The Effectiveness of State-Level Policies on Solar Market Development in Different State Contexts

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Prepared under Task No. SM13.1530

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List of Abbreviations and Acronyms

ACEEE	American Council for an Energy Efficient Economy
ACP	alternative compliance payment
ACS	American Community Survey
DG	distributed generation
DSIRE	Database of State Incentives for Renewables & Efficiency
FERC	Federal Energy Regulatory Commission
FTG	Freeing the Grid
GWh	gigawatt-hour
IOU	investor-owned utility
IREC	Interstate Renewable Energy Council
ITC	investment tax credit
kW	kilowatt
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
MW	megawatt
NCUC	North Carolina Utility Commission
NEG	net excess generation
NNEC	Network for New Energy Choices
NREL	National Renewable Energy Laboratory
PPA	power purchase agreement
PSC	Public Service Commission
PUC	Public Service Utility
PUMS	Public Microdata Sample
PRC	Public Regulatory Commission

PV	photovoltaics
REC	renewable energy certificate
REPSA	Renewable Energy Portfolio Standards Act
RPS	renewable portfolio standard
SDTC	Solar Development Tax Credit
SREC	solar renewable energy credit
TPO	third-party ownership
W	Watt

Executive Summary

In response to public interest in customer-sited distributed solar photovoltaics (PV), state and local policymakers have implemented policy initiatives with the goal of encouraging private investment and building a robust PV market. Policymakers face challenges, including limited budgets and incomplete information about the effectiveness of the various policy options in their specific situation and in crafting and executing policy that supports market development goals. Recent work (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, such as interconnection standards and net metering, can have on the success of states in promoting PV markets. Findings indicate that implementation of interconnection standards and policy related to the valuation of excess electricity (e.g., net metering), along with indicators of long-term government support for a solar PV market (e.g., renewable portfolio standard [RPS]) and a non-policy determinant (population), explain about 70% of the variation among states in new PV capacity.

This paper builds on that research to determine the most effective policy strategies for different types of states, as determined by their physical, demographic and macroeconomic context. A number of researchers have investigated the effectiveness of state-level policy using various statistical methods to determine relationships between installed solar PV projects and policy initiatives (Barbose et al. 2006; Taylor 2008; Nemet 2009; Drury et al. 2011a; Drury et al. 2011b, Burns and Kang 2012; Krasko and Doris 2012; Sarzynski et al. 2012). In this study, the grouping of states by non-policy factors added dimension to these analyses by identifying how policies function in different non-policy environments.

In order to identify specific actionable strategies for solar policy support at the state level, states were first broken into four groups based on physical and demographic characteristics, then each group was examined statistically, as well as qualitatively, to identify successful policy strategies specific to those contexts. Finally, all this was discussed together to identify relevant conclusions for policymakers and suggest pathways for developing actionable strategies for each context.

While many ways exist to group the states (see Section 3.1 and the Appendix), this study used four broad categories of background contextual factors, selecting a single, state-wide data metric as an indicator for each of the categories. These gross indicators were selected to identify high-level common elements shared by the states in a group that play a role in determining the effectiveness of policy in supporting solar markets. While more complex strategies were examined, none provided substantial improvement over this broad characterization, and thus the simplest was used for this effort. The categories selected were:

- Personal economic context represented by median household income (U.S. Census 2010)
- Solar resource availability as represented by the technical potential for solar on rooftops (Denholm and Margolis 2008; Lopez, Roberts et al. 2012)

- 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).

The criteria used to group the states are listed in Table ES-1. The resulting groupings of states are shown in Figure ES-1.

Table ES-1. State Context Grouping Criteria

State Types			
Expected Leader	**Rooftop Rich**	**Motivated Buyer**	**Mixed**
Criteria			
1. ACEEE Energy Efficiency Scorecard score ≥ average 2. Estimated technical potential for rooftop PV ≥ median	1. ACEEE Energy Efficiency Scorecard score < average 2. Cost of electricity < average 3. Income < average 4. Estimated technical potential for rooftop PV ≥ median	1. ACEEE Energy Efficiency Scorecard score ≥ average OR Cost of electricity ≥ average and Income ≥ average	States not identified in the previous three groups. These states have a variety of values for the characteristics evaluated.

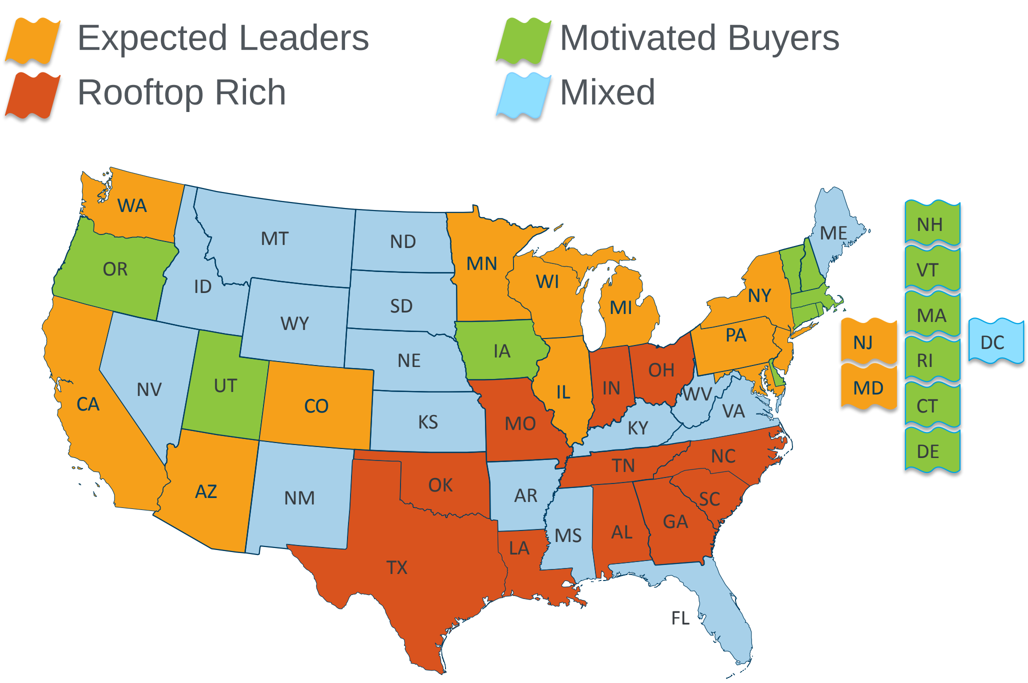

Figure ES-1. States grouped by types of non-policy factors. Lopez et al. (2012) did not include rooftop solar technical potential values for Alaska and Hawaii; therefore, these states were not included in the groupings of states.

After grouping the states according to non-policy contextual factors, policy differences and differences in installed PV capacity between groups of states and among states within each group were compared using statistical correlations (Table ES-2). While the small sample size of the context-related groups of states limited the statistical certainty of connections, there were observable differences in the relationship between policies and solar installed capacity in each of the groups. For example, while RPS set-asides had a moderate correlation with increased solar PV installation across all states, the relationship of this market-creation policy to market development was stronger in the expected leader and mixed groups. The expected leader group of states was remarkable in that all nine states in the group had an RPS, and six (50%) had long running solar set-asides. This early start and consistent use of mandates was correlated with robust solar markets in the group.

The mixed group of states had a less defined set of common policies. Six states (35%) in this group have an RPS, and three of those (18% of group total) have a solar set-aside. Like the states with a set-aside in the expected leader group, those three states are experiencing a surge in solar installations, reflecting the very strong correlation between solar set-aside age and solar installations. As their markets grow, they may also experience the robust markets seen in the expected leader group.

Table ES-2. Summary of Correlation Strength between Policies and Increased Installed Solar by State Grouping

Policy Indicator	All States[a] (n=49)	Expected Leaders (n=12)	Rooftop Rich (n=11)	Motivated Buyers (n=9)	Mixed (n=17)
RPS Solar Set-Aside Age	**	**	*	*	***
FTG 2011—Interconnection Score	N/A	N/A	*	*	N/A
Third-Party Ownership Allowed	*	*	N/A	**	*
FTG—2011 Net Metering Score	*	**	N/A	**	N/A
Suite of Policies	*	*	**	***	**

[a] Forty-eight states and the District of Columbia
* Moderate relationship (correlation coefficient between 0.4 and 0.6)
** Strong relationship (correlation coefficient between 0.6 and 0.8)
*** Very strong relationship (correlation coefficient between 0.8 and 1)

Another example is the development of policies that allow access through a number of different mechanisms (e.g., RPS, self-ownership through interconnection and net metering, allowance of third-party ownership) tend to result in increased development. For the motivated buyers group, the relationship between having a suite of policies and increased solar installations may be especially strong because these states have generally higher electricity prices that encourage buyers to take advantage of the many options available to them.

Following this quantitative analysis, the case histories provide examples of policy strategies that have been successful in market support within the demographic and resource context of the group, and, as such, serve as potential lessons learned for states with similar non-policy contexts. The purpose of these is to illuminate potential strategies for the role of policy in supporting market development in each context. States that are generally outperforming other states or states that have shown marked improvement in relation to other states in the group were selected for case studies. Maryland, in the expected leader group, has shown rapid growth in solar installations in recent years, going from less than 6 megawatts (MW) in 2009 to approximately 80 MW at the end of 2012. North Carolina is profiled for the rooftop rich group because it has the highest per capita installed capacity of all the states in this group despite having one of the highest costs for solar PV in the nation. Like North Carolina, Delaware has the highest per capita installed capacity for its group, and is detailed because of its aggressive promotion of solar PV. New Mexico was selected from the mixed group of states because its long history of enacting and improving existing solar policy uniquely illustrates the importance of implementing a suite of effective policies.

Results and observations from the quantitative analysis and case histories are detailed throughout the report, with major findings being:

- Solar-related policy has a quantified effect on solar markets (as measured by installed capacity).
- Non-policy factors influence the effectiveness of those policies in driving solar markets in situations where the non-policy factor is extreme. For example, if costs are very low for competing electricity, the influence of market-enabling policy, such as interconnection and net metering, is weakened due to reduced economic motivation.
- Solar set-aside is most consistently correlated with increased installed capacity. This connection spans across all groups. However, the connection is particularly strong in states with lackluster non-policy market support factors. This is borne out in the mixed group of states, which have a lackluster, non-policy-driven market for solar, and the findings indicate the impact of solar set-asides is particularly strong in this group.
- Having a suite of policies in place that are compliant with best practices is correlated with increased solar PV installations.
- The case histories illustrate policy pathways specific to the non-policy contexts of the states in question:
    - **Expected leaders**. In Maryland, a comprehensive policy portfolio, with equal emphasis on all policy types, is driving recent market development.
    - **Rooftop rich**. In North Carolina, strong interest from the populous in clean energy-related policy distinguishes it from other members of the group.
    - **Motivated buyers**. The state of Delaware's experience illustrates targeted market preparation and creation policy can effectively stimulate markets.
    - **Mixed**. In New Mexico, the leading state for installed capacity in the group, policy diversity and strategic implementation have proven to be critical in effectively supporting the market.

- Findings from the quantitative analysis and the case histories indicated 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. This is the primary focus of follow-on work to this research.

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1 Purpose

Current discourse surrounding solar market development points to state policy as the primary driver in the U.S. market. However, without a firm understanding of how policies interact with the market and lead to effective market support, there is little applicability of this information for policymakers. Without further information about the impact of specific policies within their specific context, policymakers could be investing resources in a sub-optimal way. For example, a state policymaker may invest public resources heavily in the design and execution of a financial incentive policy that could be much more effective if minimal resources were concurrently invested in policies that approach non-financial barriers to solar market development. Knowing that policy is a driver for market development has limited actionable outcomes if it is not followed with a clear understanding of which policies work in which context. With that information, policymakers can make educated decisions about the appropriate investment of public funds.

This report aims to move the discourse forward into a more detailed understanding of policy impact on solar markets by examining the influence of non-policy factors (e.g., population demographics, competing electricity costs) on the effectiveness of policy. The goal is to understand how non-policy factors influence policy effectiveness, for the purpose of identifying the policies that are most appropriate for states with similar non-policy characteristics.

In order to evaluate the impact of policy in various non-policy contexts, states were allocated into peer groups based on shared non-policy characteristics (Section 2). Each peer group was then analyzed empirically and statistically to determine the role of policy in driving distributed photovoltaic (PV) development in that context (Section 3). Section 4 presents case histories examining the policy history of a state in each context group to augment the statistical analysis.

2 "Types" of States

There are a variety of non-policy factors that might influence the effectiveness of PV policy at the state level. These factors were evaluated to develop state "typologies" or "contexts" that can be used to guide policy strategies in similar states (see the Appendix). The characteristics were selected with the goal of capturing the physical, economic, and demographic environment within each state relevant to the success of various policy options and policy implementation strategies. Grouping similar states into typologies also served to normalize, within each group of states, for the factors used in the selection of states for that group. Differences in solar installations among states in the same grouping were expected to be attributable to differences in policy. This analysis intentionally focused on state physical, economic, and demographic characteristics that were not directly related to solar PV installations but that might impact whether the state had a favorable or unfavorable climate for investment in behind-the-meter PV, regardless of whether state policy programs were in place. Section 2.1 lays out the methodology for the state typology and Section 2.2 outlines observations and findings from the resulting groups.

2.1 Methodology

States were grouped based on a combination of four physical and demographic characteristics:

- 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, Roberts et al. 2012).[1] Estimated technical potential is calculated as potential gigawatt-hour (GWh)/year for each state. This factor, in addition to accounting for the solar resource available in each state, includes an estimate of the rooftop area potentially available for PV. Because housing demographic factors influence the rooftop area per person (for example, apartment buildings have less rooftop area per resident than suburban single-family homes), the estimated technical potential factor captures housing type and population, which have been shown to be important correlating factors for solar PV (see the Appendix).
- 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). The State Energy Efficiency Scorecard score was selected as a proxy measurement of the state's interest in, and progress toward, addressing energy conservation-related issues within the state without consideration of specific policies regarding solar PV.

[1] Lopez does not present technical potential for rooftop PV for either Alaska or Hawaii. Both states are also somewhat anomalous in their primary drivers for distributed solar PV, resulting in data that skews overall results. For example, because of its latitude, Alaska has very low capacity factors for solar in relation to the other states. Therefore, Alaska and Hawaii are generally excluded from the analyses presented in this report.

The four context groups were selected as follows:

- **Expected leader**. States in the expected leader category were selected first, thereby eliminating them from further consideration for other groups. These states have excellent solar resource and good physical potential for residential solar installations. States in the expected leader category also have a higher than average ACEEE Energy Efficiency Scorecard score, indicating a general policy interest in energy-related issues. In general, it is expected these states, based on non-PV policy-related characteristics, should have high installed capacity of PV.
- **Rooftop rich**. These were selected from the states remaining after eliminating states in the expected leader category. These states also have higher-than-median technical potential for rooftop PV but lower-than-average median income, electricity price, and ACEEE Scorecard score. As such, states in the rooftop rich context group have good solar resource availability, but lack economic motivators and demonstrated community interest in solar development.
- **Motivated buyers**. These are states with poorer-than-median technical potential for rooftop solar PV but might be expected to have high interest in PV due to higher-than-average electricity prices and income and/or a general interest in energy-related issues.
- **Mixed**. These states have a lower-than-average ACEEE Scorecard score but show a broad range of income, electricity price, and technical potential. As such, they are not characterized by an individual factor that would serve as clear motivation for a high rate of installed PV capacity. Furthermore, because states that are expected to have high PV penetration were already grouped in previous categories, these states would be expected to have lower PV penetration.

Table 1 summarizes the resulting groupings. Summary statistics for the criteria used to develop the state contexts are presented in Table 2 and mapped in Figure 1.

Table 1. State Context Groupings

State Contexts[a]			
Expected Leader	**Rooftop Rich**	**Motivated Buyers**	**Mixed**
Criteria			
1. ACEEE Energy Efficiency Scorecard score ≥ average 2. Estimated technical potential for rooftop PV ≥ median	1. ACEEE Energy Efficiency Scorecard score < average 2. Cost of electricity < average 3. Income < average 4. Estimated technical potential for rooftop PV ≥ median	1. ACEEE Energy Efficiency Scorecard score ≥ average OR 1. Cost of electricity ≥ average and 2. Income ≥ average	States not identified in the previous three groups. These states have a variety of values for the characteristics evaluated.
Arizona California Colorado Illinois Maryland Michigan Minnesota New Jersey New York Pennsylvania Washington Wisconsin	Alabama Georgia Indiana Louisiana Missouri North Carolina Ohio Oklahoma South Carolina Tennessee Texas	Connecticut Delaware Iowa Massachusetts New Hampshire Oregon Rhode Island Utah Vermont	Arkansas District of Columbia Florida Idaho Kansas Kentucky Maine Mississippi Montana Nebraska Nevada New Mexico North Dakota South Dakota Virginia West Virginia Wyoming

[a] Lopez 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.

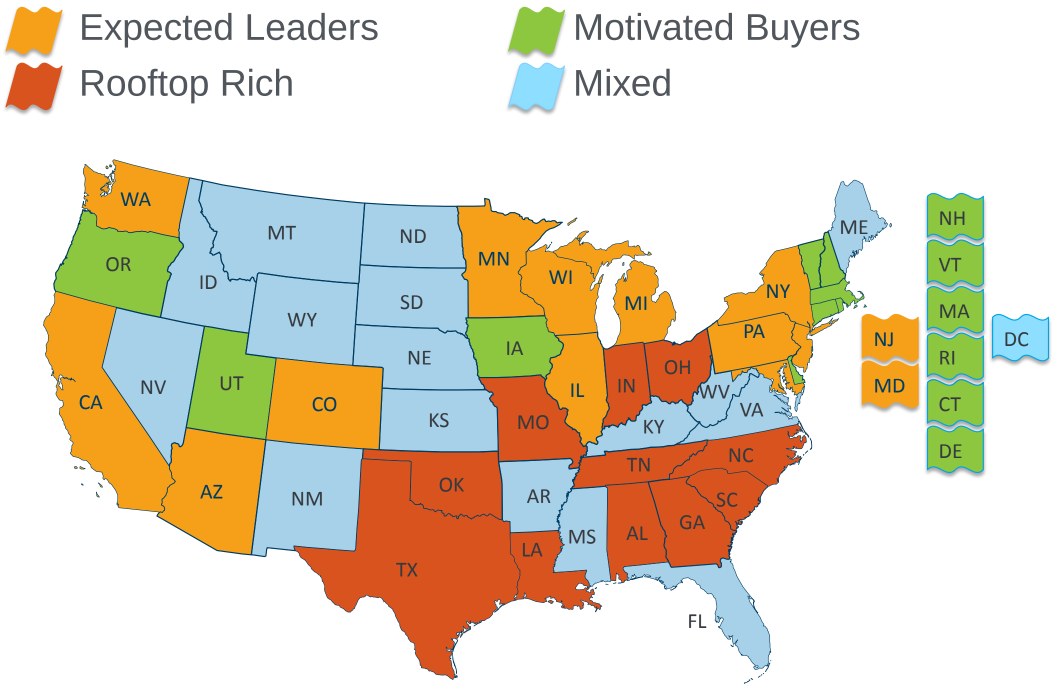

Figure 1. Grouping of states based on non-policy factors

Table 2. Statistics for Criteria Used in State Context Groupings

Group	Median Household Income (average 2010 $/year)	Residential Electricity Price (average $/kWh) 2010-2012 Average[a]	Technical Potential for Rooftop PV (median GWh/year)[b]	ACEEE 2012 Scorecard Score (average)
Expected Leader	$53,714	0.118	26,866	28.4
Mixed	$47,198	0.098	9,894	12.5
Motivated Buyers[c]	$57,123	0.121	5,570	30.1
Rooftop Rich	$43,467	0.102	25,274	13.3
All States	$50,115	0.114	12,443	19.6

[a] The source of the data was the Energy Information Administration.
[b] The median value was used as the criteria cutoff for the estimated technical potential for rooftop PV.
[c] The Motivated Buyers category includes states with ACEEE Scorecard values greater than the average of all the states or both higher-than-average income and higher-than-average electricity prices.

2.2 Typology Findings and Observations

A bar chart showing the variations in installed capacity (Sherwood 2013) between the four groups and for all states[2] is presented in Figure 2. Although the group averages of per capita capacities appear considerably different between groups, there is a wide range of variation within groups, resulting in inconclusive statistical significance between groups. Even so, there are observations that can be drawn from within the groups:

[2] Forty-eight states (excluding Alaska and Hawaii) and the District of Columbia

- Within the expected leader, motivated buyer, and mixed groups, there are a broad range of installed capacities, indicating that policy plays a large role in whether or not markets are developed, even in the presence of strong non-policy contexts.
- There is little variation in terms of installed capacity within the rooftop rich group. This group has good physical potential for solar, but low values for other potential non-policy drivers and little in terms of examples of successful markets.

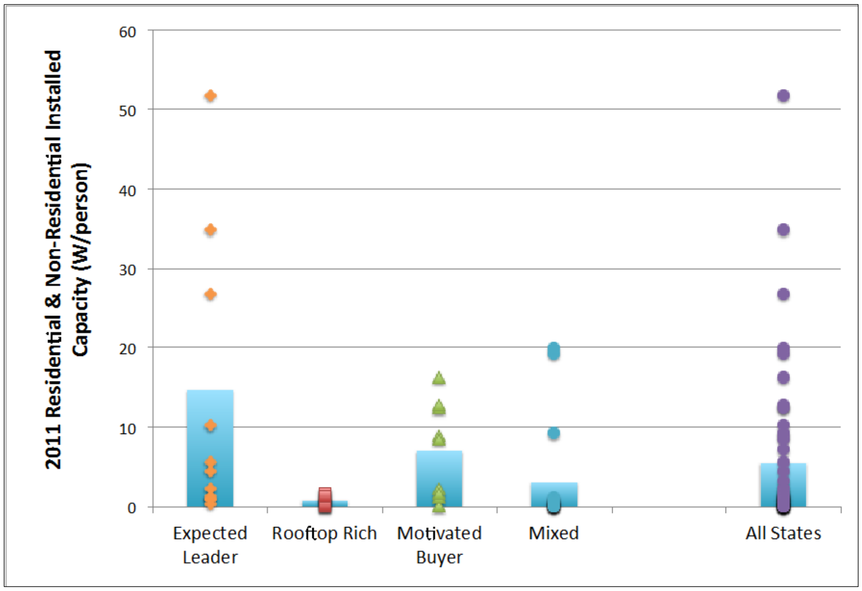

Figure 2. Variations in installed capacity of solar PV between the groups of states (individual state values are shown as colored symbols and group averages are shown as blue bars)

Analyzing the correlations between non-policy contextual factors and installed capacity in each of the four groups helps to further understand these observations. Table 3 lists the correlation coefficients between non-policy factors and installed capacity for the four groups and for all states combined. The strength of the correlation is categorized using a simple scale based on the correlation coefficient for each relationship:

- Correlation coefficients < 0.2 = no relationship
- Coefficient between 0.2 and 0.4 = weak relationship
- Coefficient between 0.4 and 0.6 = moderate relationship
- Coefficient between 0.6 and 0.8 = strong relationship
- Coefficient > 0.8 = very strong relationship.

Table 3. Correlations between Non-Policy Contextual Factors and Installed Capacity[a]

Value	All States[b]	Expected Leaders	Rooftop Rich	Motivated Buyers	Mixed
ACEEE score	0.39 (W)	-0.01 ()	0.55 (M)	0.28 (W)	0.40 (M)
Electricity Price	0.34 (W)	0.34 (W)	0.09 ()	0.26 (W)	-0.06 ()
Income	0.43 (M)	0.36 (W)	0.25 (W)	0.16 ()	0.35 (W)
Technical Potential	0.22 (W)	0.31 (W)	0.48 (M)	-0.07 ()	-0.07 ()

[a] Correlation coefficients < 0.2 = none (), 0.2 to 0.4 = weak (W), 0.4 to 0.6 = moderate (M), 0.6 to 0.8 = strong (S), > 0.8 = very strong (VS)
[b] Excluding Alaska and Hawaii

There are only weak to moderate correlations between contextual factors and installed capacity for all the groups. This result indicates that something other than state non-policy context drives the majority of differences in installed capacity between the states in each group where contextual factors are similar. The strength of correlations also varies in some cases between groups, indicating that non-policy context does make a difference, at least under some conditions, and those relationships are explored for the remainder of this section.

Our analysis of the relationship between the ACEEE Scorecard score and installed PV capacity provided valuable insight into the influence of this potential driver on solar markets. There is a moderate correlation between ACEEE Scorecard score and states having a suite of solar policies in place. It is not surprising that states interested in energy issues in general would also be more likely to have adopted complimentary solar policies. A scatter plot of installed capacity and ACEEE Scorecard score for all states included in the grouping analysis and the District of Columbia (see Figure 3) reveals that states with very low ACEEE Scorecard scores (below 15), also have very little installed capacity. However, a high ACEEE Scorecard score (as an indication of a community ethic for sustainability) does not necessarily correlate with greater levels of solar PV installation. As expected, this result suggests there is a more complex relationship between general interest in energy efficiency and conservation issues and actual installed capacity than is revealed by analysis of a single contextual factor.

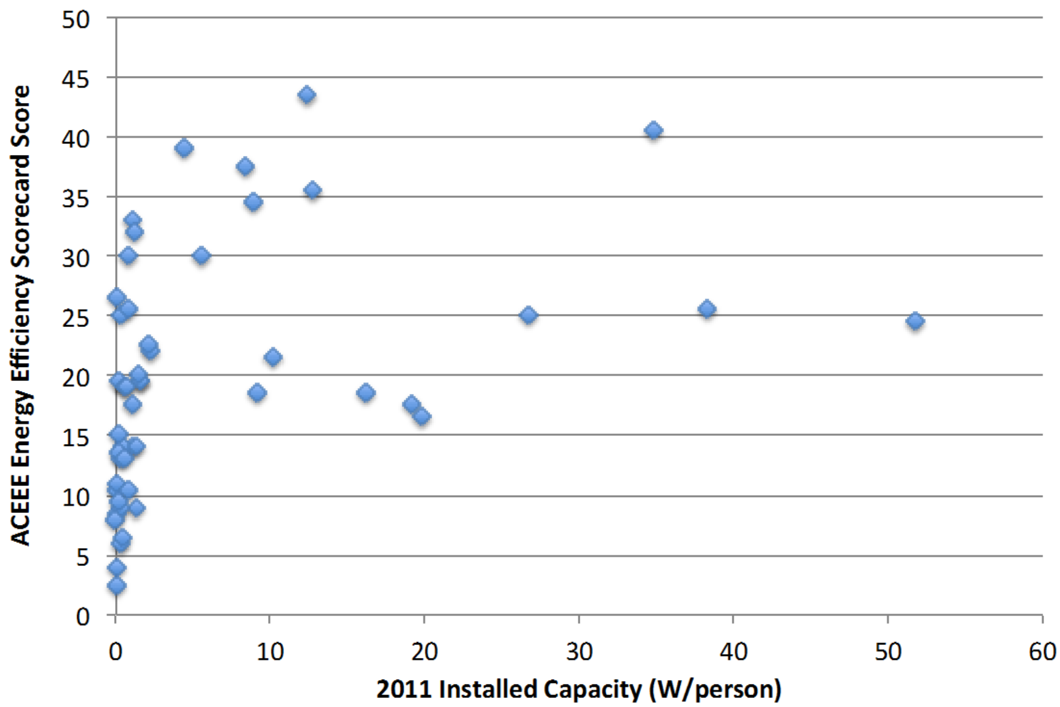

Figure 3. Scatter plot showing the relationship between ACEEE scorecard score and installed capacity

While a single factor for grouping would have resulted in more clearly defined groups, the primary observation is that a combination of factors offers a richer view of non-policy related context for solar markets that is more reflective of the complex reality:

- The relationship between the populous' interest in clean energy (as measured by the ACEEE scorecard) and installed PV capacity suggests there is a threshold level of general interest, but even high levels of interest are not sufficient to drive solar market penetration alone.
- Technical potential for rooftop PV correlates with installed capacity, indicating the technical potential has a moderate influence on solar markets, but only in cases where the technical potential is high (expected leader and rooftop rich groups).
- Similarly, electricity price is only correlated with installed capacity in groups where electricity price is generally high (expected leaders and motivated buyers).

  Median household income, however, does not show the same trend in correlations with installed capacity. Income is weakly correlated with installed capacity even in groups of states where income is generally lower (e.g., the rooftop rich group) and not at all correlated in the highest income group (motivated buyers). It is probable that a certain level of economic security is needed for people to contemplate purchasing a solar PV system, but that once that level of income has been achieved, other factors become more important in the decision-making process.

3 Impact of Policies Across State Groups

A number of researchers have investigated the effectiveness of state-level policy using various statistical methods to determine relationships between installed solar PV projects and policy initiatives (Barbose et al. 2006; Taylor 2008; Nemet 2009; Drury et al. 2011a; Drury et al. 2011b; Burns and Kang 2012; Krasko and Doris 2012; Sarzynski et al. 2012). The grouping of states by non-policy factors in Section 2 partially normalizes for common non-policy factors, allowing for added dimension to these analyses that identifies how policies function in different non-policy environments. This section analyzes the impacts of policies within and across these groupings.

The focus of this work is on state-level policies that are intended to facilitate solar markets, rather than those intended to provide direct financial incentive for development. Krasko and Doris (2012) found that market preparation (e.g., interconnection) and market creation (e.g., renewable portfolio standards with solar set-asides), along with non-policy factors can explain 70% of the variation between installed capacity levels across states. While direct financial incentives have a role to play in development of solar markets, the focus of this study is on low-cost (to government) policies, and how they can be implemented with maximum effectiveness for supporting installed capacity additions. Therefore, state-level financial or tax incentives, such as sales tax rebates or reductions or property taxes are not included in this analysis. State-level tax and financial incentives are included in case studies associated with this report.

3.1 Methodology

Statistical analysis is used to assess the effect of policy drivers on solar markets in the context of the groups of states. The remainder of this chapter outlines how policies are defined in the analyses.

3.1.1 Renewable Portfolio Standards with Solar Set-Asides

Previous analyses found that both renewable portfolio standard (RPS) age and solar set-aside age 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 the non-policy factors used for grouping of states. For this analysis, the age of the solar set-aside (if present) is calculated as the number of years prior to and including 2011 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.

3.1.2 Interconnection Standards

The 2011 Freeing the Grid (FTG) scores were used to assess interconnection standards. Although more recent data was available, the 2011 scores were used because 2011 was the most recent year for which complete solar PV capacity data was available. A higher FTG score has been shown to indicate policy more likely to effectively support distributed generation markets (Krasko and Doris 2013).

3.1.3 Third-Party Ownership

Twenty-two states and Washington, D.C., currently specifically authorize or allow third-party ownership (TPO) through power purchase agreements (PPAs) or the leasing of solar PV systems.[3] TPO is expected to be more attractive to investors in states where the value of net metering or other sources of production-based income, such as selling of renewable energy certificates (RECs), is high (Drury et al. 2011b). TPO might also be more attractive to customers who have lower disposable income or do not own their home because it allows for renting or leasing of systems. This analysis evaluates the relationship between current TPO policy,[4] solar PV installations, and other policy drivers in the four groups of states. States that specifically authorize TPOs are given a score of 1. States that specifically prohibit or restrict TPOs are given a score of -1. States that are silent on the issue receive a score of 0.

3.1.4 Net Metering

Forty-three states and Washington, D.C., have adopted a net-metering policy.[5] FTG scores for net metering policies, which have previously been shown to be correlated with increased installed capacity nationally, are applied to the four groups in this analysis. As with interconnection standards, a higher FTG score is indicative of higher quality policy.

3.1.5 Suite of Solar Policies

Having a suite of high-quality solar policies in place may also affect solar markets independently from the influence of any one policy. In this paper, this is analyzed by developing a simple scoring system for policies in each state and then adding up the scores to determine the extent to which the state has a suite of solar policies in place. Each of the four policy variables—FTG interconnection score, FTG net metering score, PPA score, and solar set-aside age—counted as being included in a "suite of policies" if the value of the variable for a particular state was greater than the national average for that variable. For example, if a state's FTG net metering score and interconnection score are above the respective national averages, but the solar set-aside age and TPO score are below national averages, the state received a score of 2 for having a suite of policies. The maximum value is four because four types of policies were evaluated.

3.2 Results/Discussion

Table 4 shows significant policy correlations for each group of states. The asterisks indicate the strength of the correlation between the policy value and behind-the-meter solar PV installed capacity for each group, as described in the notes of the table.

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

[4] As compiled for the Database of State Incentives for Renewables & Efficiency, which is available at www.dsireusa.org.

[5] DSIRE. "Net Metering." Accessed July 9, 2013: www.dsireusa.org/documents/summarymaps/net_metering_map.pdf.

Table 4. Summary of Correlations between Behind-the-Meter Installed Capacity and Policy by State Grouping

Policy Indicator	All States	Expected Leaders	Rooftop Rich	Motivated Buyers	Mixed
RPS Solar Set-Aside Age	**	**	*	*	***
FTG 2011—Interconnection score	N/A	N/A	*	*	N/A
Third Party Ownership Allowed	*	*	N/A	**	*
FTG—2011 Net Metering score	*	**	N/A	**	N/A
Suite of policies	*	*	**	***	**

Blank: No correlation or only a weak relationship (correlation coefficient < 0.4)
* Moderate relationship (correlation coefficient between 0.4 and 0.6)
** Strong relationship (correlation coefficient between 0.6 and 0.8)
*** Very strong relationship (correlation coefficient between 0.8 and 1)

Evaluating the policies within the different state context groups offers insights into how policies function. Nationwide, it appears that policies are only marginally correlated with increased installations of behind-the-meter solar. When evaluated relative to states with similar contexts, however, the specific policies with higher correlations become clear. Findings indicate:

- While policy drives solar market development, the context of the state in which the policy is in place, in addition to the quality and type of policy in place, contribute to policy effectiveness in the development of markets. This concept is illustrated in the Table 4 because the relationships between policy drivers and solar markets are different for the different groups of states.
- All of the policies evaluated are influential in the motivated buyers group, and having a suite of policies in place is especially important in this group. The favorable non-policy economic attributes of these states provide conditions that encourage potential buyers to take advantage of diverse policy incentives.
- One individual policy driver, solar set-aside age, while important in all groups, was overwhelmingly the most influential policy in the mixed group of states. A possible explanation for this is that in the absence of strong non-policy drivers, mandate-style policies may result in the most market support.
- The expected leaders group was most correlated with RPS and net-metering policies, indicating that this group emphasizes both market pull strategies of valuing energy produced, and market push strategies of setting up mandates to be reached in order to develop markets.
- Having a suite of policies in place is also moderately correlated (correlation coefficient of 0.57) with installed capacity for all states. A scatter plot of the 2011 installed capacity and the number of policies with values greater than the national average (Figure 4) reveals a potential minimum threshold of complimentary solar policies needed to effectively promote solar markets.

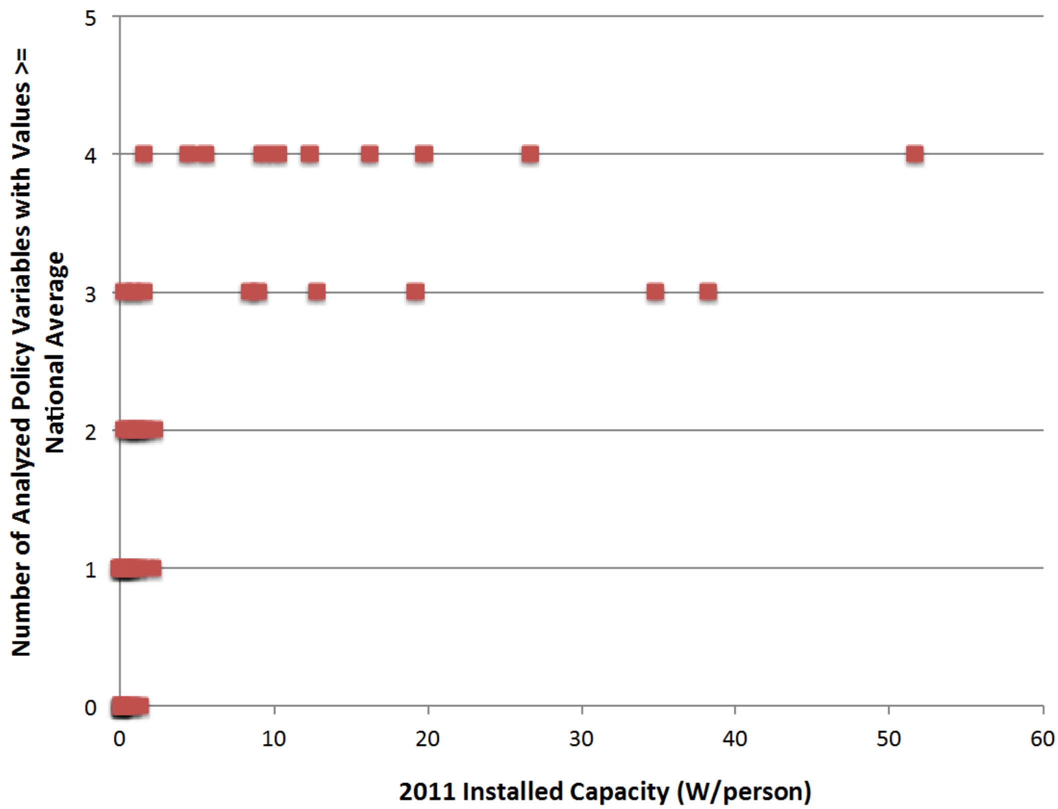

Figure 4. Relationship between having a "suite" of policies and installed capacity for the states included in the grouping analysis

4 Case Histories

Findings from the quantitative analysis illustrate the value of examining policy effectiveness within the confines of the context in which policy is applied. That value is the allowance for a better understanding of actionable policy strategies for state policymakers in a specific context. The contexts as defined in this paper are illustrated in Figure 5. Because of the variation in policies that have been applied and how they have been applied, there is discordance within the groups of state contexts in terms of the installed capacity within those states. By better understanding the outliers in the groups in terms of increased capacity or innovative policy implementation, effective policy strategies within each group can come into focus. In this section, a state from each group is profiled through a policy history in order to identify specific strategies that could be effective within each group. The histories are organized with an overview of the group and the position of the state within it, followed by a history of policy development and implementation of market preparation, creation, and expansion policy types (Krasko and Doris 2012), and conclude with a summary of observations from the development of policies in the state.

Major takeaways from each group are:

- **Expected leaders**. In Maryland, a comprehensive policy portfolio, with equal emphasis on all policy types, is driving recent market development.
- **Rooftop rich**. In North Carolina, strong interest from the populous in clean energy-related policy distinguishes it from other members of the group.
- **Motivated buyers**. The state of Delaware's experience illustrates that targeted market preparation and creation policy can effectively stimulate PV development.
- **Mixed**. In New Mexico, the leading state for installed capacity in the group, policy diversity and strategic implementation have proven to be critical in effectively supporting the market.

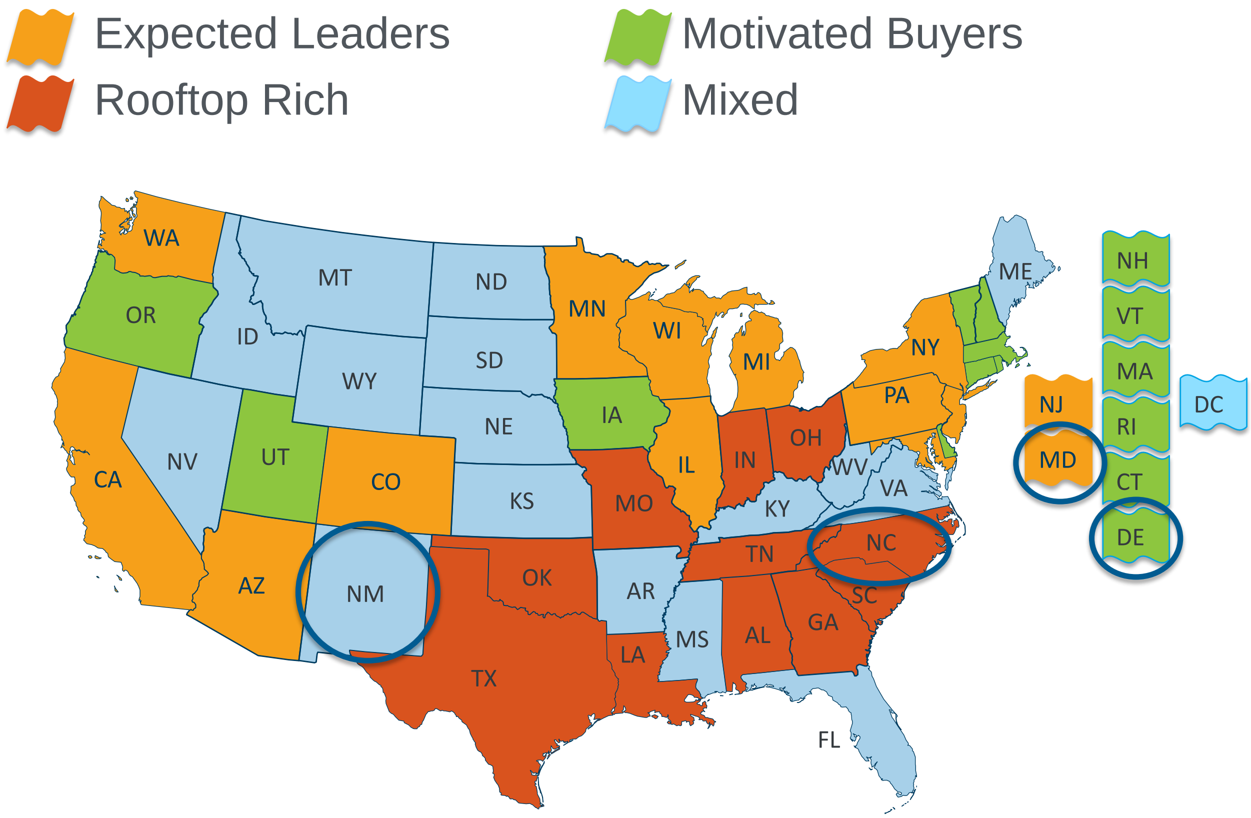

Figure 5. States by context grouping with case history selections circled

Looking across the groups, there are also interesting observations from the policy histories. All groups provide supporting evidence for the widely held supposition that public interest in clean energy development drives policy development. For example, in New Mexico, much progress on implementation of effective policy occurred following the election of a governor who ran on a platform of clean energy development. This finding indicates it may be more effective for policymakers to capitalize on constituent demand when it is at its peak.

4.1 Expected Leader Group: Maryland

This case history focuses on the expected leader group and the policy history of Maryland. The expected leader group comprises twelve states that possess above-average technical potential for rooftop PV and have historically demonstrated public support for clean energy policy. These criteria generally captured states with more mature solar policy, particularly as it relates to solar set-asides. The expected leader group exhibits the highest correlation between non-policy drivers and installed PV capacity, suggesting that policy may be relatively less important in favorable economic or motivational climates (see Section 3), but that policy that sets a baseline allowing entry to a variety of players may be important to fostering market development.

4.1.1 State Profile: Maryland

While Maryland does not lead its group in installed PV capacity, it has experienced rapid growth in PV adoption compared to its peers, which makes it a good candidate for study. In 2009, it was one of six states in the bottom half of the expected leader group with less than 6 megawatts (MW) of total installed capacity (GTM 2010). At the end of 2012, Maryland's total installed capacity had grown to approximately 80 MW, while each of the other five states remained below 20 MW[6] (GTM 2012; IREC 2013).

Table 5. Quick Facts: Maryland (Expected Leader Group)

	Maryland (Rank)	Group Average
ACEEE Scorecard[a]	30.0 (4/12)	28.4
Retail Electricity (¢/kWh)[b]	11.6 (5/12)	11.8
Median Income[c]	$64,025 (1/12)	$53,714
PV Technical Potential (kW/capita)[d]	14,850 (9/12)	26,866
Installed Capacity (W/capita)[e]	5.6 (6/12)	14.8

[a] Foster et al. 2012
[b] Three-year average residential electricity (EIA 2010-2012)
[c] Median household income (U.S. Census Bureau 2010)
[d] Lopez et al. 2012
[e] Sherwood 2013

4.1.2 Market Creation

In 2004, the Maryland state legislature adopted the Renewable Energy Portfolio Standard and Credit Trading Act (House Bill 1308), which required utilities to procure 7.5% of retail sales from renewable energy resources by 2019. In 2007, a solar set-aside was added, which is currently 2% by 2020. Maryland is the only state of the six with less than 6 MW of installed PV capacity in 2009 that has a solar set-aside as part of its RPS. This is significant because solar set-aside age is the most meaningful determinant of installed PV capacity across states (Section 3). The growth experienced by Maryland subsequent to 2008—the first compliance year of the solar set-aside—is consistent with this finding.

In addition to establishing an RPS, House Bill 1308 allowed utilities to purchase renewable energy credits (RECs) to fulfill RPS obligations. By doing so, the legislature created additional value for the electricity produced by renewable energy. The act also instructed the Public Service Commission (PSC) to devise a market-based trading system for RECs, which can reduce transactional barriers and attract market participants. The PSC responded by allowing energy producers to list RECs available for sale on the PSC website. In 2007, when the legislature created the first set-aside for solar, it also created a new category of RECs specifically for solar.

The rules for solar renewable energy credits (SREC), however, are different. To ensure Maryland utilities have an opportunity to purchase the SRECs, energy producers must list them on the PSC website for 10 days before they can sell them on the open market. This rule is unique to Maryland (DSIRE 2013). Furthermore, SRECs sold through the PSC require a 15-year minimum contract and a single, up-front payment. These policies are intended to reduce economic barriers by lowering initial capital requirements and reduce investment risk by requiring long-term contracts.

[6] Total capacity installed for Michigan and Minnesota was approximated for 2012 using data provided by the Interstate Renewable Energy Council (IREC).

Having created demand for renewable energy by allowing utilities to purchase RECs and SRECs to meet RPS obligations, lawmakers sought to stimulate in-state supply by revising the state's net-metering rules. With the adoption of House Bill 1016 in 2007, the legislature increased statewide aggregate capacity from 35 MW to 1,500 MW. Utilities were also required to offer net metering for systems up to 2 MW in size, whereas previously it was only required for systems up to 200 kilowatt (kW). By revising these limits, policymakers extended the benefits of PV development to more participants, particularly on the commercial scale. Since 2007, the year Freeing the Grid began evaluating state net-metering and interconnection standards, Maryland has received the highest possible grade for its net-metering practices (FTG 2013).

In 2009, Maryland's state legislature enacted a bill to allow third-party ownership of renewable energy generating facilities (Senate Bill 981). This was a significant occurrence because it allowed PV developers access to pooled capital for the first time. Third-party ownership structures can lower economic barriers by reducing or eliminating initial capital requirements for individuals. Furthermore, third-party ownership is a way that communities without suitable space for PV can benefit from renewable energy development.

4.1.3 Market Preparation

Prior to allowing third-party ownership, the state legislature determined it was necessary to improve existing utility interconnection practices to remove unnecessary barriers to renewable energy development. In 2007, the legislature instructed the PSC to form a task force to develop small generator interconnection standards that would be consistent with national best practices (Senate Bill 595). Following the task force's recommendation, the PSC promulgated rules in 2008 using Federal Energy Regulatory Commission (FERC) timelines (Case 9060 Final Order). These include a fast track process for smaller systems and standardized agreements for all system sizes.

PV developers in Maryland also enjoy strong solar easement and property rights. Property owners are protected from any restrictions that would result in a significant increase in system cost or decrease in system efficiency (House Bill 117).

4.1.4 Market Expansion

Maryland has also implemented a variety of market expansion policies. This type of policy addresses higher-level barriers like technology first-costs and investment uncertainty. The policies that Maryland has in place include production tax credits, equipment sales tax exemptions, property tax exemptions, and rebate programs.

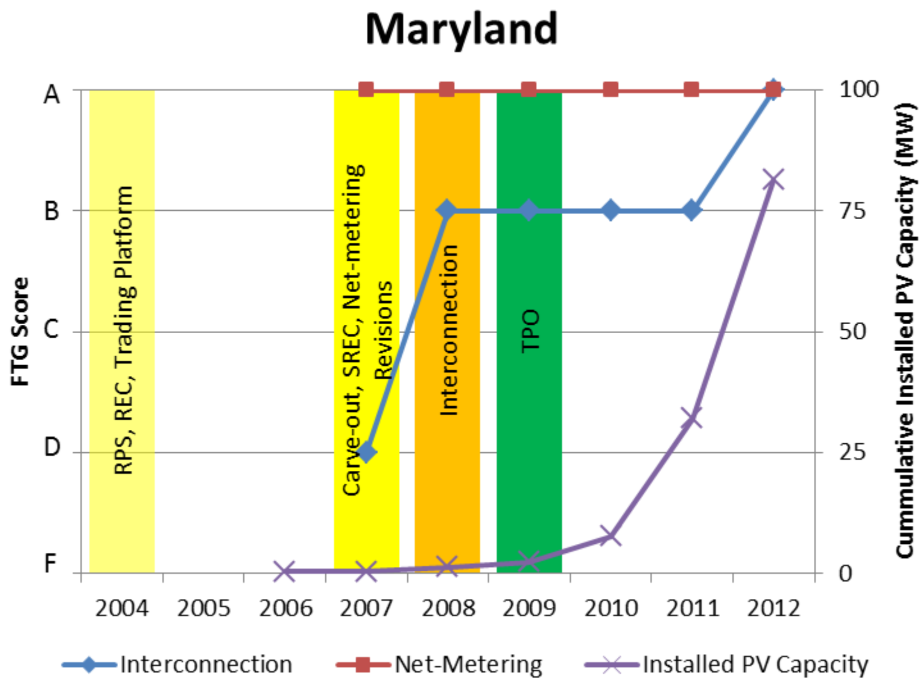

Figure 6. Total installed PV capacity with policy timeline, Maryland 2004-2012

4.1.5 Summary

The case of Maryland demonstrates the importance of comprehensive policy. Prior to 2010, it was one of six states in the expected leader group that was significantly behind its peers in terms of installed PV capacity. While all six have grown in the period since, Maryland is approaching 80 MW of installed capacity, while none of the other five states have reached 20 MW. It is difficult to point to a single policy to explain Maryland's recent growth. However, Maryland possesses characteristics that are consistent with the determinants for success identified in Section 3. For instance, Maryland is the only one of the six that has a solar set-aside as part of its RPS, the attribute found to be the most meaningful determinant of installed capacity across states of all the factors analyzed. In addition, the data suggest that allowing third-party ownership may have stimulated the recent growth because the nonresidential sector accounts for most of the capacity that has been installed since 2009. The Maryland example illustrates how a portfolio of best practice-based policies can support market growth in this peer group.

4.2 Rooftop Rich: North Carolina

This case history focuses on the rooftop rich group and the policy history of North Carolina. The rooftop rich group includes states that have above-average technical potential for rooftop PV, but lack favorable economic conditions to stimulate demand for PV technology. The use of these criteria resulted in a peer group comprising 11 members.

Within the rooftop rich group, installed PV capacity is most highly correlated to the ACEEE Scorecard score of the non-policy drivers. Economic factors, such as electricity price and income level, have a low correlation with installed PV capacity in the group. Among policy drivers, solar set-aside age shows the strongest relationship to installed capacity. These findings suggest policy maturity and public support can be important drivers of PV adoption in the absence of a favorable economic environment (see Section 3 for details).

4.2.1 State Profile: North Carolina

North Carolina has the highest installed PV capacity per person in the rooftop rich group, despite having one of the highest installed costs in the nation for systems under 10 kW: $6.60/Watt (W) (Barbose et al., 2012). The state also has the highest ACEEE Scorecard score within its group. These characteristics are consistent with the finding that higher interest and public support for energy-related issues is a driver of PV adoption.

4.2.2 Market Preparation

In the five-year period from 2007 to 2012, North Carolina implemented a series of policies intended to foster energy efficiency and renewable energy in the state. The majority of these policies were the direct result of Senate Bill 3 (Senate Bill 3) enacted in 2007. Senate Bill 3 contained a variety of policies designed to address market preparation, creation, and expansion.

In addition to establishing a RPS, Senate Bill 3 instructed the North Carolina Utilities Commission (NCUC) to promulgate interconnection standards for renewable energy facilities up to 10 kW in size and also to consider adopting rules that would require utilities to offer net metering for facilities with capacities of 1 MW or less. In June 2008, NCUC issued interconnection standards based on the guidelines recommended by the FERC in Order No. 2006. These standards included solar-friendly provisions, such as a fast-track application for systems smaller than 2 MW in size and no limits on individual system size. The following year, NCUC revised existing net-metering regulations to remove limits on aggregate customer participation and added a prohibition of stand-by charges for residential systems up to 20 kW (Docket No. E-100, Sub 83).

4.2.3 Market Creation

Establishing an RPS was one of the primary ways in which the legislature sought to promote renewable energy development through Senate Bill 3. While not the first state to adopt an RPS, North Carolina's initial implementation was more comprehensive than the first attempts of many others. It included provisions, such as a set-aside for solar, and standards for municipalities and cooperatives. Such provisions have frequently been added to more mature RPSs via subsequent amendment. Immediate adoption of a solar set-aside is a significant occurrence because it can be the most meaningful determinant of installed PV capacity of all the factors they analyzed. Indeed, it was also the most relevant of policy-related factors within the rooftop rich group.

Table 6. Quick Facts: North Carolina

	North Carolina (Rank)	Group Average
ACEEE Scorecard	19.5 (1/11)	13.3
Retail Electricity (¢/kWh)	10.4 (5/11)	10.2
Median Income	$43,753 (6/11)	$43,467
PV Technical Potential (kW/capita)	28,420 (4/11)	25,274
Installed Capacity (W/capita)	1.6 (1/11)	0.8

[a] Foster et al. 2012
[b] Three-year average residential electricity (EIA 2010-2012)
[c] Median household income (U.S. Census Bureau 2010)
[d] Lopez et al. 2012
[e] Sherwood 2013

Investor-owned utilities (IOU) are required to offer net metering for systems up to 1 MW in size, and there is no limit on aggregate capacity. By allowing a range of system sizes to net meter and requiring utilities to accept all system owners who qualify, there is significant potential for participation. However, this potential is governed by the treatment of net excess generation (NEG). NEG is allowed to carry forward to subsequent billing periods for 12 months at the utility's full retail rate. While this is favorable for the customer, all unused NEG is forfeited to the utility at the end of the annual billing cycle without compensation. This practice has potential benefits for the utility program implementer, but may act as a disincentive to conserve electricity when the user is faced with a possible surplus.

To ensure compliance with RPS requirements, the NCUC established a REC program to track production. Through this program, utilities are allowed to purchase RECs as a means of fulfilling RPS requirements without having to develop their own renewable energy generation facilities. This has led to the development of two markets for REC transactions. The primary way in which utilities acquire RECs is by purchasing them directly from PV system owners. This typically occurs within the context of a long-term contract, whereby the producer receives an up-front payment based on system size and a stream of payments tied to electricity production. REC procurement programs can reduce the economic barriers of PV development by lowering initial capital requirements and accelerating return on investment.

The secondary way in which utilities acquire RECs and SRECS is by purchasing them on the open market on an as-needed basis. While it is up to buyers and sellers of RECs to come together on their own, the state has organized a formal exchange to facilitate SREC trading. Through the North Carolina SREC exchange, the state aims to promote a healthy market for the smaller SREC market by creating liquidity and providing transparency to participants.

4.2.4 Market Expansion

Having initially focused on promoting renewable energy through market preparation and market creation policies, the state legislature then turned its attention to market expansion policies. In 2008, the state legislature created a property tax exemption for PV systems that is equal to 80% of the system's appraised value. In addition, residential systems that are not used to generate income or in connection with a business may be entirely exempt from property taxes as nonbusiness personal property. In 2009, the legislature authorized cities and counties to establish revolving loan programs to finance renewable energy and energy efficiency projects (House Bill 1389). In addition to these financial incentives, North Carolina has a 35% personal and corporate tax credit for renewable energy installations that has been in place since 1977 (NC Gen. Stat. § 105-129.15 et seq.). These types of tax policies can stimulate market expansion by reducing the cost of installing a system through indirect means, such as avoided property taxes. This makes systems more affordable for developers and draws new participants into the market.

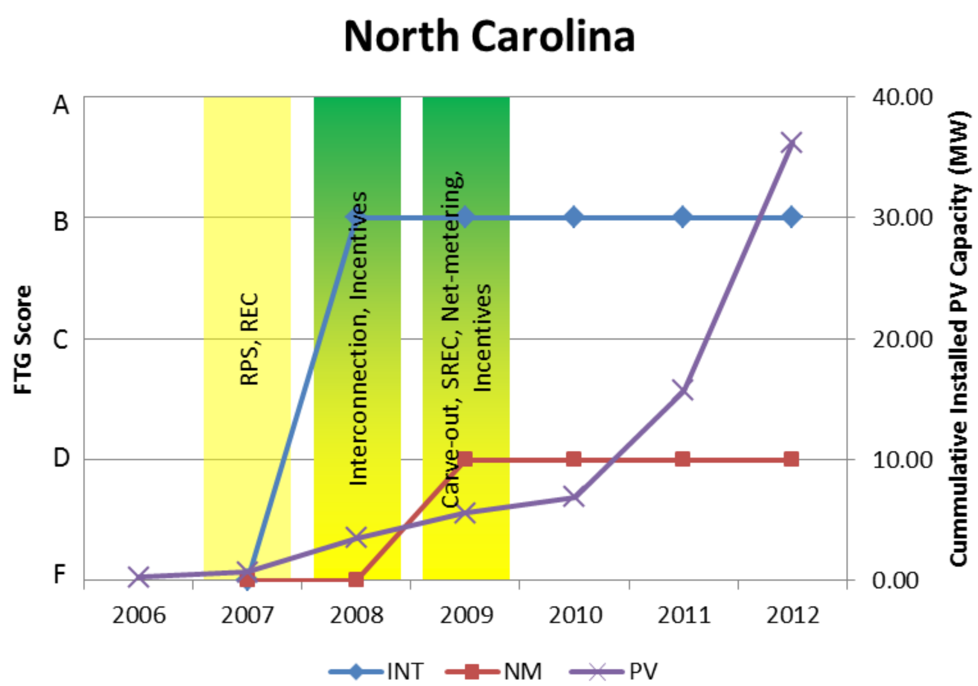

Figure 7. Total installed PV capacity with policy timeline, North Carolina 2006-2012

4.2.5 Summary

The case of North Carolina is an example of how comprehensive policy can stimulate market adoption in an environment where non-policy factors are expected to be unfavorable to market development, but public support is strong. The rooftop rich context grouping comprises states with less favorable non-policy characteristics, but with an abundance of PV technical potential within the group, North Carolina generally ranks in the middle in terms of electricity cost, income, and technical potential. However, North Carolina residents have demonstrated a stronger interest in energy-related policy than most in their group. In addition, they are one of four states within the rooftop rich group that has adopted an RPS, which has been shown to be a critical policy determinant of PV adoption (see Section 3). North Carolina's first implementation of an RPS was more comprehensive than most of its peers' RPSs. It included provisions for municipalities and electric cooperatives, as well as a solar set-aside. Therefore, while the state's RPS is relatively young, it is characteristic of more mature policies. This is particularly relevant as it relates to the solar set-aside.

In addition to having a comprehensive RPS, North Carolina has stimulated PV adoption through other types of policies, including market preparation- and market expansion-type policies.

Having adopted best practices for interconnection, the state allows energy producers to access the grid without unnecessary burdens. To expand the renewable energy market, North Carolina offers a variety of financial incentives that aim to reduce economic barriers. The state has also taken steps to ensure that there are multiple markets for SREC transactions. North Carolina is an example of the effectiveness of using a combination of market preparation, market creation, and market expansion policies.

4.3 Motivated Buyer Group: Delaware

This case history focuses on the motivated buyer group and the policy history of Delaware. The motivated buyer group comprises states that have demonstrated public support for clean energy policy in the past or have economic conditions that favor PV adoption (i.e., above-average income and cost of electricity). States in this group are expected to have greater interest in PV technology based on the presence of one or both of these characteristics. These criteria resulted in a grouping of states with significant disparity in level of PV adoption. Five of the nine states had installed PV capacity per capita greater than the group average, while each of the remaining four states had installed capacity that was less than one-third of the group average.

4.3.1 State Profile: Delaware

Delaware's non-policy characteristics suggest it should be among the bottom of its peer group for installed PV capacity. Compared to its peers in the motivated buyer group, it has the lowest ACEEE Energy Efficiency Scorecard score, below average income, below average cost of electricity, and the seventh lowest rooftop PV potential. Yet, Delaware has the highest installed PV capacity per capita in its group with 16.2 W/person—more than twice the motivated buyer group average. These characteristics are consistent with the finding (Section 3) that non-policy factors do not explain PV adoption within a highly motivated group of states.

Table 7. Quick Facts: Delaware

	Delaware (Rank)	Group Average
ACEEE Scorecard[a]	18.5 (9/9)	30.1
Retail Electricity (¢/kWh)[b]	11.9 (6/9)	12.1
Median Income[c]	$55,269 (6/9)	$57,123
PV Technical Potential (kW/capita)[d]	2,185 (7/9)	5,570
Installed Capacity (W/capita)[e]	16.2 (1/9)	7.1

[a] Foster et al. 2012
[b] Three-year average residential electricity (EIA 2010-2012)
[c] Median household income (U.S. Census Bureau 2010)
[d] Lopez et al. 2012
[e] Sherwood 2013

4.3.2 Market Creation

Net-metering rules in Delaware were first enacted as part of the Electric Utility Restructuring Act of 1999 (House Bill 10). As originally adopted, utilities were not required to offer net metering for systems over 25 kW in size, which limited potential renewable energy development to small- and medium-sized systems. Furthermore, credit for NEG could only be carried forward for 12 months, after which, it was forfeited to the utility without compensation to the producer.

This policy effectively eliminated all economic incentives for renewable energy producers to develop systems with capacity beyond their own consumption needs.

In an effort to create a larger market for renewable energy, the Delaware state legislature adopted an RPS as part of the Renewable Energy Portfolio Standards Act (REPSA) (Senate Bill 74) in 2005. The act required IOUs and municipalities to procure 10% of total retail sales from renewable energy sources by the 2019 compliance year. In addition, the legislature sought to encourage the development of specific renewable resources through the use of multipliers. As such, electricity generated from solar energy is eligible for a 300% multiplier that applies to the general renewable energy portion of the RPS if the system is installed before Dec. 31, 2014, and meets certain requirements. In 2007, the legislature took further action to expand the market for renewable energy by doubling the RPS requirement to 20% and adding a 2.005% set-aside specifically for solar (Senate Bill 19). The creation of a solar set-aside was a significant event because it is the most meaningful determinant of installed PV capacity across all the policy and non-policy factors analyzed (Section 3). In 2010, Delaware revised the RPS to its present standards by increasing the renewable energy requirement to 25%, with a 3.5% solar set-aside by 2025 (Senate Bill 119).

To track compliance with RPS requirements, the Delaware PSC established a REC program with SRECs specifically for electricity generated from solar energy. These credits belonged to the energy producer, with the exception of NEG, which was forfeited to the utility. While the forfeiture was suboptimal from the owner perspective, facility owners retained control over the majority of their RECs that were fully transferable under REPSA. This created additional value for renewable energy producers, as utilities would purchase RECs and SRECs as a means to satisfy RPS and solar set-aside obligations without having to develop their own renewable energy facilities. As a result, additional markets have formed to facilitate the acquisition of SRECs by utilities. Initially, all SRECs were traded on the open market through organized exchanges. However, in an effort to stabilize prices through long-term contracts, the PSC has begun authorizing procurement programs, whereby renewable energy producers may respond directly to open solicitations from utilities seeking to enter into long-term contracts to purchase the SRECs that their systems produce.

If a utility does not fulfill its RPS obligations in a given year through either its own production or by purchasing credits, it may compensate for the deficit through alternative compliance payments (ACPs). ACP programs create a ceiling on potential regulatory costs through a predetermined price schedule. Delaware’s ACP program becomes increasingly expensive each year that a utility is out of compliance. While this provides an escalating incentive to satisfy RPS obligations, utilities benefit from being able to anticipate the cost of noncompliance. Furthermore, ACP programs provide a basis to price RECs and SRECs trading in the open market. For example, under the current schedule, the cost of an ACP to meet the general renewable energy requirements of the RPS starts at $25 per MWh, whereas a solar ACP to satisfy the solar set-aside starts at $400 per MWh. By placing a premium on solar ACPs, utilities have a meaningful financial incentive to comply with the solar set-aside.

In 2007, the legislature addressed the issue of net-metering limitations by requiring utilities to offer net metering to nonresidential customers with systems up to 2 MW in size for IOUs and 500 kW for cooperatives (Senate Bill 8). By doing so, lawmakers expanded the potential market for renewable energy development. In 2009, the legislature improved the economics of net metering for PV system owners by requiring utilities to offer annual payments for NEG and by reassigning ownership of the associated RECs to the system owner (Senate Bill 85). Furthermore, Senate Bill 85 also increased the aggregate capacity of net metering that utilities had to offer from a maximum of 1% of monthly peak demand to 5%.

4.3.3 Market Preparation

Even though the PSC instructed utilities to adopt interconnection rules based upon Interstate Renewable Energy Council (IREC) best practices in 2007 (Senate Bill 8), the state routinely received failing grades from Freeing the Grid (FTG 2013).[7] Recognizing the need for improvement, the PSC determined it was necessary to issue specific rules for interconnection to standardize practices across utilities. Rather than promulgating entirely new rules, the PSC chose to use Maryland's interconnection standards, which were based upon IREC standards, as a template (DSIRE 2013). Since adopting the revised rules, Delaware has received an "A" from Freeing the Grid for three consecutive years (FTG 2013). The new interconnection procedures include solar-friendly features, such as a fast track process for smaller systems (26 Del. C. § 1014).

4.3.4 Market Expansion

In addition to market creation and market preparation policies, Delaware has used market expansion policies to stimulate adoption of PV technology. In 2010, the state legislature lowered economic barriers to PV development by allowing additional ownership structures for energy generating facilities (Senate Bill 267). Third-party ownership structures can lower economic barriers by reducing or eliminating initial capital requirements for individuals. Furthermore, third-party ownership is a way communities that lack suitable space for PV to benefit from renewable energy.

A number of state and utility rebate programs also support market expansion in Delaware. Utility customers throughout the state are eligible to receive rebates on PV systems based on installed capacity (DSIRE 2013). The rebates are funded under the authority of the Electric Utility Restructuring Act of 1999 and REPSA. Rebates lower economic barriers to PV development by reducing total system cost. Furthermore, because the rebates are paid up front, initial capital requirements are less burdensome.

[7] Freeing the Grid is a policy guide that evaluates the net metering and interconnection practices of every state. It is a collaborative effort of several nonprofit organizations. For more information, see http://freeingthegrid.org/.

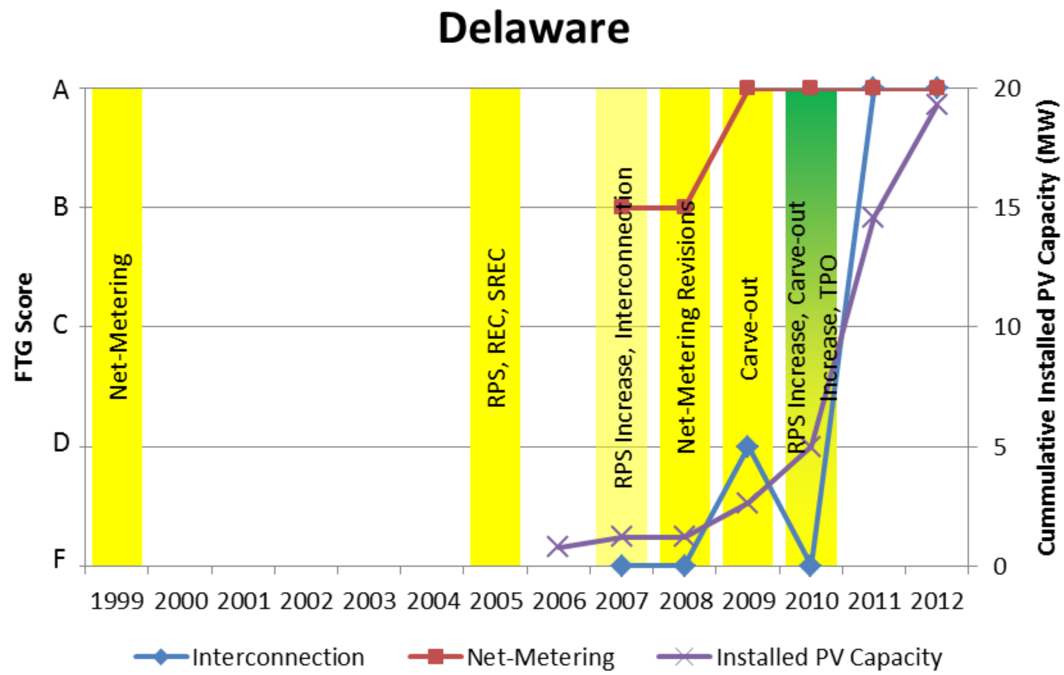

Figure 8. Total installed PV capacity with policy timeline, Delaware 1999-2012

4.3.5 Summary

The case of Delaware is an example of how policy can be effective in stimulating market adoption in an environment where non-policy determinants have demonstrated little or no influence. The motivated buyer group is characterized by states with higher expected interest in energy-related policy, higher cost of electricity, higher income, but less abundance of solar resources. Delaware, which ranks near the bottom of its group in all of these non-policy categories, has the highest installed capacity per capita of its peers. Delaware was able to accomplish this by enacting a variety of policy types that included market preparation, market creation, and market expansion. Chief among these was the adoption of a solar carve-out within the state's RPS. Solar carve-outs have been shown to be the most meaningful determinant of installed PV capacity across states of all the factors they analyzed (see Section 3). At four years old, Delaware's set-aside is the most mature in the group. However, it was not by market creation policy alone that Delaware emerged as a leader among its peers. In conjunction with the solar set-aside, the state prepared the market by adopting best practices for interconnection. This made it possible for renewable energy producers to access the grid and sell their SRECs in the open market or directly to utilities through procurement programs facilitated by the PSC. The legislature also worked to expand the PV market by lowering economic barriers through financial incentives. Delaware's experience is an example of how comprehensive policy can be an effective tool to stimulate market adoption of PV in states where non-policy factors are favorable, but have not driven installed capacity.

4.4 Mixed Group: New Mexico

This case study focuses on the mixed group and the policy history of New Mexico. The mixed group is the largest of the state peer groups with seventeen members and comprises states with a variety of non-policy factors influencing installed PV capacity, none of which suggests a singular motivation for adopting PV as it might in other peer groups. States in this group have a less robust history of enacting clean energy policy than the national average, sub-optimal economic conditions to stimulate PV adoption, and a range of technical potential for rooftop PV.[8] Based on these non-policy characteristics, states in the mixed group are expected to demonstrate lower market penetration relative to the other three peer groups absent of policy.

4.4.1 State Profile: New Mexico

The state of New Mexico represents an opportunity to study the influence of policy on PV adoption because its non-policy characteristics suggest it should rank low in installed capacity within its peer group; yet, it is third out of 17. New Mexico's installed capacity is nearly three times the group average, while only possessing two-thirds of the average rooftop PV potential and below average household income. However, New Mexico also exhibits one non-policy characteristic that would suggest a higher propensity for PV technology relative to its peers. The state has a robust history of supporting clean energy policy, ranking fourth in the group in terms of the ACEEE Energy Efficiency score. Economic conditions are mixed with an approximately 20% higher average cost of residential energy, but below average median household income.

4.4.2 Market Creation

In 1999, the New Mexico state legislature took its first step toward creating a market for renewable energy by instructing the PRC to evaluate the merits of adopting an RPS (Electric Utility Industry Restructuring Act [Restructuring Act] Senate Bill 428). The PRC concluded that an RPS was desirable and promulgated Rule 591 (NMAC 17.9.591), which established an RPS for IOUs that would go into effect with deregulation under the Restructuring Act. However, as deregulation neared, the legislature grew concerned regarding difficulties that other states were having with deregulation and decided in 2001 to delay implementation of the Restructuring Act. With the act facing delays and possible repeal, the PRC promulgated Rule 573 (NMAC 17.9.573), which implemented the RPS as an independent measure. Rule 573 also established a REC program to document RPS compliance. Furthermore, by allowing utilities to purchase RECs to meet RPS obligations, the PRC created financial value for distributed generation (DG) facility owners by creating a market for the RECs they produced and allowed utilities the flexibility to acquire RECs rather than invest in renewable energy facilities. Rule 573 went into effect in July 2003 and was codified into state law through the Renewable Energy Act (Senate Bill 43) the following year.

[8]Technical potential for rooftop PV is not simply a measure of available solar resources in a state. It is also a function of existing constraints to PV development, such as rooftop space and land-use restrictions.

Table 8. Quick Facts: Mixed Group

	New Mexico (Rank)	Group Average
ACEEE Scorecard[a]	18.5 (4/17)	12.5
Retail Electricity (c/kWh)[b]	11.0 (4/17)	9.8
Median Income[c]	$45,098 (11/17)	$47,198
PV Technical Potential (kW/capita)[d]	6,513 (8/17)	9,894
Installed Capacity (W/capita)[e]	9.2 (3/17)	3.1

[a] Foster et al. 2012
[b] Three-year average residential electricity (EIA 2010-2012)
[c] Median household income (U.S. Census Bureau 2010)
[d] Lopez et al. 2012
[e] Sherwood 2013

As the Renewable Energy Act went into effect in 2004, Governor Bill Richardson issued Executive Order 2004-019, declaring his intent to make New Mexico the "Clean Energy" state and creating a cabinet-level position to oversee the initiative. This was consistent with Governor Richardson's 2002 campaign platform for economic development through leadership in renewable energy. Over the next several years, the state legislature supported this initiative by passing numerous clean energy laws, which are now the framework for New Mexico's current renewable energy policy.

Senate Bill 418, which amended the Renewable Energy Act in 2007, was the most significant legislation enacted during this period. While the amendments expanded the scope of the RPS to include rural electric cooperatives and created greater RPS requirements for IOUs to achieve by 2015 and 2020, the real impact in terms of distributed PV was that it caused the PRC to review its portfolio diversification rules. As originally enacted Rule 572 (formerly Rule 573), renewable energy producers received a different number of RECs depending on the resource used to generate the electricity. Indeed, this reflected the legislature's intent of creating a diversified energy portfolio. After four years, however, wind accounted for 99% of the renewable energy requirement (Final Order Case 07-00157-UT). The PRC considered this a failure in terms of creating a diversified energy portfolio. It therefore instituted specific portfolio diversification requirements (set-asides) in 2008 that included a 20% allocation to solar technology (NMAC 17.9.572). Furthermore, the revised rules established a new set-aside specifically for DG. IOUs would be required to procure no less than 1.5% of energy sold from DG by 2011, increasing to 3% by 2015.

4.4.3 Market Preparation

In an effort to remove unnecessary obstacles to the DG set-aside of the state's RPS, policymakers enacted a series of market preparation policies. In 2007, the state legislature strengthened solar access laws by amending the Solar Rights Act to preclude all restrictions on the placement of solar collectors, except in historic districts (Senate Bill 1031). They also adopted the Solar Collector Standards Act (House Bill 610), which modified the state's residential building code to require that all new construction include PV-ready roofs.

In 2008, the PRC addressed interconnection and net-metering challenges by promulgating rules specifically for small energy producers with installations no larger than 10 kW. The new and revised rules (Rule 568, Rule 569, and Rule 570) simplified utility interconnection standards. Krasko and Doris 2012 found that best practices for DG-compliant net metering and interconnection standards reduce system costs by effectively allowing customers to store excess generation.

4.4.4 Market Expansion

New Mexico has also implemented a number of complementary market expansion policies. In 2006, the state enacted the Solar Development Tax Credit (SDTC), which allowed for a 30% investment tax credit (ITC) up to $9,000. When Congress renewed the federal ITC and lifted the $2,000 federal limit in 2008, the state legislature revised the SDTC to be a 10% credit that was independent of the ITC. PV systems are also exempt from property taxes until the property is sold. Finally, to meet the state's DG set-aside requirements of the RPS, utilities have enacted programs to purchase RECs from customers with PV systems. In New Mexico, REC payments are based on estimates related to system size and paid to the customer once the system is put into service. This allows customers to recover a portion of initial system costs immediately (as opposed to REC payments paid over time based on actual production). REC procurement programs such as these are only possible when DG system owners have ownership of the RECs they generate and utilities are allowed to purchase RECs to fulfill RPC obligations.

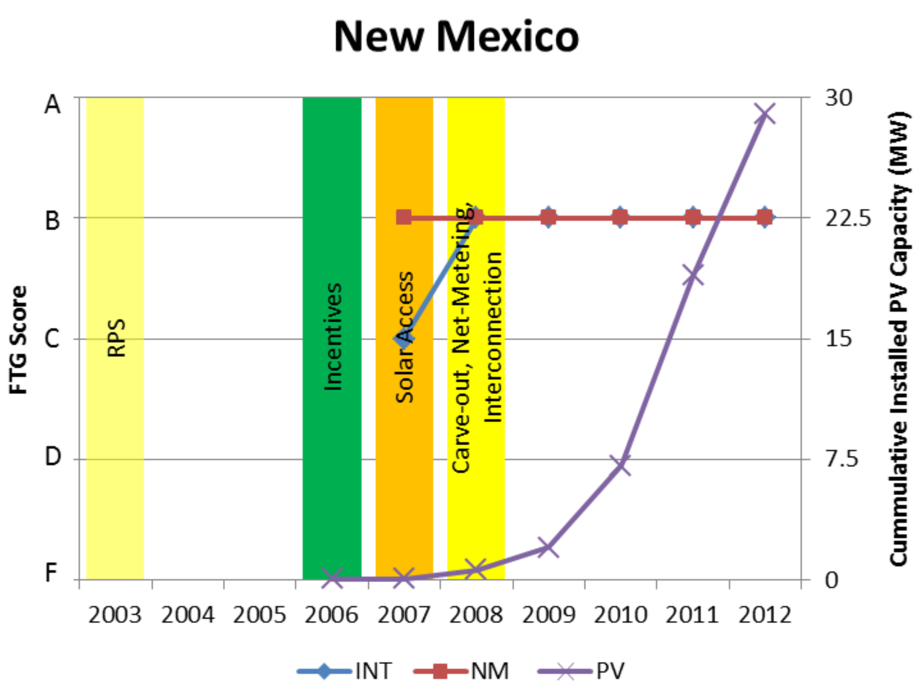

Figure 9. Total installed PV capacity with policy timeline, New Mexico 2003-2012

4.4.5 Summary

The state of New Mexico is an example of the importance of policy diversity and strategic implementation. While the first solar access laws were enacted in 1977, initial market preparation policies alone were insufficient to facilitate broad adoption of PV technology. Moreover, policy diversity is not enough to achieve market penetration goals. It is also important to develop effective policies that are consistent with best practices. The Solar Rights Act serves as an example. While it established solar energy as a property right, it did not initially protect system owners from local ordinances or restrictions, thereby reducing the effectiveness of the policy.

The overarching political environment in New Mexico had an impact on the development of policy. The bulk of activity occurred at a time when there was significant public support for the environmental agenda in the state capital. In 2002, the people of New Mexico elected Governor Bill Richardson on a platform advocating for the state to become a leader in renewable energy. The legislature demonstrated its support for this goal by repeatedly enacting and amending state laws to further this aim. The PRC promulgated rules to execute the legislature's intent and actively revised regulations they found to be ineffective. As a result, New Mexico developed a comprehensive framework for renewable energy policy and emerged as a leader among its peers in installed PV capacity.

5 Conclusion

The purpose of this research is to better understand the role of state policy in the effective development of behind-the-meter PV markets. In order to do so, a two-pronged approach was taken. First, a grouping and analysis of the states based on non-policy context was developed to increase understanding of policy impact in different situations. Second, case histories were developed to augment the quantitative analytics through richer context to the policy development processes within each state grouping. The result is the beginning of actionable strategies for states that understand their own non-policy context and are interested in developing comprehensive support systems for the development of solar PV markets that emphasize private sector development and short- to medium-term government intervention. Results and observations from the quantitative analysis and case histories are detailed in the body of the report, with major findings being:

- Solar-related policy has a quantified effect on solar markets (as measured by installed capacity)
- Non-policy factors influence the effectiveness of those policies in driving solar markets in situations when the non-policy factor is extreme. For example, if costs are very low for competing electricity, market-enabling policy, such as interconnection and net metering, influence is weakened due to increased economic hurdles to overcome.
- Solar set-aside is most consistently correlated with increased installed capacity. This relationship spans across all groups. For example, the correlation is particularly strong in states with less supportive non-policy market factors. This is borne out in the mixed group of states, which has a lackluster non-policy-driven market for solar, and the findings indicate the impact of solar set-asides is particularly strong in this group.
- Having a suite of policies in place that is consistent with best practices is correlated with increased solar PV installations.
- Based on the case history findings, there appear to be effective pathways specific to the non-policy contexts of the state in question:
    - **Expected leaders**. In Maryland, a comprehensive policy portfolio, with equal emphasis on all policy types is driving recent market development.
    - **Rooftop rich**. In North Carolina, strong interest from the populous in clean energy related policy distinguishes it from other members of the group.
    - **Motivated buyers**. The experience in the state of Delaware illustrates that targeted market preparation and market creation policy can effectively stimulate PV development.
    - **Mixed**. In New Mexico, the leading state for installed capacity in the group, policy diversity and strategic implementation have proven to be critical in effectively supporting the market.
- Findings from the quantitative analysis and the case histories indicate 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. This is the primary focus of follow-on work to this research.

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Appendix: Alternative Grouping Strategies Based on Non-Policy Contextual Factors

Introduction

A wide variety of policy and non-policy factors affect the development of solar photovoltaic (PV) markets in the United States. There is a broad and growing body of literature on how national and subnational policy factors influence development (including Krasko and Doris 2013; Carley 2009). Study of non-policy factors is typically done within these studies as a background measurement, normalized through energy price and/or per capita income (including Sarzynski et al 2012). The research presented here attempts to describe these non-policy factors with more nuance and detail. Understanding the complexities of these factors and their interaction allows for greater depth of study in how different policies and policy designs can impact the development of PV markets in different types of jurisdictions. A densely populated urban area with high electricity prices and relatively few detached one-family households, for example, may be more suitable for certain policy tools than a more suburban jurisdiction with low electricity prices, which has its own optimal policy pathway.

Previous literature on the subject provides some guidance in identifying important non-policy factors that influence the decision to adopt solar PV technology. Zahran et al (2008) used county-level, cross-section regressions to predict whether a county had any homes heated with solar energy (logistic) and the number of homes heated with solar energy (negative binomial). They found evidence that the number of housing units, solar radiation, the square of the maximum temperature, median home value, urbanization, and political leanings measured by percentage voting democrat in the last presidential election and participation in the International Council for Local Environmental Initiatives were all significant factors in the logistic regression predicting whether or not a county had any households heated with solar energy.

Carley (2009) used a fixed effects vector decomposition model on state-level panel data to predict the logged proportion and the total amount of the share of renewable energy in a state's annual electricity generation. Significant factors in predicting a state's logged share of renewable energy generation included solar potential, average retail electricity price, electricity use per capita, gross state product per capita, natural resource employees per capita, percent petrol/coal manufacturing of total gross state product, House League of Conservation Voters' environmental scorecard, and several other mostly policy-related factors.

Doris and Gelman (2011) used regression analysis to explain between 40% and 60% of the variations between state renewable energy market growth through policy factors, including mandates and incentives. Significant non-policy factors in that analysis included population and electricity price. The work also found evidence that differing combinations of policies, which varied by location, could be correlated with different market penetration levels.

Sarzynski et al (2012) used a cross-sectional time-series regression on state-level data to predict the amount of grid-tied photovoltaic capacity installed in a state. Although the focus was on policy-related factors, there were some non-policy control variables that were found to be significant, including the logged average commercial electricity price and the logged gross domestic product per capita in a state.

Although there are numerous non-policy factors that are significant with respect to several measures of solar market penetration, many of these are closely related and in practice could likely be combined, resulting in a small number of variables. This analysis take two different approaches—one involving a comprehensive set of significant factors and the other a more limited set, focusing only on the most critical variables.

To date, researchers have tried to normalize for non-policy factors to focus on the effects of policy. This approach naturally leads to a "one size fits all" view of policy and could overlook important relationships between non-policy factors and the effectiveness of various policy tools. In order to gain an insight into these relationships, the states were grouped and clustered with respect to the significant non-policy factors that describe the context of their customer-sited solar PV market.

The strategy of this analysis was to first identify the likely factors that drive solar development outside of policy intervention using two different methods, and then develop state groupings based on those two different strategies. This paper follows a similar structure. The discussion section provides a comparison of the differences between groupings that result from the inclusion of different factors.

Identifying Significant Non-Policy Factors

This research took two different approaches in identifying important factors for consideration. The first approach was to test the significance of various non-policy factors in a household's decision to adopt solar PV technology using a household-level logistic regression. The second approach was a list culled from existing literature that aimed to combine related factors and capture only the most critical variables.

Comprehensive Factors: Household-Level Logistic Regression

In this area of the analysis, a household-level logistic regression was used to find significant non-policy factors that help explain whether a household is heated with solar energy or not. The data set used was the 2007-2011 5-year American Community Survey (ACS) Public Microdata Sample (PUMS). The ACS is a statistical survey that samples a small percentage of the population every year and asks various questions pertaining to the household and the people living there.

The PUMS data contains individual survey responses, rather than aggregate data for a geographic region, and therefore allows one to analyze individual household decisions directly. The full data set contains 6,999,047 housing observations corresponding to a single household each, 15,199,756 population observations corresponding to a single person each, and a number of variables. A full data dictionary with all of the variable definitions is available from the Census Bureau (Census Bureau 2013). Unless otherwise stated, all variables are defined as in the data dictionary. Due to the size of the data, this analysis was done using the R programming language along with ff, ffbase, and biglm packages.

Dependent Variable

The most pertinent ACS question asks "which fuel is used MOST for heating this house, apartment, or mobile home?" and allows respondents to answer by completing check boxes.[9] The dependent variable, *SOLAR*, is equal to one if the respondent answers "solar energy" and zero otherwise. Although this question does not distinguish between passive and active solar heating systems, the word "fuel" implies an external source of energy, and similar to previous research (Zahran et al. 2008), it is assumed this generally refers to active PV systems.

Data Preparation

The original data set contains a number of household observations that do not have an answer to the question about house heating fuel; they were dropped from this analysis. More than half of these are vacant lots, while the rest are group quarters, such as correctional facilities, military barracks, and student housing.

Most household observations are connected to multiple population observations because multiple people live there. For the purpose of this analysis, however, all but the head of the household was dropped, which was assumed to be the first person listed on the ACS survey response. Households, rather than individual people, were of interest because the decision to install customer-sited PV is presumably done at the household level. This also avoided the complication of having multiple values for population variables associated with a single household observation by only considering one influential person in the household.

After merging the remaining housing records with the heads of the households from the population records (matched by household serial number), 5,960,233 observations were left, which were associated with both housing and population variables. The dependent variable was very sparse, with only 2,455 households in the sample heating their home with mostly solar energy.

Property Characteristics

As customer-sited solar PV installations are specific to a place of residence, the characteristics of the property are thought to influence the decision to adopt customer-sited PV technology. The most basic of these is property type, or whether or not the property is a single-family detached building, denoted by the binary variable *HOU*. This was included because installing customer-sited PV on other property types, such as apartment homes, mobile homes, and duplexes, may present extra challenges above what a single-family detached house would.

Another related property characteristic is ownership status, represented by the variable *RENT*, which is equal to one if the property is a rental unit and zero otherwise. Ownership status is thought to influence the decision to install customer-sited PV because an investment into this technology has a payback period measured in years, and it would be more difficult to make such an investment on a property one is renting.

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[9] Possible answers are "Gas: from underground pipes serving the neighborhood," "Gas: bottled, tank, or LP," "Electricity," "Fuel oil, kerosene, etc.," "Coal or coke," "Wood," "Solar energy," "Other fuel," or "No fuel used."

The variable *YBL* denotes the time period the house was built. This variable is coded between one and nine, as defined in the Census data dictionary, where a value of one corresponds to a property that was built in 2005 or later and larger integers denote earlier time periods. It is hypothesized that installing PV on a newer home is easier because a newer home may be more PV ready and the investment may make more sense. In addition, newer homes do not face the potential difficulties of installing PV in historic neighborhoods.

To account for the popularity and acceptance of solar technology in the area, a peer effects variable, denoted *PEER*, was included. This is equal to the percentage of household observations in the same Public Use Microdata Area (PUMA) that reported heating homes with solar energy. The Census Bureau defines a PUMA as an area with a population of 100,000 or more that can vary in size.

It is also possible the size of the property has some effect on whether or not a household is heated with solar energy. To test this, *BDS* (the number of bedrooms), was included.

Resident Characteristics

Previous studies found that gross state product per capita had an effect on PV capacity (Sarzynski et al 2012) and renewable energy generation (Carley 2009) in states. The income factor was accounted for by including *HINCP*, the reported total household income in the past year.[10] These values were all converted to 2011 dollars using weighting factors found in the data set.

To get a measure of the average electricity cost in an area, a new variable, *AVGELEP*, was generated, which is equal to the average reported monthly electricity cost for households in the PUMA that reported paying for electricity and did not report heating with solar energy. Before averaging, the *ELEP* values were also converted to 2011 dollars using weights found in the data set.

Head of Household Characteristics

Zahran et al. (2008) found some evidence the proportion of residents aged 40 to 49 had an effect on the number of households in a county using solar energy for heating. The age of the head of the household, *AGEP*, and its square, $AGEP^2$, were included to test for a nonlinear relationship between the age of the head of the household and whether the home is heated with solar energy.

Educational attainment is hypothesized to affect the decision to adopt PV in a similar way so *SCHL* was recoded to create *COLL*, which is equal to one if the head of the household has a bachelor's degree and zero otherwise, and *GRAD*, which is equal to one if the head of the household has a graduate degree and zero otherwise.

There is some evidence that household solar energy use is more prevalent in more urbanized areas (Zahran et al. 2008). It is important to account for this factor, but it is not immediately obvious how to measure it at the household level. The variable *TR_WALK* was included, which is equal to one if the head of the household reportedly walks to work and zero otherwise. While

[10] The units on this variable are rescaled from dollars to thousands of dollars in the regression.

biking or using public transport to get to work can be seen as an indication of energy saving behavior, it is assumed being able to walk to work is more of an indication of living in an urbanized area. It is also hypothesized certain behavior pertaining to energy use may be correlated with the decision to adopt solar PV technology, so *TR_BIKE* and *TR_PUB* were also included. These variables were recoded from *JWTR* in the data set and equal to one if the head of the household reportedly bikes or takes public transport to get to work, respectively, and zero otherwise.

Results

The regression results are presented in Table A-1. Yearly effects denote the year the household was interviewed and data was gathered, and are relative to 2007. State-fixed effects were used to account for various other factors, including state policy and solar resource, and are relative to California. There is no variable for District of Columbia because there are no solar heated households for DC found in this data set.

Table A-1. Logistic Regression Results[a]

Variable	Coefficient	Std. Error	P-Value
(Constant)	-9.1632	0.3444	0.0000***
HOU	0.6352	0.0599	0.0000***
BDS	-0.2033	0.0243	0.0000***
YBL	-0.1237	0.0097	0.0000***
RENT	-0.1207	0.0615	0.0496*
AVGELEP	0.0060	0.0019	0.0015**
PEER	0.2331	0.1153	0.0431*
HINCP	0.0006	0.0002	0.0071**
AGEP	0.0636	0.0083	0.0000***
$AGEP^2$	-0.0005	0.0001	0.0000***
COLL	0.1934	0.0528	0.0002***
GRAD	0.3347	0.0628	0.0000***
TR_WALK	0.4074	0.1424	0.0042**
TR_BIKE	0.8759	0.2124	0.0000***
TR_PUB	0.3340	0.1235	0.0069**
Year 2008	0.0279	0.0684	0.6828
Year 2009	0.0687	0.0675	0.3092
Year 2010	0.2013	0.0653	0.0021**
Year 2011	0.3129	0.0639	0.0000***
AL	-2.3844	0.3372	0.0000***
AK	-2.5721	1.0014	0.0102*
AZ	-0.3080	0.1138	0.0068**
AR	-1.5941	0.2930	0.0000***
CO	0.4307	0.0934	0.0000***
CT	-1.2448	0.2345	0.0000***
DE	-1.2495	0.4504	0.0055**
FL	-1.3168	0.1116	0.0000***
GA	-2.2190	0.2246	0.0000***
HI	2.7472	0.0851	0.0000***
ID	-0.6709	0.2630	0.0108*
IL	-1.7213	0.1664	0.0000***
IN	-1.5076	0.1989	0.0000***
IA	-1.3096	0.2630	0.0000***
KS	-1.3923	0.2816	0.0000***
KY	-1.6551	0.2546	0.0000***
LA	-1.9311	0.2927	0.0000***

Variable	Coefficient	Std. Error	P-Value
ME	-0.7932	0.2929	0.0068**
MD	-1.9019	0.2554	0.0000***
MA	-0.9859	0.1594	0.0000***
MI	-1.4772	0.1602	0.0000***
MN	-1.3473	0.2018	0.0000***
MS	-2.6594	0.5025	0.0000***
MO	-1.8168	0.2346	0.0000***
MT	-0.8712	0.3570	0.0147*
NE	-0.9194	0.2815	0.0011**
NV	-0.7576	0.1998	0.0001***
NH	-1.0986	0.3369	0.0011**
NJ	-1.7402	0.1988	0.0000***
NM	1.0497	0.1067	0.0000***
NY	-1.1696	0.1152	0.0000***
NC	-1.3459	0.1483	0.0000***
ND	-1.8129	0.7089	0.0105*
OH	-1.3714	0.1450	0.0000***
OK	-2.8808	0.5023	0.0000***
OR	-0.7059	0.1705	0.0000***
PA	-1.2370	0.1364	0.0000***
RI	-1.5223	0.5023	0.0024**
SC	-2.1579	0.3057	0.0000***
SD	-0.8820	0.4113	0.0320*
TN	-2.3741	0.2929	0.0000***
TX	-2.3329	0.1594	0.0000***
UT	-0.9033	0.2430	0.0002***
VT	-0.6186	0.3814	0.1048
VA	-1.8261	0.2037	0.0000***
WA	-1.0827	0.1559	0.0000***
WV	-0.8445	0.2630	0.0013**
WI	-1.0865	0.1696	0.0000***
WY	-0.1818	0.3371	0.5897

[a] Observations: 5,960,233
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

The regression results indicated a detached one-family household is more likely to heat their home with solar energy. Comparing the units in structure variable between solar heated households and all households in Figure A-1, solar heated households are more likely to be detached one-family units.

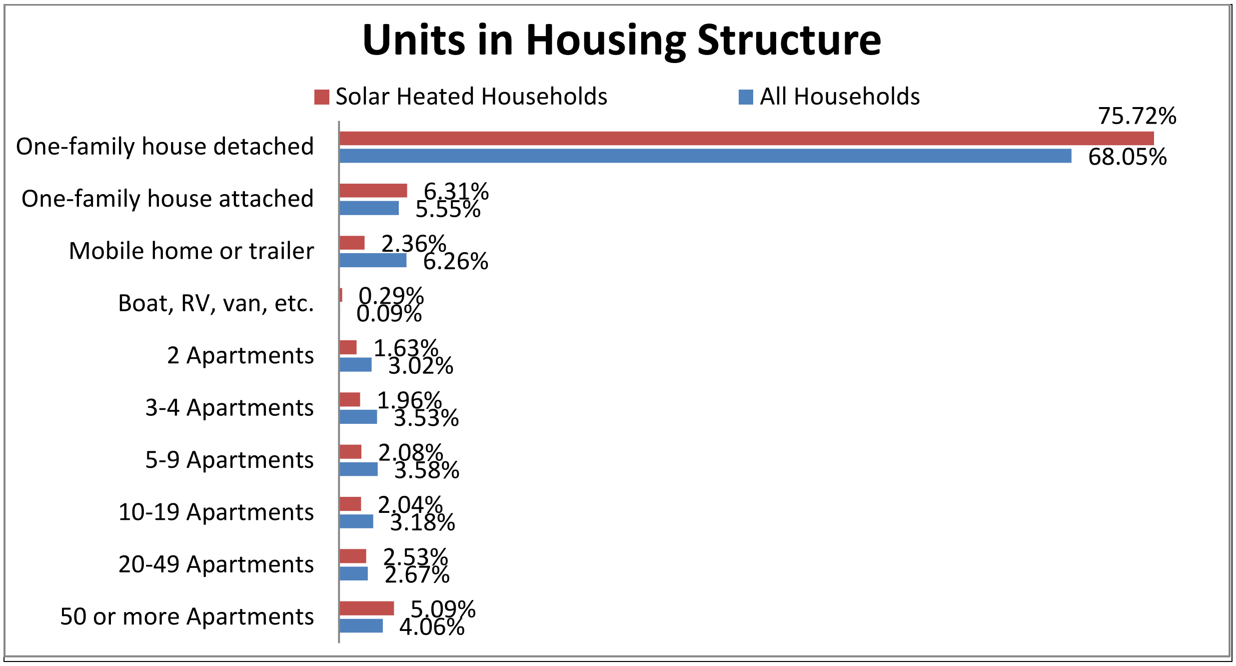

Figure A-1. Units in structure—all households compared to households heated with solar energy

Household age, represented by *YBL*, was found to be significant with newer properties being more likely to be heated with solar energy. Comparing the values of *YBL* between solar heated households and all households in Figure A-2, solar heated households tend to be newer. There are also more solar heated homes built in the 1980s, likely because of the response to the previous decade's oil crisis and increased concern over energy security at the time.

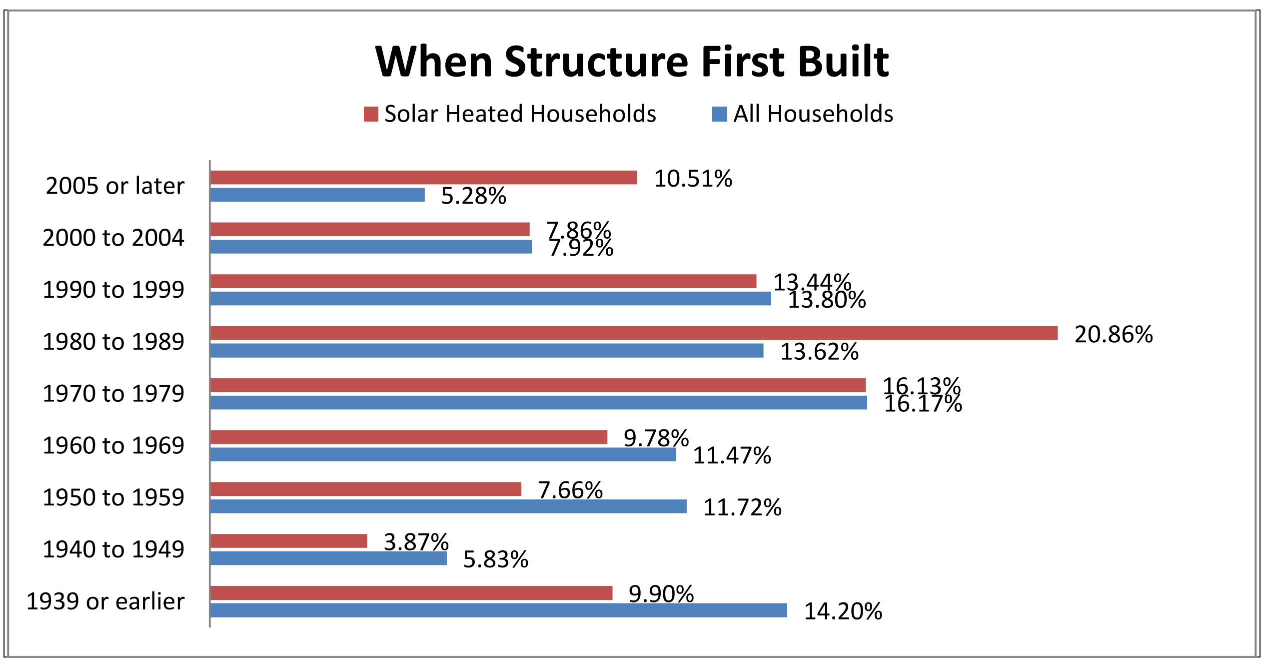

Figure A-2. When structure first built—all households compared to solar heated households

The variable *RENT* was found to be significant at the 5% level with a negative effect. This is somewhat expected given what is known about investment into customer-sited PV technology. Household income was found to be significant, with a positive effect on the probability of PV adoption. This was also expected, given what is known about the relative costs of PV technology.

The average electricity cost in the area, *AVGELEP*, was significant and positive, which could mean higher electricity prices provide incentive to adopt solar technology. Peer effects were also found to be significant and positive, suggesting the acceptance and popularity of solar technology in the area likely influences a household's decision to adopt solar.

For demographic variables associated with the head of the household, age, college, and advanced degree were found to be significant. There was some evidence for a nonlinear relationship between age and PV adoption, but the maximum effect seemed to be for householders in their early 60s rather than their 40s, as suggested in Zahran et al. (2008). It is possible this regression suffered from omitted variable bias, so strong conclusions were avoided about the peak age for PV adoption; however, it is accepted age is a significant factor. The assumption the first person listed on the ACS is the "head" of the household may also have contributed to this result.

The method of transportation used by the head of the household to get to work was found to be significant for walking, biking, and public transport. These variables can be seen as both an indication of urbanization and an indication of energy conserving behavior, but here it was assumed walking corresponds more to urbanization and biking corresponds more to general energy saving behavior, while public transport is a combination of both.

Yearly effects, relative to 2007, were all positive and increasing but only the last two years were statistically significant. This indicates that PV adoption is on the rise through time, likely due to increased public awareness, lower technology costs, and other factors.

The state effects, relative to California, were statistically significant at the 5% level for 48 out of the 50 states. These were used to control for other omitted factors. Their significance indicates various state-level factors, most importantly state policy, play an important role in PV adoption.

Limited Factors

While the regression above produced many significant factors, several of these are related or go hand in hand. A limited and manageable set of factors may be good enough to reflect reality in practice. The age and education variables, for example, are likely correlated with household income to some extent. When grouping the states according to similar market context for customer-sited PV, accounting for average ages and average levels of education may not be all that useful after accounting for household income.

The limited set of factors consisted of median household income, average residential electricity price, energy efficiency score, and solar technical potential. Household income (Census Bureau 2010) was included because of the relative costs of PV technology. Although this is less important when power purchase agreements are available, different measures of wealth generally correlate with solar or renewable energy capacity (Zahran et al. 2008; Carley 2009; Sarzynski et al. 2012). Electricity price (DOE 2013) was included because a higher price is expected to increase the rate of return on customer-sited PV, and has been found to be significant in previous literature (Carley 2009; Doris and Gelman 2011; Sarzynski et al. 2012). The state energy efficiency scores were included as a proxy measurement for each state's interest in, and progress toward, addressing energy-related issues. They were found in Foster et al. (2012) and based on utility public benefits programs and policies (40%), transportation policies (18%), building energy codes (14%), combined heat and power (10%), and appliance and equipment efficiency standards (4%). Previous literature identified similar proxy variables to be significant, including participation in the International Council for Local Environmental Initiatives (Zahran et al. 2008), and House League of Conservation Voters' environmental scorecard (Carley 2009). The estimates for state technical potentials of rooftop PV were gathered from Lopez et al. (2012), and originally derived in Denholm and Margolis (2008). These estimates were based on solar resource and available flat roof area after accounting for shading, rooftop obstructions, and other constraints. Measures of solar resource have also been found to be significant in previous literature (Zahran et al. 2008, Carley 2009).

Grouping States by Non-Policy Factors

In this section, different methods of grouping the states according to the similarity of their non-policy market contexts for solar PV are explored.

Comprehensive Factors

In this area of the analysis, the states were grouped using a comprehensive set of factors informed by the logistic regression. The states were partitioned into their groups using *k*-means clustering. This method partitions data points into *k* distinct clusters based on the distances between the cluster centers. For this study's purpose, a data point was a state, represented by a vector of variable values. Most of these were state aggregate versions of significant variables found in the regression. The one exception was electricity price, which was reported in terms of cents per kilowatt-hour (kWh) (EIA 2013) instead of monthly cost. Variables that define each state vector included the following:

- Percentage of households that are one detached structure (*agHOU*)
- Percentage of households that were built in 2005 or later (*agYBL*)
- Percentage of households that are rental units (*agRENT*)
- Average household electricity price in cents/kWh (*agELEC*) from (EIA 2013)
- Average household income in thousands of dollars (*agHINCP*)
- Percentage of heads of households with a college degree (*agCOLL*)
- Percentage of heads of households with an advanced degree (*agGRAD*)
- Percentage of heads of households that walk to work (*agTRWALK*)
- Percentage of heads of households that bike to work (*agTRBIKE*)
- Percentage of heads of households that take public transit to work (*agTRPUB*).

There are various distance measures, normalization techniques, quality indices, and methods available for clustering. In this study, clustering was done using the *clusterSim* R package, which compares several of these and returns the best solution according to a chosen cluster quality index (Walesiak and Dudek 2013; Walesiak 2008). To choose *k*, the number of clusters, the rule of thumb can be used: $k \approx (n/2)^{0.5}$ (Mardia et al. 1979), and initially set, *k* = 5. A different number of clusters can potentially create more distinct groups, so *k* was allowed to vary between 4 and 6. The *clusterSim* package returned a clustering found using the general distance measure (see Jajuga et al. 2003), normalization within range [-1, 1], and four clusters based on the Silhouette cluster quality index. A visual representation of the results, as mapped to two dimensions (Components 1 and 2), is presented in Figure A-3. The group averages are displayed in Table A-2.

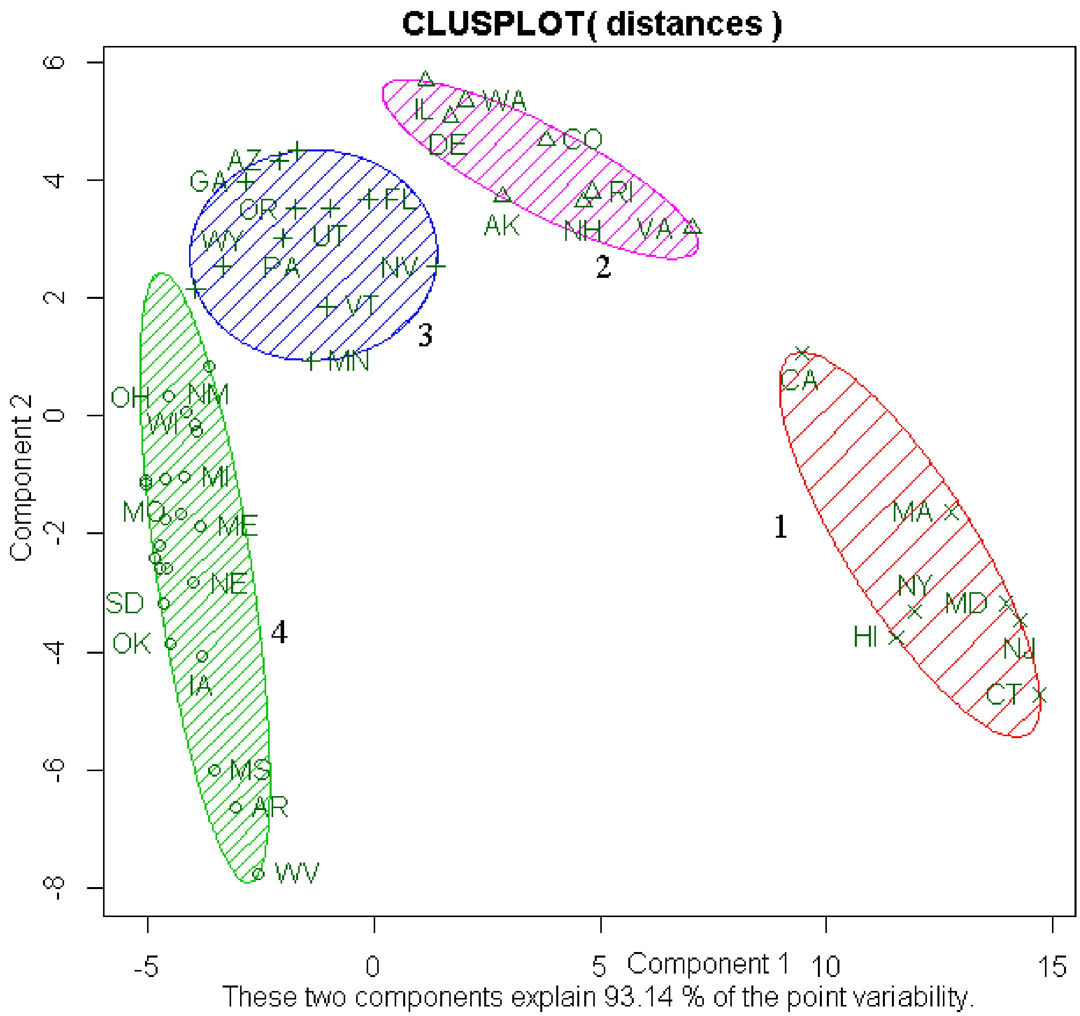

Figure A-3. State clustering

Table A-2. Group Averages with Comprehensive Grouping

	Group 1	Group 2	Group 3	Group 4
	California Connecticut Hawaii Maryland Massachusetts New Jersey New York	Alaska Colorado Delaware Illinois New Hampshire Rhode Island Virginia Washington	Arizona Florida Georgia Minnesota Nevada North Carolina Oregon Pennsylvania Texas Utah Vermont Wyoming	Alabama Arkansas Idaho Indiana Iowa Kansas Kentucky Louisiana Maine Michigan Mississippi Missouri Montana Nebraska New Mexico North Dakota Ohio Oklahoma South Carolina South Dakota Tennessee West Virginia Wisconsin
agHOU	59.8	67.6	70.1	75.4
agYBL	3.5	5.1	6.9	5.1
agRENT	29.8	24.9	24.1	21.4
agELEC	18.6	13.0	11.2	10.4
agHINCP	92.9	79.9	70.0	60.9
agCOLL	38.0	34.0	29.7	24.6
agGRAD	16.7	13.7	11.1	8.8
agTRWALK	1.9	2.2	1.6	1.6
agTRBIKE	0.3	0.4	0.4	0.2
agTRPUB	5.5	2.1	1.3	0.4

The most distinct group of states is made up of the leading markets for solar PV. Group 1 has by far the highest group average electricity price, the highest average household income, and the most educational attainment among the population. In terms of housing, this group of states has the smallest percentage of single-family detached homes, the largest percentage of rental units, and the smallest percentage of households built in 2005 and after. Despite the fact that its housing stock does not look favorable for customer-sited PV, this is a very motivated group in terms of PV technology adoption, and it includes some of the highest solar capacity states, including California, New Jersey, and Hawaii. This group does not stand out in terms of walking or biking to work, but it has the most developed public transportation, with over 5% of the observations (heads of households) taking public transit to work.

On the other side of the spectrum, Group 4 has the lowest group average electricity price, the lowest household income, and the least educational attainment. The average percentages of the population either walking, biking, or taking public transit to work are also the lowest among the groups. Despite this, Group 4 has the highest percentage of single-family detached households and the lowest percentage of renters. While the housing stock does seem well-suited for customer-sited PV, the usual financial motivators are not present.

Groups 2 and 3 are somewhere in between the two extremes. Group 2 is more urban, it has the highest percentage of observations that walk to work and the second highest for biking and public transit. Group 3 is the leader for biking to work and has the highest percentage of households built in 2005 or after.

Limited Factors

With the limited set of factors, the groups were defined as follows:

- Expected leaders have technical potentials for rooftop PV above the median value and energy efficiency scores above the average. Therefore, expected leaders have a lot of potential for customer-sited PV and are motivated to address energy-related issues.
- Motivated buyers have above-average energy efficiency scores or both above-average electricity prices and income. This group is motivated to invest in customer-sited PV either because high electricity prices and incomes make it an attractive investment or because they are generally motivated to address energy-related issues.
- The rooftop rich group has an above-average technical potential with below-average incomes, electricity prices, and energy efficiency scores. This group has the potential for a large amount of PV without having the usual motivators to take advantage of this potential.
- The remaining states are mixed. First, the selected leaders were picked; second, the motivated buyers; third, the rooftop rich. The remaining states were assigned to the mixed group, creating the grouping in Table A-3.

Hawaii and Alaska were excluded because the data for their technical potential for rooftop PV is not available.

Table A-3. Group Averages with Limited Grouping

	Expected Leaders	Motivated Buyers	Rooftop Rich	Mixed
	Arizona California Colorado Illinois Maryland Michigan Minnesota New Jersey New York Pennsylvania Washington Wisconsin	Connecticut Delaware Iowa Massachusetts New Hampshire Oregon Rhode Island Utah Vermont	Alabama Georgia Indiana Louisiana Missouri North Carolina Ohio Oklahoma South Carolina Tennessee Texas	Arkansas Florida Idaho Kansas Kentucky Maine Mississippi Montana Nebraska Nevada New Mexico North Dakota South Dakota Virginia West Virginia Wyoming
Tech. Potential (GWh/year)	26,866	5,570	25,274	10,356
Energy Efficiency Score	28.4	30.1	13.3	12.2
Household Income (thousands of dollars)	53.7	57.1	43.5	46.7
Electricity Price (cents/kWh)	11.8	12.1	10.2	9.7

Discussion

The two grouping strategies presented here have their own merits and produced somewhat different results.

With the first strategy, a comprehensive, though admittedly not an exhaustive, set of non-policy factors using a household-level logistic regression was tested and used to inform variable selection for state clustering. Advantages of this method include being relatively certain that most important non-policy factors have been included and that the states have been grouped in the most logical way based on the data. The major disadvantage is factors that are related to each other are included as separate variables when clustering, which could give more weight to these demographic factors than warranted. After accounting for income and age, it may not be useful to include two measures of educational attainment on top of all that, for example.

The second strategy attempted to combine important, but related, non-policy factors together into a small number of variables and use measures or proxy values of these variables to group the states. One of the major advantages is that grouping is done based on broad, equally weighted categories. Solar rooftop potential, for example, is a broad measure based on available rooftop area, solar resource, shading, and other factors; by not including all of these factors separately, they are not given the same significance in grouping. The energy efficiency score is also a broad measure, but household income was used as a proxy. Ideally, this would be a broad measure of wealth, including income, housing prices, cost of living, and other factors. The major disadvantages of this method are that it may be difficult to identify an appropriate proxy, and the order of group selection alters the results.

Despite the different methods, the resulting groupings appear similar. All but one of the states in Groups 1 and 2 ended up in expected leaders and motivated buyers, for example. The main differences seem to be some shifting of states that could potentially fit into more than one group.

Conclusion

This research identified likely factors that drive solar development outside of policy intervention using a household-level logistic regression predicting whether a household is heated with solar energy.

Grouping of the states was done to find states with similar market contexts for customer-sited solar PV and to inform policy pathways for each specific group. Groups were formed using two different strategies—one informed by the results of the regression and the other based on a limited set of broad variables informed by previous literature.

There is some evidence non-policy context influences the effectiveness of policy. It is therefore important to define those non-policy contexts so that context-specific policy pathways can be developed. This work demonstrated two ways this could be done, but more research may be needed to evaluate various groupings in terms of the policy implications that come from them.

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