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Strategic Sequencing for State Distributed PV Policies: A Quantitative Analysis of Policy Impacts and Interactions

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National Renewable Energy Laboratory

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Executive Summary

State and local policymakers show increasing interest in spurring the development of customer-sited distributed generation (DG), in particular solar photovoltaic (PV) markets. Prompted by that interest, this analysis examines the use of state policy as a tool to support the development of a robust private investment market. This analysis builds on previous studies that focus on government subsidies to reduce installation costs of individual projects provides an evaluation of the impacts of policies on stimulating private market development.

The hypothesis being tested in this work is: if states and localities can stage policies in a particular order, then they can cost-efficiently draw private investors to develop PV markets. This is particularly important given the limited current economic capabilities of governments to support market development. The policies selected for evaluation emerge from a policy stacking theory which begins by instigating low-cost policies that remove institutional barriers to DG development (market preparation policies) and moves toward establishing markets (market creation policies), and finally looks toward more public sector investment-intensive incentive policies (market expansion policies) (Doris 2012). The specific policies selected for evaluation are those that address interconnection and net metering in the market preparation category, and renewable portfolio standards (RPS) and their technology-specific set-asides in the market creation category.

These specific policies were selected based on previous literature evaluating their role in market development. Evidence from previous literature suggests that a lack of (or poorly designed) interconnection standards present a barrier to installing DG technologies. Furthermore, net metering effectively helps finance PV systems by providing credit for excess electricity produced (e.g. Gouchoe et al. 2002). There is also a large body of research on RPS and their ability to create demand in the PV market (e.g. Wiser et al. 2011).

Primary Research Findings:

- Institutional barrier reduion (e.g. interconnection), valuing of excess electricity (e.g. net metering), indication of public support for a solar PV market (e.g. RPS), and a non-policy determinant (population) explain about 70% of the variation between new PV capacity among US states.
- Implementing low cost policies (interconnection and net metering) prior to more expensive policies (RPS, incentives) may bolster the effectiveness of the latter policies.
- The quality of the components of interconnection and net metering policies has an impact on overall effectiveness on the development of PV markets.

This research uses a cross section econometric analysis with data from 50 states and the District of Columbia to explain the variation in newly installed PV capacity across states. It focuses on interconnection, net metering, RPS and set-asides, while considering a non-policy determinant (population). Results indicate that these factors are all significant indicators of new PV capacity and the model explains about 70% of the variation in newly installed PV capacity across states.

A major contribution of this analysis is a more nuanced approach to quantify the effectiveness of interconnection and net metering standards, rather than using dichotomous (standards either exist or do not) variables. This methodology reflects the complex nature of these policies and uses scores from the Network for New Energy Choices (NNEC) Freeing the Grid (FTG) report. FTG grades interconnection and net metering standards based on a best practice grading rubric with approximately 30 metrics of success. These metrics include limits on system capacity, restrictions on rollover of net excess generation, safe harbor provisions, certification, and technical screens.

This analysis also considers the impact of strategic sequencing of policies. Building on previous literature, the ability of interconnection and net metering standards to modify the effectiveness of other policies is evaluated. Qualitative evidence is presented supporting the idea that more effective interconnection standards and, to a lesser extent, net metering policies, increase RPS effectiveness in PV market development. These findings suggest that policymakers interested in building a distributed solar market may find it most efficient to start with low public cost market preparation policies in order to build the foundation for higher cost policies that promote necessary niche markets or secondary policy goals.

Introduction

In recent years, interest in promoting local economic development and energy security and reducing the environmental impact of electricity production has led to increasing interest from state and local policymakers in the development of renewable energy markets. Evidence of this interest can be seen in the volume of policies entering the market (as an example, the enactment of statewide renewable portfolio standards is shown in Figure 1). The suite of available policy tools is extensive, including various forms of standards, mandates, and incentives. The goal of this analysis is to identify strategies for ordering cost-effective policies in a sequence that will draw private industry to invest capital in developing a market for distributed generation[1] (DG) solar photovoltaics (PV).

[1] Precise definitions of DG vary. It is used here to mean any projects that are smaller than utility-scale.

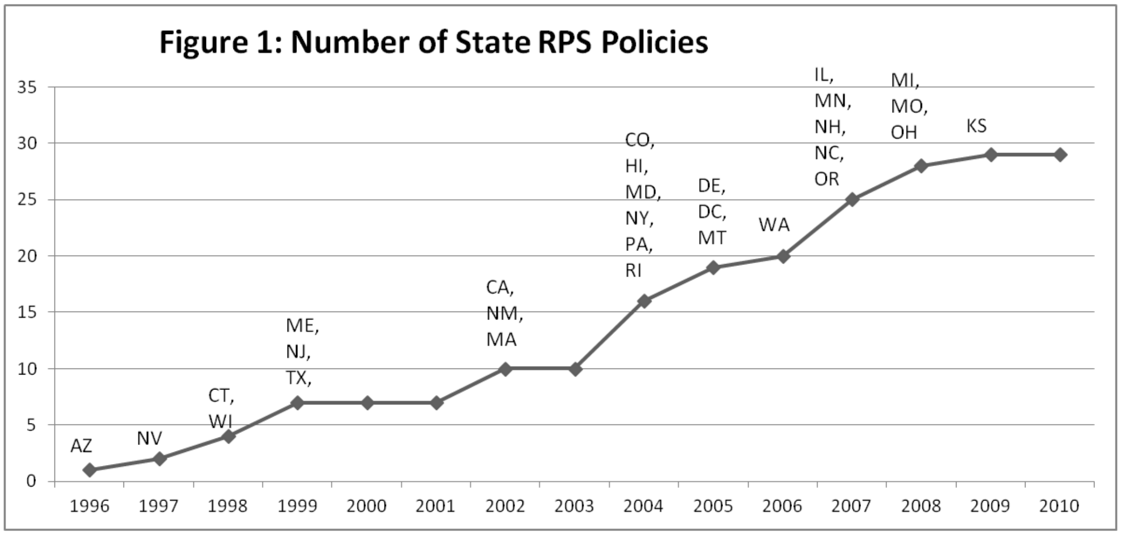

Figure 1: Number of State RPS Policies by year

Policy Framework

This analysis is built on a previously suggested framework for policy ordering (Doris 2012) in which the policies are placed into categories: market preparation, market creation, and market expansion (see Figure 2).

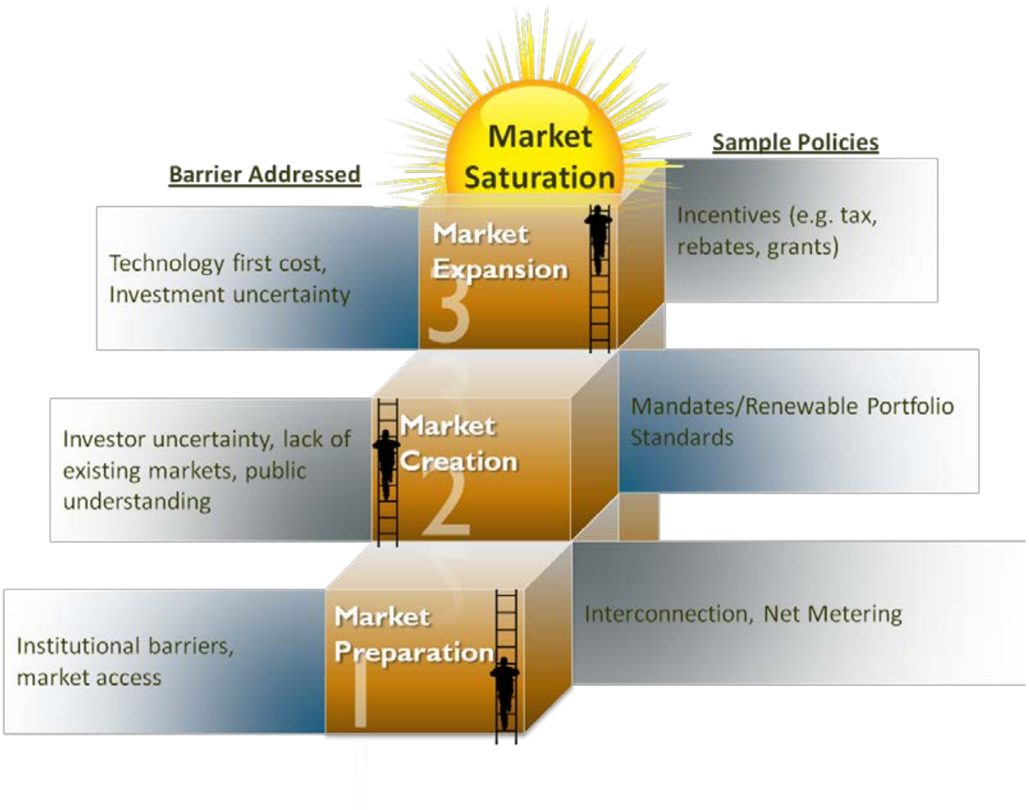

Figure 2: Framework for policy stacking (Doris 2012)

Market preparation policies focus on initially removing institutional barriers to prepare the market for solar; such policies “ensure that market players *can*, technically and legally, use the technology to its fullest extent” (Doris 2012). These policies have low costs for the public sector (Stoutenborough and Berverlin 2008) because they primarily standardize market access and the value of DG to the grid and jurisdiction.

The most common of these policies are interconnection and net metering standards.

Interconnection standards outline the procedures and legalities of connecting an energy generating system, such as rooftop PV panels, to the grid. These standards are developed by regulating agencies and can place a limit on system capacity, establish interconnection and engineering related fees, outline certification and technical screening procedures, and establish a standard agreement form to be used between customers and their utility. The standards may apply to investor-owned utilities only or to all utilities in the state. Some standards have breakpoints for system size so that a small system can bypass the rigorous technical screening process required for larger systems.

Net metering standards establish the compensation system for putting energy back into the grid once the interconnection process is complete. These standards can also place limits on system capacity and on total utility-wide net metering capacity, define eligible technologies, establish fees, and address third party owned systems as well as monthly roll-over of excess energy generation credits among other factors.

These standards are especially important for customer-sited DG projects because net metering allows customers to receive credit for generating excess energy. Hence, a rooftop PV system can put extra energy into the grid on a sunny afternoon and the system's owner can use the resulting credits to avoid paying for grid energy later. If the standards include a small system capacity limit, they may effectively exclude commercial and industrial customers, therefore preventing larger customers from taking advantage of net metering and putting excess energy into the grid. Excessive fees, a time consuming interconnection process, and other barriers also discourage system installation. One previous study reported that out of 65 case studies of DG projects all but 7 reported interconnection related barriers imposed by utilities that led to increased costs, a longer timeframe for project completion, and project cancelation (Alderfer et al. 2000). The situation has likely improved since the time that study was conducted. Nevertheless, further evidence from case studies suggests that a more streamlined interconnection process increases the effectiveness of financial incentives (Gouchoe et al. 2002), while net metering provides its own incentive because it “dramatically improves” the internal rate of return for DG systems (Ross and Hendricks 2008).

Following market preparation, broader market creation policies indicate to developers and investors that there is a long-term public commitment to the market by creating demand and therefore increasing confidence for private sector investment. Examples include the establishment of a public benefits fund and renewable portfolio standards (RPS). By mandating a minimum amount of energy that must come from renewable sources by a specified date, the RPS creates demand for renewable energy and makes investment into renewable technologies more attractive. Specific set-asides within these mandates target more expensive technologies that would otherwise experience minimal demand growth from a general RPS.

Finally, market expansion policies are implemented in which incentives are used to target the development of niche markets that are of particular long-term public good. These policies can be broadly summarized as financial incentives that include performance based incentives, grants, rebates, low interest loans, and other direct monetary support for specific projects.

Observations

The effectiveness of these various policies in terms of economic development, energy security, and environmental impact is mixed (Hurlbut 2008, Couture and Cory 2009) and often difficult to quantify. The large volume of policies and associated research has, however, led to a wide variety of observations that, if better understood, could inform cost effective investment of public dollars in policy development going forward. In order to narrow the scope, the observations and subsequent analysis will focus specifically on solar photovoltaic (PV) technology.

One observation is that various combinations of policies to support renewable energy development have been effective, to varying degrees, in multiple states. The state of New Jersey, which is now ranked second in grid tied PV capacity only behind the much more populous California, provides a notable example. The state enacted an RPS and net metering standards in 1999 as part of a comprehensive strategy to increase the use of renewable energy (Freeing the Grid 2008) that also included financial incentives such as rebates and tax incentives. Despite a lower solar resource availability, New Jersey has expanded from less than a megawatt of total solar capacity in 2002 to nearly 260 megawatts (MW) by the end of 2010 (Sherwood 2011). While neighboring Pennsylvania and New York had a total PV capacity of about 55 MW each by the end of 2010 (Sherwood 2011), New Jersey had about the same amount of capacity in DG PV alone in mid 2008 (Freeing the Grid 2008). One major contributor to this success is an older RPS policy with a set-aside that was coupled with financial incentives. Another influence was the well designed interconnection and net metering standards, which were consistently ranked at the top when graded against the Freeing the Grid (FTG) best practices guide that is specifically designed to support improved markets for DG.

Another observation is that the order in which different policies are enacted has an impact on market development. The state of Louisiana, for example, has high quality resource availability and technical potential for solar (Lopez et al. 2012) and, since 2007, one of the most aggressive solar tax incentives in the nation—50% of the first $25,000 in system costs, paid as a refund if the value of the incentive is greater than the system owner's liability. The state also offers tax incentives, low interest loans, and utility incentives (DSIRE 2012). Yet, the entire installed PV capacity in the state was only 0.2 MW at the end of 2010 (Sherwood 2011). Despite the state's high solar resource availability, financial incentives, and decent net metering standards (graded B to C by FTG), poor or failing interconnection standards (Freeing the Grid 2011) contribute to the lack of effective market development. A complex, expensive, and time-consuming interconnection procedure may actually deter customers who would otherwise install these systems, thereby leaving the generous financial incentives unused. If the impact of policy sequencing on market development was better understood, policies could be developed and implemented in a more effective way without additional implementation of unused and possibly high public cost policies.

A final observation is that structuring policies in a particular order can increase the effectiveness of other policies. One of the more recent success stories in PV development is the state of Massachusetts. Having less than a megawatt of total PV capacity in 2003 (Sherwood), the state has expanded to more than 100 MW in 2012 (MassCEC). Although the state created its public benefits fund in late 1997 and enacted an RPS in 2002, major growth in the PV market did not occur until 2009. Since then, more than 90% of the state's current capacity has been installed (MassCEC, Sherwood). There are numerous factors that contribute to increased installation, including decreasing solar technology prices, a developing national market, and the establishment of a solar set-aside—yet the statewide interconnection and net metering standards cannot be ignored entirely. Massachusetts has steadily improved its interconnection and net metering standards, as graded by FTG, from C grades in 2007 to some of the highest A grades in the most recent 2011 report. Data from the OpenPV[2] project suggests that as of March 2012, DG systems that are less than 60 kW in capacity (this is the net metering limit for nongovernment-owned systems in the state) made up about 93% of the installations and 28% of capacity in Massachusetts. It is therefore not surprising that the increasing number of installations is correlated with improvements in interconnection and net metering standards. Although two market creation policies, a public benefits fund and an RPS, were enacted much earlier, they were not preceded by market preparation policies that could have increased their effect.

This paper aims to better understand these three policy interactions through quantitative and qualitative reviews of available state level solar distributed generation datasets:

1) The extent to which policies influence market development
2) The impact of policy ordering on market development
3) The impact of policy ordering on the effectiveness of subsequently applied policies.

There is literature in this theme that provides a baseline understanding. The strategy of using state policy as a tool to provide the starting point for the development of a robust private investment market has been outlined previously (Doris 2012, Sarzynski et al. 2012, Doris and Gelman 2011, Shrimali and Kniefel 2011). Furthermore, RPSs have been found to be successful in supporting wind market development (Wiser et al. 2011). Financial incentives are illustrated to provide immediate support to markets and

[2] http://Openpv.nrel.gov. The Open PV Project is a collaborative effort between government, industry, and the public that is compiling a comprehensive database of photovoltaic (PV) installation data for the United States. Data for the project are voluntarily contributed from a variety of sources including utilities, installers, and the general public. The data collected is actively maintained by the contributors and are always changing to provide an evolving, up-to-date snapshot of the US solar power market.

encourage installations (Sarzynski et al. 2012). Financial incentives can reduce system costs by a substantial percentage (Barbose 2011) but they come with potentially high costs for the implementing jurisdiction.

This analysis builds on that literature by providing a quantitative and qualitative look at a suite of policies thought to be effective at developing such markets for states. Instead of looking at financial incentives that aim to reduce system costs, this paper attempts to evaluate the impacts of low cost market opening policies. While financial incentives are often presented as the most powerful policy market driver (Sarzynski et al. 2012, Pitt 2008), interconnection and net metering standards, which can be implemented at a lower cost and be flexible enough to build markets consistently regardless of PV price reductions, may prove to be of equal or higher value in a low technology cost environment.

The specific hypothesis tested is: by implementing market preparation policies initially, and following with market creation policies, it can be illustrated that robust markets can develop based on low cost policies. If supported by the available data, this could indicate pathways for policy development that fit within the current economic conditions, support a market for lower cost solar technology, and develop robust markets without extensive government supported incentives.

Quantitative Analysis: Extent to Which Policies Influence Market Development and Impact of Policy Implementation Order

Econometric methods are used to assess the relationship between PV market development and select policies: interconnection, net metering, RPS set-asides, and RPS with any simultaneously enacted financial incentives. A cross-section analysis attempts to explain the variation in new PV installations across states.

The development of the model considered several factors, including:

- The premise that market preparation and market creation policies are baseline policies for the development of robust markets. These policies can be implemented "at little to no cost to the state" (Stoutenborough and Beverlin 2008) so they may be a good starting point for states interested in developing the DG market.
- Testing of other non-policy factors that are expected to explain some of the variation in PV capacity.

The model variables and datasets are described in detail below. The model itself is:

$$LCAP = \beta_0 + \beta_1 LPOP + \beta_2 INT + \beta_3 NET + \beta_4 SETASIDE + \beta_5 RPS + error$$

in which:

LCAP= natural log of statewide newly installed PV capacity (MW DC) in 2010 plus one. Includes both DG and non-DG installations due to the lack of DG specific data.

Intercept= the theoretical value of LCAP for a state with zero population, no interconnection, net metering, set-asides, or RPS.

LPOP= the natural log of the state's population in 2010, reported in millions.

INT= the state's interconnection score from the 2009 Freeing the Grid report.

NET= the state's net metering score from the 2009 Freeing the Grid report.

SETASIDE = number of years since the solar-specific or DG-specific set-aside within the RPS was enacted if there is one, zero otherwise.

RPS= number of years since the RPS was enacted if there is one, zero otherwise.

Error= includes all other factors that determine LCAP.

The dependent variable (LCAP) is the newly installed PV capacity for each state in 2010, the most recent year with publicly available data. The data comes from a report by the Interstate Renewable Energy Council (Sherwood 2011). This report tracked grid-connected installations and may be missing about 40 to 60 MW or 4 to 6% of the actual capacity installations in 2010 (Sherwood 2011). The variable is normalized by taking the natural log of 2010 installed capacity plus one. The log transformation rescales the data and is appropriate because the data contains large outliers and ranges over many orders of magnitude. As is commonly done when a log transformation is used and the data contains zeros, one is added to the newly installed capacity because some states did not add any capacity that year and the log of zero is undefined.

The independent variables are population and four policies: interconnection, net metering, RPS set-asides, and RPS. These policies were selected based on interest in determining the connection, if any, between low cost market opening policies (as opposed to technology cost reduction incentive policies) and market development.

It has been shown in previous research (Sarzynski et al. 2012, Doris and Gelman 2011, Shrimali and Kniefel 2011) that there are various explanatory factors beyond policies that could influence solar capacity. For this reason we include population in the model. Population data was obtained from the U.S. Census and reported in millions. It was also transformed using the natural log because the original data was heavily skewed. Other factors including annual net energy generation, per capita energy generation, and per capita state gross domestic product (GDP) were also tested but did not produce meaningful results. These variables were insignificant and their inclusion did not have an impact on the rest of the model, so they were excluded from the model.

This analysis takes into account a graded view of interconnection and net metering policies by using the scoring methods of policy best practices as defined by the Network for New Energy Choices (NNEC) Freeing the Grid report (FTG 2009). The FTG methodology for rating state interconnection and net metering policies is based on the likelihood that the policy would achieve increased DG goals that are often laid out in the preamble of the related legislation.

To reflect the complex nature of these policies, this methodology presents a more nuanced approach than the common use of dichotomous variables for the presence of interconnection and net metering standards (Sarzynski et al. 2012, Doris and Gelman 2011, Carley 2009). The purpose of this part of the analysis is to determine if a more nuanced approach is necessary to illustrate important differences between the impacts of these policies across states. Potential differences that could affect the impact of a policy on the development of DG markets include varying limitations on system size, with some states effectively excluding commercial and industrial customers, allowance of monthly roll-over of net excess generation, coverage of types of utilities, and limitation of insurance and engineering fees among other factors (Carley 2011, Doris et al. 2009, FTG 2011).

This more nuanced approach evaluates the effectiveness of interconnection and net metering policies in promoting DG by awarding or subtracting points based on an index of almost 30 metrics of success. For example in the standard form agreement category in interconnection, one point is awarded for a standard agreement with friendly clauses to the customer, zero points for a standard agreement with standard clauses, half a point is subtracted for no standard agreement, and one point is subtracted for a standard agreement with excessively complex or hostile clauses. Two independent variables (INT and NET) included in the regression are the total interconnection and net metering scores from Freeing the Grid 2009. The 2009 numbers are used because we expect a two year lag between policy implementation and project completion (Doris and Gelman 2010). States without interconnection or net metering standards and states with negative scores are assigned a value of zero. Although this limits the range of data, an assumption is made that having no statewide standards at all is no better than having poor standards represented with negative scores.

The RPS has been found to be a significant explanatory factor for various renewable technologies (Sarzynski et al. 2012, Shrimali and Kniefel 2011, Carley 2009, Wiser et al. 2007) and is also included. The variable is taken from DSIRE 2012 and equals the number of years since the RPS was enacted if the state has one in place, and zero otherwise.[3] Several alternative attempts were made at defining the RPS variable, including incorporating the value of the standards in each state, but none had as significant effect on policy impact as number of years since enacted.

[3] Some assumptions are made regarding RPS design. Arizona is credited with its 1996 RPS despite the fact that it was repealed and later replaced by new legislation. Iowa is assigned the average RPS value (3.7) because the megawatt obligations (rather than percentage) that were effective nearly three decades ago are not expected to increase renewable capacity the same way other RPS mandates did in the time period studied. Other values are assigned based on calendar year of enactment.

It is commonly thought that specific set-asides drive solar and DG so this variable is also included. The set-aside variable equals the number of years since a solar-specific or DG-specific RPS provision was enacted if the state has one, and zero otherwise[4]. It does not necessarily equal the general RPS variable for states that have these provisions in place because some did not enact it as part of the original RPS legislation but added it later on through revisions.

Admittedly the general RPS variable is not a unique effect because it captures the impact of various financial incentives that are often simultaneously enacted along with the RPS. The inclusion of this variable helps diminish the omitted variable bias that arises from excluding these incentives. Variables specific to different financial incentives are excluded because the focus of this research is on low-cost market opening policies.

As with interconnection and net metering, there is likely a more nuanced approach that could reflect the more effective components of RPS and set-asides for the development of DG resources, but there is no agreed upon set of renewable energy best practices or grading system that can currently be applied. There are a number of best practices guides and suggestions, but the state application of the RPS has not been standardized behind a single goal, as interconnection and net metering policies have, to the extent that a grading system can be applied. The model uses the enacted date of the RPS and set-asides, as opposed to the enforcement date, because enactment of the legislation signals a commitment to developing the market, and energy producers likely start planning and installing new capacity in anticipation of future RPS obligations rather than waiting for the first compliance period.

The availability and legality of the third-party power purchase agreement model is another influencing factor, but it was excluded from this analysis because many states do not explicitly address it and it may be treated differently in different parts of the state. Retail electricity rates likely have some influence as well but were excluded to avoid introducing simultaneity bias.

Analysis Strengths and Limitations

Due to the complex nature of energy markets and policy environments and the lack of clear understanding of the interaction of policies and market factors, it is challenging to illustrate direct causation between policy and project development. It is challenging, for example, to attribute the development of a robust market to market preparation and creation policies alone because these policies often lead to the development of incentives and market structures that facilitate meeting their increased use. In Massachusetts, for example, the RPS was designed to include an Alternative Compliance Payment (ACP) that allowed for responsible entities to pay a fine instead of developing renewable resources. The fines were combined with the existing public benefits fund and then used to create programs and incentives for the development of renewable resources. In the

[4] An assumption is made that credit multipliers without specific goals do not drive demand in the same way. Only those with specific DG, solar, PV, customer-sited, or non-wind (Texas) goals are considered set-asides in this analysis.

early compliance period of the Massachusetts RPS (2003-2006) ACPs were common forms of accomplishing compliance (Figure 3), resulting in $51 million dollars (Massachusetts Department of Energy Resources) of payments that were funneled into multiple programs for the development of renewable resources. Figure 3 also shows the lagged increase in installed solar capacity following the compliance payments, that could reflect either the impact of the RPS requirements or the effectiveness of the ACP funded programs, or most likely, a combination of both of these and other factors.

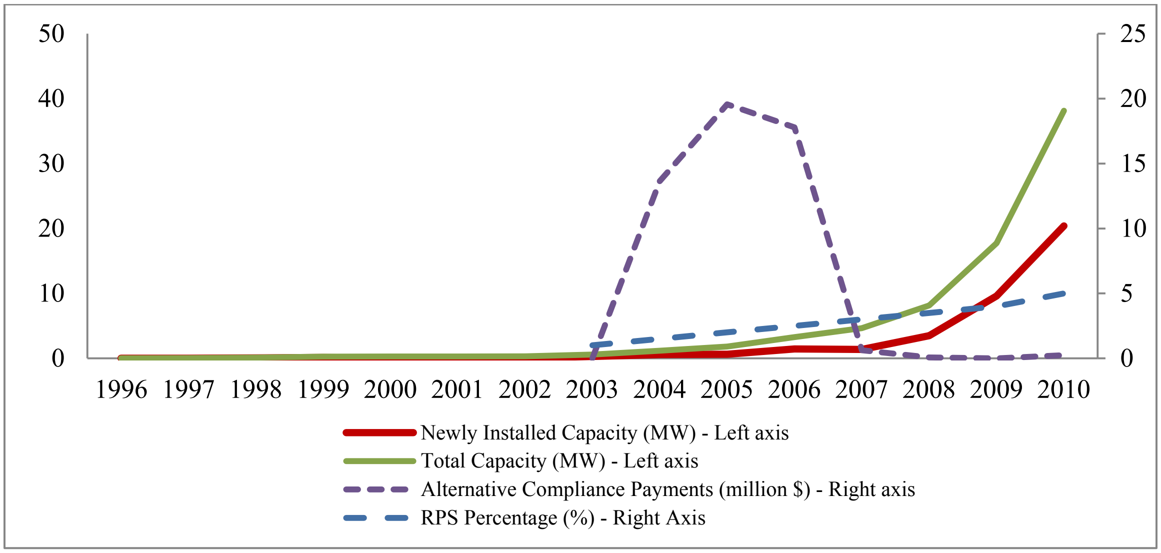

Figure 3: Massachusetts PV Capacity, RPS Obligations, and ACPs

Technical limitations include the possibility of omitted variables which, if correlated with both the dependent and at least one of the independent variables, will create a bias in the coefficients and may lead to false conclusions. There is also a possibility of endogeneity bias, which is often present in policy regressions, due to interest groups that promote certain policies. In other words, having a developed market with high PV capacity may lead to adoptions of policy which may or may not in turn increase PV capacity, and this bias may lead to false conclusions.

Another potential bias comes from the methodology of the FTG grading criteria. It is possible that the individual metrics (system capacity limit, insurance requirements, etc.) were designed with current DG capacities in mind, in effect awarding more points to states that already have more cumulative DG capacity. This is another possible bias and in the extreme case it could mean that a correlation exists between FTG scores and DG capacity because the scores are caused by capacity rather than capacity being caused by the effectiveness of the standards as measured by FTG scores. We acknowledge the possibility of this bias, yet the independent variable used in this analysis is *new PV* capacity installations that include both DG and utility-scale systems, while the bias in the scores would come from *cumulative DG* capacity that includes PV and all other sources. So if a bias is present it should be minimal.

RPS measures are complicated by regional markets that reach beyond the state level. For example, a 2010 58 MW solar installation in Nevada sells electricity to a utility in California to help meet California RPS obligations (FTG 2011) and Massachusetts only met 8.5% of RPS obligations using in state generation in 2010 (Massachusetts Department of Energy Resources 2012). Although RPS mandates have been shown to increase in-state market penetration for renewable technologies, there is some evidence of regional effects as well and these are not considered in the current study.

Findings

Table 1 presents the resulting regression. For a plot of residuals and actual and predicted values, see the appendix. Because evidence of heteroskedasticity was found using the White heteroskedasticity test, robust standard errors are used. The results indicate that states with a higher population, better interconnection and net metering standards, older RPS set-aside provisions, and older RPS installed more PV capacity in 2010.

Table 1: Policy Impact on PV Development

Dependent Variable: Ln(PV Capacity added in 2010 + 1)

Variable	Beta	P-Value
Constant	-0.518	0.039 *
Ln(Population) [2010]	0.564	0.000 *
Interconnection [2009 report]	0.062	0.037 *
Net Metering [2009 report]	0.046	0.028 *
Set Aside Age [2010]	0.155	0.004 *
RPS Age [2010]	0.091	0.023 *
Adjusted R^2	0.735	
Number of Observations	51	

**Significant at the 5% level*

Sources: IREC, Freeing the Grid, DSIRE, Census

The p-values are all less than 0.05, indicating that the variables are all statistically significant at the 5% confidence level and that the probability of observing these values, if the variables were truly insignificant, is less than 5%. Furthermore, the resulting coefficients suggest that a one point increase in a state's interconnection score leads to an average of 6.2% increase in annual PV capacity installations the following year, and for each point increase in net metering annual capacity additions increase about 4.6%. A 1% increase in population is associated with a 0.56% increase in PV capacity installations. With each passing year, an RPS with set-aside provisions increases new PV capacity by 15.5% on average, and the effect of a general RPS with simultaneously enacted financial incentives is about 9.1%. Although these numbers give us an indication of how these policies impact PV installations, they are approximated averages and actual impacts for different jurisdictions in various situations are likely to differ considerably.

The adjusted R^2 value provides a statistical measure of how well the regression approximates the actual data points, and with this regression it equals 0.735, suggesting that 73.5% of the variability in the data set is accounted for by the model. It is important to note that this statistic does not prove causality nor does it indicate whether the correct regression was used or whether various biases exist.

To further assess the validity of the relationship between the two market preparation policies and PV capacity additions, states with different letter grades are compared using nonparametric methods. The states are grouped according to interconnection and net metering letter grades, as shown in Table 2. The states' 2010 PV capacity additions are adjusted for population, and the median adjusted additions are compared collectively using the Kruskal-Wallis one-way analysis of variance. The adjusted capacity additions are then compared between groups using the Mann-Whitney test. These tests are used because there is heterogeneity of variance among the groups and the number of states in each one is different. The groupings are made based on the number of states in each letter grade category. The groupings are different for the two policies because the grade distribution is different. For example, in interconnection there is only one state with an A grade and 14 with F while in net metering there are 11 states with A grades and 3 with F grades (see Appendix for grade distribution).

Table 2: Nonparametric Testing Categories

Interconnection Groups	A and B	C and D	F	None	
State count	15	12	14	10	
Median MW/Population	3.12	1.19	0.10	0.00	
Mean MW/Population	6.69	1.89	1.09	0.08	
Net Metering Groups	**A**	**B**	**C**	**D and F**	**None**
State count	11	16	8	9	7
Median MW/Population	2.67	0.23	0.26	0.13	0.03
Mean MW/Population	5.21	3.70	1.95	0.56	0.24

** Population reported in millions*

The nonparametric testing results (Table 3) indicate that there is a statistical difference in the 2010 PV capacity additions adjusted for population between different groupings of states based on interconnection and net metering grades.

Table 3: Nonparametric Testing				
Null Hypothesis	**Kruskal-Wallis**	**Mann-Whittney**	**P-value**	
IntAB = IntCD = IntF = IntNone	26.22		0.000	*
IntAB = IntCD		1.83	0.067	
IntCD = IntF		3.06	0.002	*
IntF = IntNone		1.38	0.169	
NetA = NetB = NetC = NetDF = NetNone	14.55		0.006	*
NetA = NetB		2.15	0.032	*
NetB = NetC		0.28	0.783	
NetC = NetDF		0.43	0.665	
NetDF = NetNone		0.58	0.560	

** Reject null at 5% level*

For interconnection, the A B group is not statistically different from the C D group at the 5% level although it would be statistically different at the 10% level, and the means and medians are different. The CD group had more capacity additions per person than the F group at the 5% level, and the F group is not statistically different from the group with no interconnection standards. For net metering, the A group is statistically different than the B group at the 5% level, but no other statistical differences in adjusted PV capacity additions exist.

This part of the analysis supports the econometric model and confirms that there are differences in PV capacity additions among states based on the quality of their interconnection and net metering standards, as scored by FTG. Other factors not considered in this comparison and small sample sizes contribute to the inconclusive results for some comparisons. It is expected, however, that not many statistical differences were found between net metering groups because there are many states with poor or failing interconnection standards that have good net metering policies, and the difficulties presented by the interconnection process likely discourage customers from taking advantage of net metering. This suggests that the two policies interact with each other and interconnection may be needed to make net metering effective. Comparing the 18 states with at least C grades for both policies (median adjusted capacity addition of 2.83) against all other states (median 0.08) returns a Mann-Whitney test value of 4.64 (p-value close to zero) and provides overwhelming evidence that there is a statistical difference between the two groups in adjusted PV capacity additions.

Qualitative Analysis: Impact of Policy Implementation Order on the Effectiveness of Subsequent Policies

The evidence presented here suggests that interconnection, net metering, RPS set-asides and general RPS policies with simultaneously enacted financial incentives have a positive effect on PV capacity additions. The important question for policy sequencing has to do with how these policies interact with one another. Interconnection and net metering are market preparation policies that ease the implementation of DG technologies, while the RPS is a market creation policy (Doris 2012) that creates demand in the renewable energy market. In theory, interconnection standards increase DG PV capacity by removing barriers and decreasing costs for connecting these systems to the grid. Net metering effectively helps finance the installation by improving the compensation system for putting energy into the grid. Net metering may also provide more revenue through Solar Renewable Energy Credits (SRECs), depending on the RPS policy. Previous research has stated that if the process of interconnection is “burdensome and costly, the effectiveness and value of incentive programs that encourage the installation of grid-connected technologies is severely compromised” (Gouchoe et al. 2002). These observations suggest that interconnection standards modify the effectiveness of other policies, including RPS and various financial incentives, in addition to having their own impact on the DG market.

If this is supported by data, effective interconnection and net metering policies would be expected to increase the effectiveness of the RPS and the simultaneously enacted financial incentives specific to the DG PV market. Although only a small percentage of non set-aside RPS obligations are likely to be met using DG, interconnection and net metering policies could increase this percentage. These policies make DG PV systems more attractive to homeowners and may open new markets in localities where the process is complex or expensive enough to prohibit DG installations. Utilities could then acquire RECs generated by these systems for RPS obligations and may further encourage customers to install them.

A qualitative approach is taken to test this concept. There are 10 states that enacted an RPS in the time period during which Freeing the Grid scores are available (2007 to 2011). If the effectiveness of each RPS specific to the PV market is evaluated and compared to average interconnection and net metering standards during the time period, it might provide some evidence as to whether or not these market preparation policies modify the impact of the RPS.

To do this a rudimentary measure of RPS effectiveness is created by taking the average per capita annual PV capacity additions from before the RPS enactment and subtracting it from the same measure after RPS enactment during the time period of 2006 to 2010. While this measure has some inherent flaws, including different enactment years for different states and different RPS structures, it still provides a rough qualitative assessment of RPS effectiveness. It may also pick up some non-policy effects and the effects of some financial incentives.

Findings

The results are presented in Table 4, which lists the ten states in order of increasing RPS effectiveness with letter grades represented by different colors. High grades for interconnection standards are generally coupled with high levels of RPS effectiveness. When states have similar interconnection grades, generally the ones with better net metering have a more effective RPS.

Table 4: Comparison of Market Preparation Policies and RPS Effectiveness				
State	RPS enacted	Average interconnection grade 2007-2011	Average net metering grade 2007-2011	Change in average per capita capacity additions from pre-RPS to post-RPS
*KS**	2009	-0.5 (F)	5.25 (D)	***+0.015****
MO	2008	-1.625 (F)	7.75 (C)	**+0.050**
MI	2008	5.9 (D)	9.7 (B)	**+0.111**
MN	2007	3.7 (D)	5.9 (D)	**+0.173**
WA	2006	3.2 (D)	8.8 (C)	**+0.201**
IL	2007	10.8 (B)	8.6 (C)	**+0.329**
NH	2007	4.5 (D)	10.3 (B)	**+0.361**
OH	2008	7 (C)	12.6 (B)	**+0.819**
NC	2007	8.1 (C)	3.7 (D)	**+1.352**
OR	2007	11.8 (B)	16.9 (A)	**+1.622**

**Kansas capacity information is a proxy from OpenPV. IREC reports it as "less than 100KW or data not available", which is consistent with OpenPV*

One of the 10 states that enacted an RPS in the time period does not fit into the above framework. Illinois has good interconnection and net metering policies yet it does not have much PV capacity and the measure of RPS effectiveness was far lower than expected. This could be because of low resource quality, or because having one of the most developed wind markets in the country (Gelman et al. 2010) leads to wind being a more popular DG source than solar. There are many other factors beyond interconnection and net metering that determine RPS effectiveness and PV capacity growth, so the existence of a single outlier is not unexpected.

Although the letter grades in interconnection steadily increase as the measure of RPS effectiveness increases, the numeric scores do not always follow this trend. Judging by the numeric scores, Michigan should have a more effective RPS than the other states with D letter grades in interconnection, and Ohio should be closer to North Carolina because of the large difference in net metering scores.

The case of Illinois and the unexpected variation in RPS effectiveness given the numeric scores (rather than letter grades) illustrate that there are numerous other factors that contribute to differences in policy effectiveness that limit the ability of the analysis to lead to strong conclusions. However, this analysis does present some qualitative evidence suggesting that interconnection and, to a lesser extent, net metering make RPS mandates more effective in the PV market.

Factors Influencing Analysis

There is quantitative and qualitative evidence developing over time that interconnection and net metering policies that meet the best practices outlined in the Freeing the Grid report result in increased project development. That report provides the most comprehensive measure of the effectiveness of interconnection and net metering standards available, yet there is still a need for improving metrics as illustrated by changes in the grading criteria over the years since the first publication.

One important grading criterion in which the authors admit "there is room for improvement" (Freeing the Grid 2011) has to do with timelines for the interconnection process. The latest report grades timelines by awarding a point for having shorter timelines than FERC standards and subtracting a point for having longer ones. While this grading system gives us a rough idea of the timelines, there is much more depth to this criteria and evidence from case studies suggests that project delays attributed to interconnection issues can last anywhere from one to 14 months, with a few special cases lasting as long as a decade (Alderfer et al. 2000). In the case of small DG PV systems, for which the actual installation only takes a couple of days, these delays present substantial barriers to interconnection (Freeing the Grid 2011). A better measure of how long the interconnection process takes in different states could provide more insight.

Another related issue not included in the Freeing the Grid report has to do with solar access laws. Bans by homeowners associations (HOAs) can effectively prohibit DG PV systems (Pitt 2008, Starrs et al. 1999), despite any interconnection and net metering standards in place at the state level. Solar access laws and their enforcement are therefore an important determinant of the statewide effectiveness of interconnection standards. While some states have these laws in place, they are "routinely violated" (Pitt 2008) due to inadequate enforcement. Furthermore, HOAs can sometimes force system owners to install on a less efficient area with less sun exposure, even when a south facing rooftop is available, because of perceived aesthetic reasons (Starrs et al. 1999). This can occur in places where access laws prevent HOAs from banning these systems outright but fail to address these limitations. Zoning rules, usually put in place at the local level, can also introduce various barriers (Pitt 2008) that strong solar access laws may be able to overcome.

Previous literature has stated that interconnection and net metering policies "plac[e] the economic burden on the private utility industry… at little to no cost to the state" (Stoutenborough and Beverlin 2008) and while the cost to the state can be determined with relative ease, the implications for utilities are less clear. Other research has stated that "utilities choosing to embrace rather than oppose customer-sited PV installations may be able to benefit substantially from doing so, by maintaining or even enhancing revenues, reducing costs and capturing administrative efficiencies, and realizing significant public relations benefits that promote customer satisfaction and loyalty" (Starrs 2000). Further research is needed to quantify the effects of DG on utilities and to assess the implications of a large and developed DG market for consumers and ratepayers.

Summary Findings and Discussion

Primary Research Findings:

- Institutional barrier reduction (e.g. interconnection), valuing of excess electricity (e.g. net metering), indication of public support for a solar PV market (e.g. RPS, set-asides), and a non-policy determinant (population) explain about 70% of the variation between new PV capacity among US states.
- Implementing low cost policies (interconnection and net metering) prior to more expensive policies (RPS, incentives) may bolster the effectiveness of the latter policies.
- The quality of the components of interconnection and net metering policies has an impact on overall effectiveness on the development of PV markets.

Previous research has highlighted the importance of interconnection and net metering standards (Carley 2011, Carley 2009, Doris et al. 2009, Pitt 2008), and although quantitative evidence is limited (Carley 2011), there seems to be a general consensus that these policies improve market penetration for DG technologies. This paper builds on previous literature by providing further quantitative and qualitative evidence supporting the relationship between interconnection, net metering, RPS and PV market penetration. This methodology augments the previous dichotomous (policy/no policy) evaluation of policies by integrating a more nuanced, best practices based approach. Until now there has been no published quantitative research, to the best knowledge of the authors, studying the correlation between Freeing the Grid scores and DG market deployment.

The results of this study indicate that quantitatively, about 70% of the variation in capacity installations of grid connected PV in 2010 between states can be explained by a model that considers a non-policy determinant as well as the existence of market preparation and creation policies. The results indicate that building on this low public cost policy foundation can lead to the development of a robust market. Nonparametric testing methods confirm the differences in PV capacity additions between states with different FTG grades for the two market preparation policies. Furthermore, evidence suggests that market preparation policies, such as effective interconnection and net metering, strengthen the impact of market creation policies, such as RPS. Finally, case study based evidence for states with a compelling market development story or unused incentives indicates that the sequencing of the policies may lead to more efficient market development, particularly from the perspective of public investment.

The findings also support some previous research regarding policy design. Evidence suggests that RPS enactment dates, as well as effective dates, are correlated with the development of a market, presumably resulting from a signal to the market that the jurisdiction is committed to its development. There is also some evidence that confirms the lag between policy implementation and project development.

State level policymakers and staff can use this information to better inform decisions related to policy development. Taken together, the findings indicate that low public cost, well developed policies that prepare and create markets for distributed PV can result in the development of robust markets with PV, regardless of technology cost.

Evidence presented here suggests that effective policy ordering starts with improving interconnection standards, closely followed by improvements in net metering standards, and eventually strengthened by the enactment of an RPS and set-asides before moving on to more expensive market expansion policies such as financial incentives. This sequencing strategy allows some lower cost policies to build a foundation for more expensive policies that will be enacted in the future, therefore maximizing their impact on the market and optimizing budget use. Potential benefits to state governments include low cost policies and avoidance of complex incentive programs, except in niche markets. In addition to this being beneficial to the state, there is potential for a benefit to utilities as well, through the implementation of long term, low cost policies.

Appendix

Table A1: Descriptive Statistics					
	Capacity Additions	Interconnection	Net Metering	RPS	Population
Minimum	0.00	0.00	0.00	0.00	0.56
Mean	17.51	4.82	8.90	3.70	6.05
Median	1.70	4.00	9.00	3.00	4.34
Maximum	252.00	16.00	20.00	14.00	37.25
Standard Deviation	41.57	5.10	5.91	4.22	6.82
Observations	51	51	51	51	51

Table A2: Grade Breakdown						
Grade	None	F	D	C	B	A
States (Interconnection)	10	14	6	6	14	1
States (Net Metering)	7	3	6	8	16	11

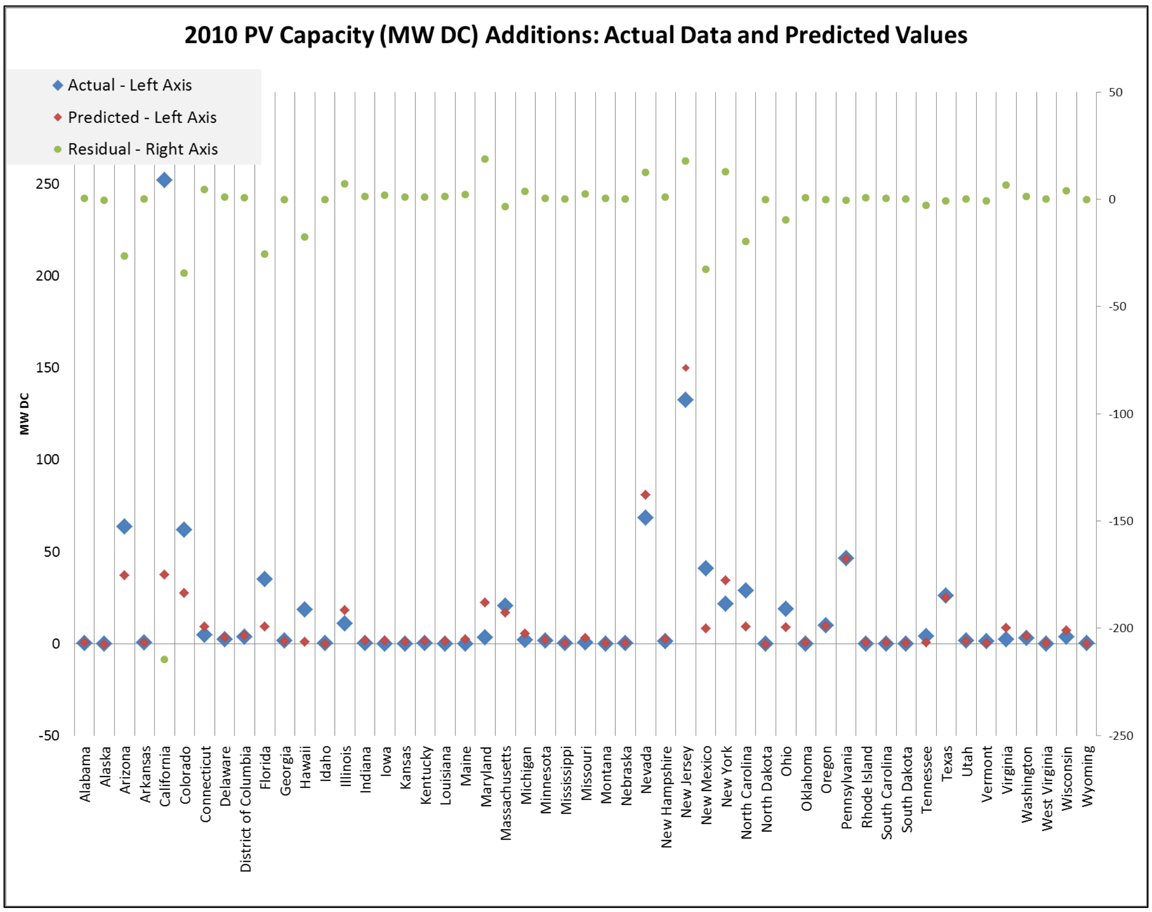

Figure A1: 2010 PV Capacity Additions – Actual Data and Predicted Values

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