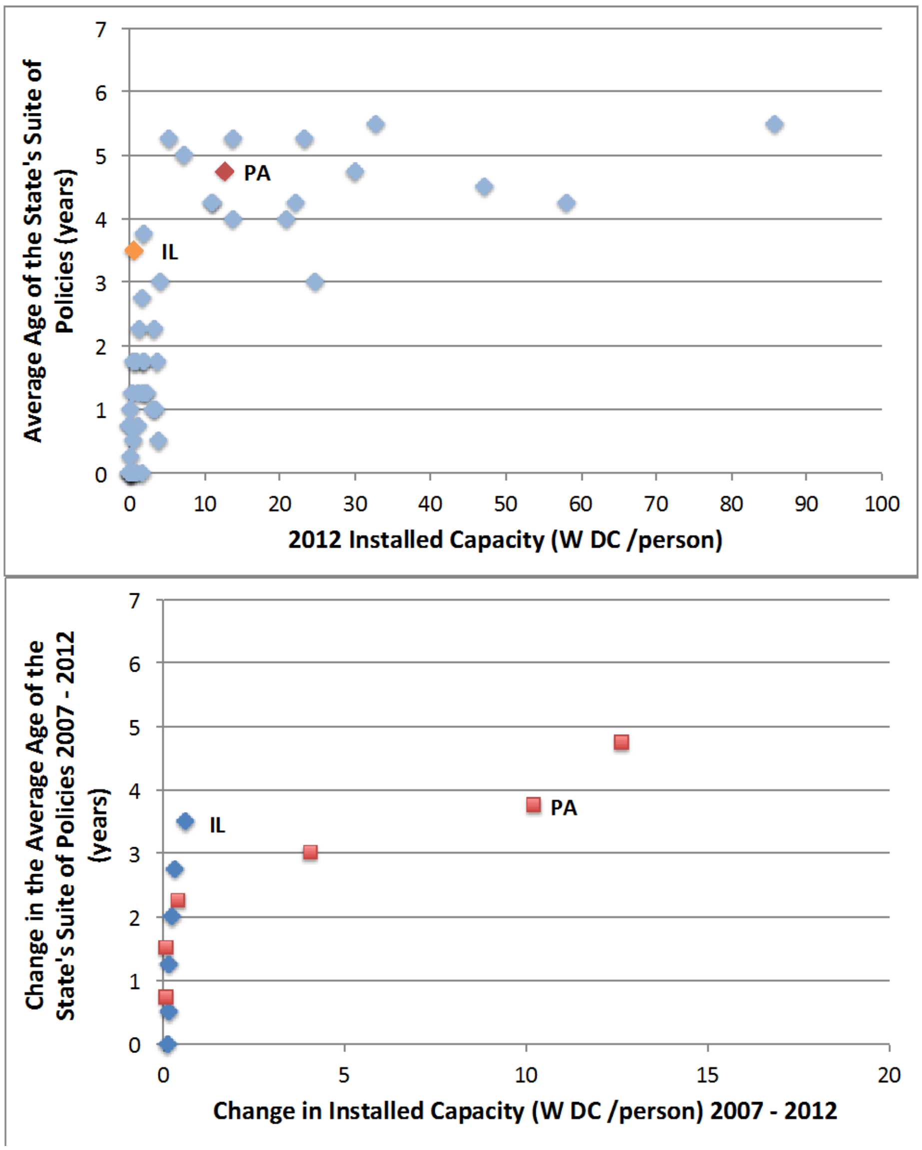
Both states have had best practice foundational policy in place for a number of years and both have well-established favorable TPO policy, but Illinois has been unsuccessful in establishing a robust market, while California's solar market has thrived (Figure 8b). Recalling the discussion in Section 3.2 provides some insight into why this policy suite has been effective in California, but unsuccessful in Illinois. California and Illinois have very different demographic and economic contexts (Table 2), and these differences are critical factors in the success of TPO policy – the third element in their common policy suite. Both the three-year average electricity price and solar rooftop potential are significantly lower in Illinois than in California. The combination of these two factors results in a lifetime revenue potential in California that is more than 70% greater than in Illinois. As illustrated in Figure 5, the potential revenue is a driver for solar markets in states with good TPO policy, especially in the absence of market creation policy (RPS set-aside). TPO is a more effective policy in California than in Illinois because third-party owners are able to make a better business case in California.

Comparing Illinois to a successful state that has a similar contextual background further reinforces the conclusion that policy suites are more effective if they are tailored to the economic and demographic background of the state. Pennsylvania and Illinois have similar demographic and economic contexts, but a solar set-aside has helped Pennsylvania's solar market despite a relatively unfavorable economic backdrop (Figures 9a and 9b and Table 3).

Rhode Island and Michigan also lag behind their peers in terms of installed capacity, and this analysis shows that the reason could be based in the structure of policies failing to match their economic and demographic context. Rhode Island has similar demographics to California and lifetime revenue potential from net metering in the top 25% of all states at $2.85/W. However, these favorable economic conditions have not resulted in significant installed capacity. Rhode Island had approximately 1.8 W per person of behind-the-meter solar PV in 2012 (Sherwood 2013). Rhode Island maintained best practice net metering policy over the period we analyzed and has had a solar requirement since 2009.[11] However, the state does not allow TPO except in

[11] IREC, RPSspread 031813.xls, Note for Rhode Island "07/28/09 - Separate requirement for 90 MW (including 3 MW solar) of long-term contracts by 2013 in State Notes section. For the time being, this requirement is not reflected in the quantitative details. Adjusting for capacity factor, the solar portion amounts to roughly a 0.3% solar requirement based on expected 2013 retail sales" downloaded 2/11/2014 from http://www.dsireusa.org/rpsdata/

municipal financing agreements.[12] Rhode Island has recently improved its interconnection standards as well as other solar incentives and programs (Barnes, J.; T. Culley, et al. (2013), Hausman, N. (2013). However, Rhode Island might especially benefit from also encouraging TPO in additional sectors based on its high lifetime revenue potential from net metering and favorable demographic and economic background. Michigan, in contrast, has very similar demographics to Illinois and a very similar suite of policies, including good TPO policy, but no solar set-aside within its RPS. Like Illinois, Michigan might benefit from market creation policy with specific targets for solar PV.



Figures 9a and 9b. Development of solar markets over time in Illinois and Pennsylvania

[12] IREC, 3rd-Party Solar PV Power Purchase Agreements (PPAs) map downloaded from http://www.dsireusa.org/documents/summarymaps/3rd_Party_PPA_map.pdf. Because of the limited nature of Rhode Island's PPA law, we assigned a value of 0 (law is silent) for the PPA age in all years in Rhode Island.

Table 3. Details of Policy Suites and Demographic Factors in Illinois and Pennsylvania

Policy Age at the End of 2012 (y)	Illinois	Pennsylvania
TPO	5	1
RPS Solar Set-Aside Age	0	6
FTG Net Metering	5	6
FTG Interconnection	4	6
State Economic and Demographic Factors		
Three-year average retail electricity price: 2010–2012 ($/kWh)	$0.11	$0.11
Technical Potential for Rooftop PV (GWh/year)	30,086	22,215
Lifetime Revenue Potential ($/W)	$2.13	$2.16
ACEEE 2012 Scorecard Score	25	21.5

3.4 Key Findings

- Both the number of policies in the suite and the overall age of the suite of policies are important indicators of success.
- Net metering policy and interconnection are important components of the suites of policies in most successful states.
- An initial investigation indicates that falling costs for installed distributed generation solar have had an uneven impact on installed capacity in states, with some states benefiting more than others. This result indicates that the effect that falling costs have on solar development depends, at least to some extent, on other policy and contextual factors within the state. Further investigation is necessary to better understand this phenomenon and establish effective strategies for solar development in different state contexts.
- Support for TPO seems to be a distinguishing factor in the success of some states in stimulating robust solar markets —but usually economic factors must also be favorable.
- States that have matched their suite of best-practice policies to their unique context have excelled.

States tend to start with enabling policies: net metering and interconnection. These policies appear to be foundational in that they facilitate increased market penetration over time. The value of strong foundational policies is applicable to all states. These policies alone do not seem to be sufficiently motivating to solar markets, but they clearly enhance the effectiveness of set-asides and TPO policy in many states.

RPS solar set-asides that build upon strong net metering and interconnection standards are valuable for successful solar markets, especially in states with less favorable demographic and economic backgrounds. However, good foundational policies are still needed. Although limited, the experience in the District of Columbia (section 3.1) indicates that the effectiveness of the District's small solar set-aside was enhanced by the addition of best-practice net metering and interconnection standards.

Unlike net metering and interconnection policies, the effectiveness of TPO policy is much more dependent on the state context. A favorable economic (and possibly demographic) climate (e.g., high competing electricity prices, high consumer interest in energy efficiency and renewable energy, good solar resource) is needed for favorable TPO structures to be connected with higher penetration.

The age of the suite of policies is an average of the ages of all four of the policies we looked at, so, in terms of average age, having one policy in place for 4 years is the same as having 4 policies in place for 1 year. However, when looking at the effectiveness of policy, these two scenarios look very different. Last year we found that having only one or two policies in place was not effective in stimulating solar markets. Three or four policies were needed. This year we showed that having a suite of policies in place for a period of time (relatively short; 1 to 2 years) was also necessary for markets to "catch up" with best practice policy. Most states that implement set-asides or TPO policy after having best practice net metering and interconnection policy in place for a few years, see rapid increases in solar markets. Although almost all states have implemented best-practice interconnection and net metering policies prior to, or simultaneous to, enacting set-asides or TPO policy, the experience of the District of Columbia (discussed in Section 3.1) indicates that the lack of best-practice foundational policy impedes market development even with market creation policy in place.

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Appendix A – Calculation of the Lifetime Revenue Potential from Net Metering

Although specific policies can be complicated, simple net metering allows distributed generators of electricity to be paid for the electricity that they generate by 1) avoiding purchase of electricity during the time period they are generating (avoided costs) and 2) being paid for electricity they generate in excess of their own needs. Over the life of their system, they will recover some or all of their initial investment. The total amount of revenue they receive depends on how much electricity they generate and how much they are paid for electricity they produce. We evaluated net metering based on the premise that avoided costs and payments for excess generation are of equal value on a per-kilowatt-hour basis so that all generation can be treated as revenue for the analysis. The purpose of this analysis was not to assign a value to solar PV but rather to determine the influence of variations in solar resource and regional electricity prices on the lifetime revenue potential from net metering (see also Drury et al. 2012)[13] in each state.

Net-Metering Assumptions

Financial and system operational assumptions for the present value analysis of net metering are presented in Table A1. The residential electricity rate used for each year in each state is derived from the EIA Annual Energy Outlook's reference case regional electricity price projections (DOE 2013).[14] The regional projections to 2040 were adjusted using a state-specific multiplier so that the 2011 price for each state matched the actual 2011 price. The regions used for the projections are shown in Figure A1.

Table A1. Financial and PV System Operational Assumptions for Net Present Value Analysis

Variable	Value	Source/Notes
PV system average size (kW)	6	Sherwood - 2011[15] market report gives average size of nonutility PV at 18 kW and 5.7 kW for residential.
State population weighted capacity factor (fraction)	Varies by state	PV system yearly electrical output (kWh) = system size (kW) * weighted capacity factor * 8,760 (calculated for each state)
Output degradation (%/year)	0.5%	Assumption from (Burns and Kang 2012)[16]
State residential electricity rate ($/kWh)	Varies by state	EIA AEO 2013 reference case residential regional projections adjusted for each state. (DOE 2013)
System life/analysis period	15 years and 25 years	Burns and Kang 2012
Discount rate	3%	Burns and Kang 2012
Net metering (¢/kWh)	Residential rate	Assume credit for all electricity at the same rate

[13] Drury, E., P. Denholm, et al. (2012). Sensitivity of Rooftop PV Projections in the SunShot Vision Study to Market Assumptions. DOE. Golden, CO, NREL.
[14] The EIA price projections do not include the District of Columbia. Therefore, lifetime revenue values were not calculated for DC.
[15] Sherwood, L. (2012). "U.S. Solar MARKET TRENDS 2011."
[16] Burns, J. E. and J.-S. Kang (2012). "Comparative economic analysis of supporting policies for residential solar PV in the United States: Solar Renewable Energy Credit (SREC) potential." Energy Policy 44: 217-225.

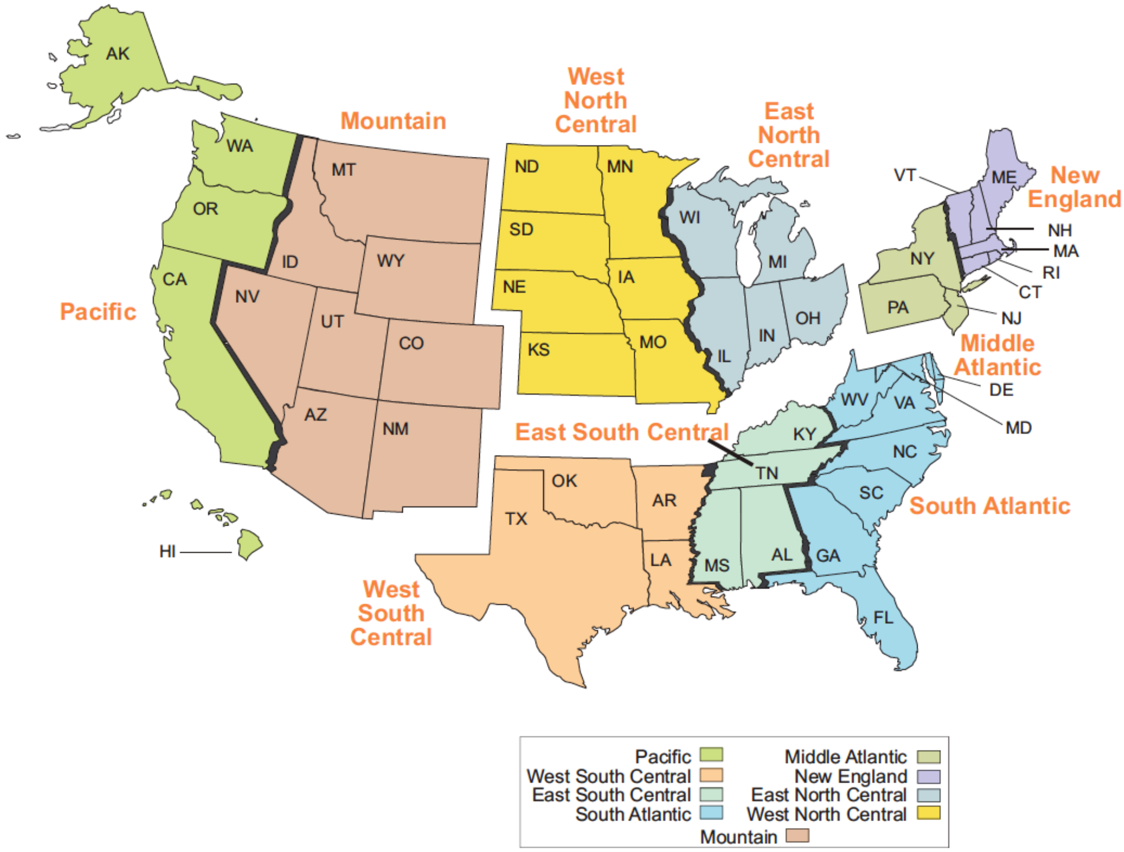

Figure A1. U.S. Census regions used for electricity price projections[17]

Solar Data and Calculation of Solar Output

Solar PV system capacity factors (actual kWh/year ÷ kWh/year at rated output for all 8,760 hours/year) were calculated for each state. Solar insolation data were obtained from typical meteorological year (TMY) inputs for a grid consisting of 10-km grid cells across the United States. These data were combined with input tilt angle to calculate output generation and capacity factor for every grid cell. Summary results consist of aggregate statistics for the cells in each state weighted by population. For all grid cells, system size was set to 1 kW and derate factor to 0.77, with south-facing (or equator-facing) fixed-tilt panels. The fixed-tilt angle for each grid cell was set to the latitude of the cell and is provided in both the summary and raw results. Weighting the capacity factor results by population provides a more accurate estimate of the capacity factor because behind-the-meter solar PV installations are more likely to be located in more populated areas. Figure A2 presents a box plot of the capacity factor results for all states (except Alaska). The population-weighted mean, which was used for our calculations of the present value of net metering, is shown as a white dot on each plot. The unweighted mean is shown as a black bar on each plot. It is useful to note the wide variation in capacity factors for some states; for example, in Washington State and Hawaii there are wide regional variations of solar insolation within each state. In both Washington and Hawaii, the population tends to be

[17] http://www.eia.gov/consumption/commercial/census-maps.cfm

concentrated along the coasts. In Washington, the coastal regions are much wetter than the drier, sunnier regions to the East so the population-weighted mean capacity factor is much lower than the overall average for the state. In contrast, Hawaii's coastal regions tend to be sunnier and drier than interior mountainous regions, so Hawaii's population-weighted mean capacity factor is somewhat higher than the unweighted mean.

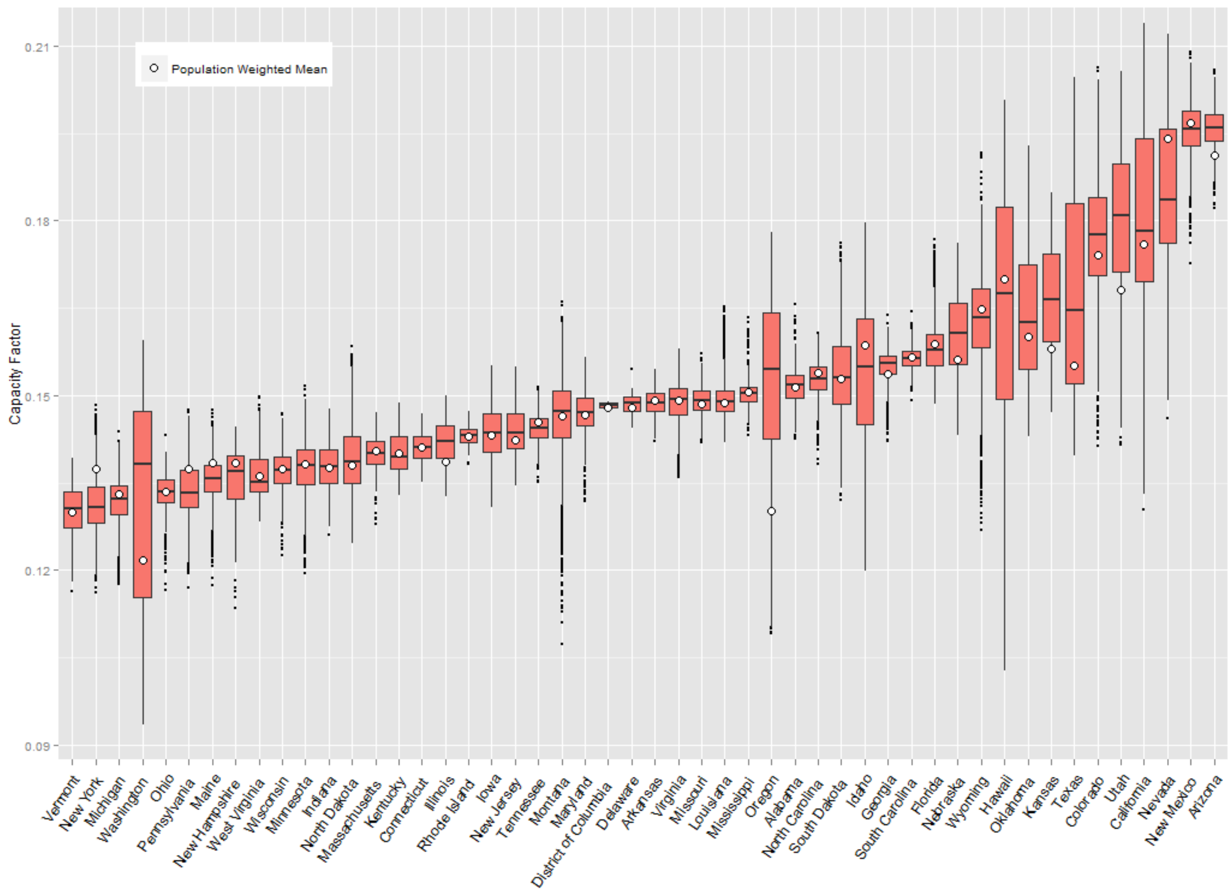

Figure A2. Box plot of calculated capacity factors for states

Source: Anthony Lopez and Mike Gleason, NREL

Results

Results for the analysis are presented in Table A2. A histogram of the results is presented in Figure A3.

Table A2. Lifetime Revenue Potential from Net Metering for the 50 States ($/W)

State	*Lifetime revenue from net metering ($/W) for net metering at 100% of residential rate, 25-year life*	*State*	*Lifetime revenue from net metering ($/W) for net metering at 100% of residential rate, 25-year life*
Alabama	$2.10	Montana	$1.81
Alaska	$2.19	Nebraska	$2.15
Arizona	$3.14	Nevada	$2.03
Arkansas	$2.04	New Hampshire	$3.04
California	$3.67	New Jersey	$2.77
Colorado	$2.88	New Mexico	$3.18
Connecticut	$3.49	New York	$3.08
Delaware	$2.53	North Carolina	$2.31
District of Columbia	not available	North Dakota	$1.73
Florida	$2.62	Ohio	$1.93
Georgia	$2.38	Oklahoma	$2.27
Hawaii	$7.93	Oregon	$1.04
Idaho	$1.89	Pennsylvania	$2.16
Illinois	$2.13	Rhode Island	$2.85
Indiana	$2.00	South Carolina	$2.49
Iowa	$2.21	South Dakota	$2.10
Kansas	$2.44	Tennessee	$1.78
Kentucky	$1.59	Texas	$2.64
Louisiana	$1.97	Utah	$2.28
Maine	$2.87	Vermont	$3.33
Maryland	$2.46	Virginia	$2.31
Massachusetts	$2.95	Washington	$0.85
Michigan	$2.24	West Virginia	$1.83
Minnesota	$2.21	Wisconsin	$2.60
Mississippi	$1.90	Wyoming	$2.23
Missouri	$2.09		

The cost of electricity is the primary driver for the revenue from net metering as can be seen in the difference between the revenue potential from net metering in Hawaii ($7.93/W) and California ($3.67/W), which have similar solar capacity factors (0.170 and 0.176, respectively[18], but significantly different electricity costs (0.33 $/kWh and 0.15 $/kWh, in 2011 respectively).

[18] Lopez and Roberts et al. (2012) did not include rooftop solar technical potential values for Alaska and Hawaii. Therefore, these states were not included in the groupings of states.

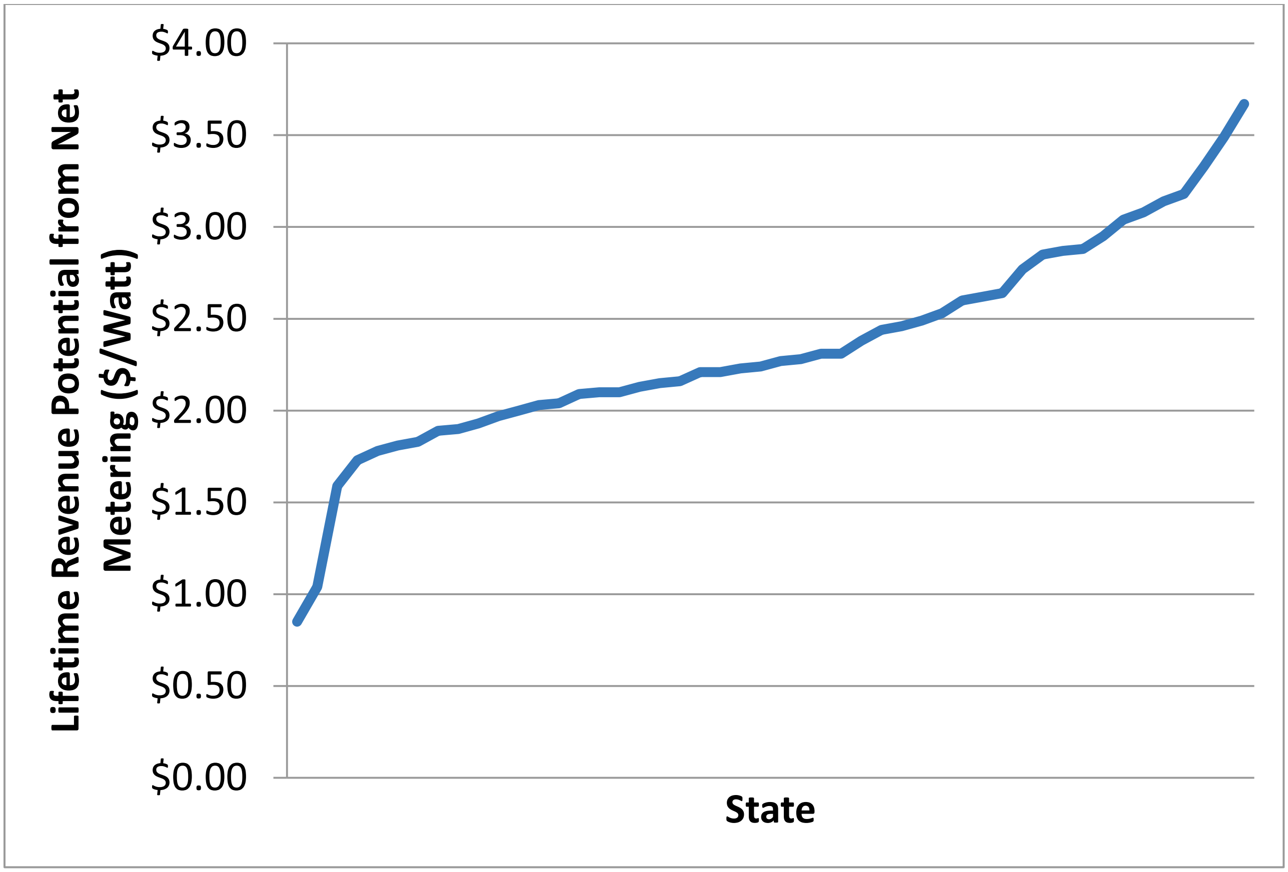

Figure A3. Lifetime revenue potential from net metering for the 50 states ($/W).