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THE IMPACT OF SOLAR INCENTIVE PROGRAMS IN TEN STATES

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1 - EXECUTIVE SUMMARY

Solar power could play an important role in a clean energy economy, but high costs remain an obstacle. Policymakers have tried to bring down the cost and risk of solar technology through financial incentives, such as tax credits or rebate programs. Since the first solar incentives were adopted in the 1970s, states have shown substantial policy leadership and innovation in the design and implementation of incentive programs (Sarzynski, 2009). Even so, little recent evidence exists regarding how much states are spending on incentive programs, what they are getting for their money, and which design or implementation features appear to work best to promote the use of solar technology. Without adequate demonstration of impact, solar incentive programs may face stiff competition with other budget priorities in today's tight fiscal environment.

This report evaluates the impact of state solar financial incentives in ten states. Impact is evaluated against three objectives: (1) encouraging consumer adoption of solar technology, (2) reducing conventional energy demand, and (3) reducing the environmental impacts from conventional energy. The analysis also seeks to uncover the characteristics of incentive design and implementation that contribute to successful programs with the least cost and administrative burden.

Ten sample states were selected for further investigation due to availability of data on incentive program participation, including Arizona, California, Connecticut, Delaware, Hawaii, Maine, Minnesota, New Jersey, Oregon, and Utah. While not comprehensive, the analysis reflects potential issues with incentive design and implementation that are worth considering for all state incentive programs.

The analysis begins by considering factors besides incentives that might influence solar technology deployment within states. The factors include per capita income, available solar resources, and conventional energy prices, which all follow directly from consumer choice theory. The factors also include relevant demographics, such as population size and citizen liberalism, and other aspects of state energy policy that are likely to support solar technology, including net-metering and renewable portfolio standards (RPS). Simple (bivariate) statistical analysis reveals many expected relationships:

- States with larger populations have more solar deployment.
- States with higher average incomes have more solar deployment.
- States with higher electricity or natural gas prices have more solar deployment.
- States that need to import more energy have stronger solar deployment.
- States with better solar resources have stronger solar deployment.
- States with a more liberal citizenry have stronger solar deployment.

The analysis is unable to identify the impact of net metering or RPS on solar deployment, as all states in the sample had net metering and some form of RPS. However, the states with a solar-specific RPS (here, Delaware, New Jersey, and Oregon) do appear to have stronger solar deployment than otherwise expected.

The results presented here were obtained using simple bivariate analysis with a small sample and should not be interpreted as evidence of causality. Future analysis will employ a multiple regression analysis with all of the factors and all 50-states to investigate the independent impact from incentives on state solar deployment. Population size, energy prices, available solar resources, and a solar-specific RPS are expected to exhibit the strongest impacts on solar market development within states.

The next portion of the analysis used the Solar Advisor Model (SAM) from the U.S. Department of Energy to illustrate how the state's current incentive might impact the financial viability of PV investments that were 100% debt-financed. The model accounts for the combination of incentives, electricity prices, state tax rates, and available solar resource. The state's incentive is judged as effective if its addition results in a positive net present value for the consumer and a levelized cost of energy below the current average electricity price.

The SAM analysis suggests that the most effective residential incentives are currently offered by California, Connecticut, and Hawaii. In each case, the state incentives make the hypothetical residential system of 4 KW financially viable and would likely contribute positively to the decision to invest in PV. Six of the ten studied states also effectively incentivize commercial installations of almost 200 KW, including California, Connecticut, Hawaii, Maine, New Jersey, and Oregon. Hawaii is the only state to incentivize large installations out of tax expenditures; the other states financed their incentives through public benefits funds (PBFs) or through the sale of solar renewable energy credits (SRECs), as in New Jersey. Hawaii is also the only state in which the addition of the state incentive did not appear necessary on top of the federal investment tax credit, either for residential or commercial systems, and thus may represent a "windfall" profit to consumers already motivated by the federal incentive.

Alternatively, the SAM analysis reveals that cost remains an obstacle in several states. Utah and Arizona currently offer the smallest incentives (both delivered through the tax system) and leave the largest financial burden on the consumer. The SAM analysis does not account for other non-state incentives that may be available to residents, such as from their utilities. States may intentionally offer small incentives because incentives are already available from other sources. Future analysis will investigate whether the state incentives are sufficient to make the hypothetical installation financially viable when added to incentives available from utilities or non-profits.

One implication of this analysis is that some states need to step up their efforts if they want to properly incentivize solar installations. Yet, an important question for public discussion is whether the expense required to properly incentivize solar installations is the best use of public resources. States may find that putting such large sums per installation towards other policy mechanisms may deliver similar energy savings and environmental benefits.

The third part of the analysis evaluates the behavioral response to state incentives using data on participation, expenditures, and solar capacity-installed, which most directly illustrate achievement of the first objective. The analysis finds that participation has been increasing across all incentives but that the incentives have so far reached very few consumers. Only 80,000 consumers have been funded recently by the studied state incentives in the ten states (with data first available from the early 1990s). Most incentives (in number) were for residential installations and in states with well-established solar markets, including Hawaii, California, and Arizona. The studied income tax incentives reached more participants than the cash incentive programs, although this finding may be skewed by strong participation in the tax programs in Hawaii and Arizona. Even so, the incentives in Hawaii and Arizona were the only ones to cumulatively reach more than 1 percent of the state's households.

The analysis finds a strong participation response to incentives in many states after 2006, when the federal investment tax credit was reinstated for residential installations and was increased for non-residential installations. Recent participation, therefore, must be attributed to the combination of the state and federal incentives. Future analysis with the SAM model will do more to illustrate the potential magnitude of the state incentives in relation to the federal incentive.

The ten studied states have so far spent more than $1 billion (in 2008 dollars) to incentivize solar installations. The tax programs typically spent far less per participant than the cash incentives. Some of the tax programs spent only $500 per residence while some of the cash programs spent more than $20,000 per residence. Average expenditures were even larger for non-residential installations, at up to $100,000 per business in some states.

An important question remains whether the states with such generous subsidies can afford to retain them in the future. Already, many of the states rely on public benefits funds (PBFs) to finance their incentives rather than paying for them out of general funds. PBFs are funded by surcharges on all utility customers. Connecticut and New Jersey, with some of the largest subsidies, have also recently reduced their incentive levels, with New Jersey aiming to phase-out rebates entirely by 2011. Instead, New Jersey is fostering a market of solar renewable energy credits (SRECs), which moves the financing for solar subsidies into a new private marketplace. The New Jersey experience may prove a valuable model for other cash-strapped states wanting to do more with less in the coming years.

Financing solar from PBFs or other funding streams places the annual available funding at the mercy of annual contributions, which fluctuate with energy prices and the economy generally. Thus, the incentive amount offered may be continually adjusted to reflect the amount of financing available each year. Tax incentives and cash incentives financed out of general funds may not experience the same annual fluctuations, although cash incentives would still be subject to annual appropriations and potentially available for raiding during tight budget years. Drastic fluctuations and changes in incentive design create an uncertain environment for potential investors. Even so, the states recently adjusting (downward) their incentive levels and structures (i.e., Maine, New Jersey, and Connecticut) have all still retained relatively strong participation, suggesting that even smaller incentives can effectively incentivize participants.

The PV incentives together partially financed the installation of 363 MW of PV capacity, with the majority from the California Solar Initiative. Average non-residential system sizes were largest in California and Connecticut, and smallest in Oregon. Average residential systems were largest in New Jersey and smallest in Maine and Oregon. Larger system sizes suggest more effective incentives, as we would expect consumers to install the largest systems they can afford in order to reap the most future energy savings.

Most states exhibited a clear response in PV capacity-installations after the initiation of their PV incentives. New Jersey and Connecticut appeared to most successfully incentivize PV capacity-installed over the course of their incentives, experiencing nearly exponential growth. California also experienced a strong response after initiation of its latest cash incentive program, which is surprising because the state already has the most mature solar market in the sample. In all three cases, the strong recent response must be attributed to the combination of state and federal incentives, as well as to their strong RPS provisions that are likely indirectly spurring more solar development.

The final section of the analysis examined the potential electricity savings and emissions avoided from the solar subsidies over a 20 year period. While the methodology used here is simple, it raises questions about the cost-effectiveness of using solar subsidies in some states to generate electricity and CO_2 emissions reductions. The studied incentives (with available data) resulted in an estimated 11.8 million MWh of electricity savings over 20 years, at an average cost of $84/MWh. Incentive costs for electricity savings are substantially lower for the solar thermal heating programs (in Maine and Oregon; less than $10/MWh) than for the PV programs (several more than $100/MWh).

In addition, the 11.8 million MWh savings would result in an estimated 6.1 million metric tons of CO_2 emissions avoided, at an average cost of $163/ton. The most efficient programs in terms of cost per ton CO_2 avoided were in Delaware (residential water heating) and Maine (space heating), at $30/ton. The most efficient PV incentive cost $57/ton CO_2 avoided (New Jersey's current non-residential program), which is less than the current price that CO_2 is currently trading at in Europe (about $73/ton). Alternatively, the most expensive PV programs cost more than $250/ton CO_2 avoided (in Connecticut, New Jersey, and Oregon). These costs reflect the state subsidy per unit output, and do not account for additional subsidies or private costs to the consumer.

Overall, the analysis finds vast disparities in impact across programs. The disparities appear to result from characteristics of the incentive, such as the eligible sector, the type of incentive, and the way the incentive is funded. The disparities also result from the size of the incentive, which may vary in accordance with what is needed to make solar cost-effective given variations in solar availability, tax rates, and energy prices. Such disparities in impact suggest that states may, in fact, be taking advantage of their situation as “laboratories of democracy” and designing incentives that match their local needs. Even so, some states appear to be spending more on their incentives than may be necessary to spur consumer adoption and more than appears warranted by the emissions reduction benefits that can be achieved through solar incentives.

Further analysis should investigate alternative options within each state that could deliver similar energy savings and emissions reductions but at a lower cost. Such a state-specific alternatives analysis is necessary to account for the local variations in energy conditions, demographics, and other state energy policies, which all may influence a program's impact on desired outcomes.

2 - BACKGROUND

Consumer choice theory provides an initial framework for understanding the adoption of solar technology (Lazzari, 1983). Solar energy technology is a durable good that substitutes for conventional energy technology typically powered by electricity or fossil fuels. Solar technology has a higher capital cost than conventional energy technologies but requires no costly fuel inputs and thus can deliver annual energy savings over conventional technology. Whether solar technology is cost-competitive with conventional technologies depends on: (1) the cost of the solar technology; (2) the expected savings of conventional energy from employing solar technology; (3) the expected price of conventional energy; and (4) available financial incentives. Rational consumers will purchase solar technology if its cost is equal to or less than conventional technology and if they can afford the investment.

Different tools have been developed to estimate the cost of solar technology and to shed light on the cost-effectiveness of solar compared to conventional technologies. One approach is to estimate the total cost of solar technology over the lifetime of the technology (typically 20 years or more), known as lifecycle cost analysis or net present value analysis. Such an approach can be used to forecast the economic feasibility of solar technology under different scenarios, including varying types and levels of financial incentives.

The cost-effectiveness for solar technology depends on the alternatives being compared and their relative prices. For instance, Ruegg (1976) found that incentives are needed to generate positive net benefits for solar heating if natural gas prices stay low, but would not be needed at all to support solar if natural gas prices double. Similarly, Kastler (1983) found that income tax credits would improve the financial viability of residential solar space heating but not to the point of generating net benefits or being cost-competitive with natural gas systems. By contrast, Kastler found that tax credits made a solar heating system cost-competitive where it was to replace an all electric heating system.

Such a result is dependent on the location selected for the analysis, as prices and energy alternatives vary spatially. Bezdek et al. (1979) found that solar water heating was cost-competitive with electricity in Los Angeles and Grand Junction, CO, but not in Boston or Washington, DC. Tax credits could make solar cost-competitive in all four cities and cost-competitive with fuel oil heating in Grand Junction, but were not sufficient to make solar cost-competitive with natural gas in any of the four cities. Alternatively, Bezdek and Sparrow (1981) found that subsidized solar heating would be cost-competitive with electricity in New York and New Mexico but not in Wisconsin.

In a larger study of 69 U.S. cities in 1984, Fry (1986) found residential solar water heating cheaper than natural gas heating only in Honolulu and Tucson. Solar water heating was cheaper than electric heating in 38 cities, with the most favorable conditions for solar heating relative to electric in New York, Honolulu, and San Diego. Seattle, Pittsburgh, and Rapid City, SD had the least favorable conditions for solar relative to electric, in part because these places had low electric prices, few income tax incentives, and colder climates requiring additional antifreeze components in the solar systems.

The economic simulations are valuable in identifying the sensitivity of the cost-effectiveness calculation to changes in key variables, such as energy prices, incentives, or solar availability. However, the approach suffers from one major drawback: it does not evaluate the actual behavior of consumers when faced with different energy conditions and incentives (Lazzari, 1983). Consumers may not necessarily act rationally even when energy-saving technology could generate substantial net benefits (Quigley, 1991).

For this reason, scholars also examined the impact of incentives on the likelihood of investing in energy-saving technology. For instance, Durham et al. (1988) surveyed households in 1983 from eight Western U.S. states to determine the likelihood of having installed a solar hot water heater. The survey included questions regarding household characteristics (e.g., persons in the household, education, income, homeownership), attitudes towards energy conservation, energy prices, available incentives, and solar technology installation. Regression analysis found that the availability of a state tax incentive significantly improved the likelihood of a homeowner installing a solar hot water heater, as did higher energy prices.

Similarly, Hassett and Metcalf (1995) analyzed federal income tax returns for claimants of the residential energy conservation tax credits in 1979-1981. The models tested the impact of the effective tax price of investment (adjusted for variation across states with additional energy tax incentives), income, homeownership status, climate, unemployment rates, and overall time trend on the probability of claiming the tax credit. The models controlled for individual variation (i.e., conservation preferences and housing characteristics) through fixed effects and found that the tax credits positively and significantly impacted the likelihood of making a conservation investment.

The research to date has found a positive impact of the presence of solar incentives (usually tax credits) on solar energy use, using a variety of research methods and data sources. What is less well understood is how the suite of possible financial incentives (tax credits, rebates, financing, etc.) may encourage solar energy use. In addition, there has been little attempt to distinguish effects of federal incentives from state or local incentives, or to distinguish the effect of tax credits from other programs (but see Lancaster & Berndt, 1984).

A final but major drawback of existing research is its age; most evaluations of solar financial incentives were performed in the 1970s and 1980s. Much has changed since then and new analysis is needed to update our understanding of the impact of solar incentives on today's consumers.

This report proceeds as follows. Section 3 reviews the research design. Section 4 discusses multiple factors that may influence solar market development, independent of financial incentives. Section 5 illustrates how incentive design features work together with some of these external factors to influence the financial viability of solar technology adoption. Sections 6 and 7 review multiple metrics to better evaluate program performance given highly variable incentive designs and energy situations across states. Section 8 concludes with recommendations for future data collection that would enable a more robust analysis.

3 - RESEARCH DESIGN

This analysis is motivated by the lack of consistent and comparable recent information about state solar incentive design and effect. This work was completed on a parallel track with another study evaluating state renewable energy policies, including financial incentives, but utilizing different techniques (Doris, McLaren, Healey, & Hockett, 2009).

The intent of this analysis is to evaluate the impact of state solar incentive expenditures on three outcomes of interest: (1) consumer adoption of solar technology, (2) reduction in conventional energy demand, and (3) reduction in the environmental impacts from conventional energy. The analysis also seeks to uncover the characteristics of incentive design and implementation that contribute to successful programs with the least cost and administrative burden.

The analysis focuses on ten states that were selected due to availability of information on participation in their incentive programs. This section provides information on the selection of the ten case states, the incentives that were studied, and the analysis tools that were used to evaluate the impact of state incentive programs.

SELECTED STATES

State budget and program reports were examined to identify program expenditures, participation, capacity installed, and other evidence of the impact of incentive programs on outcomes of interest. Unfortunately, most states have not published sufficient information regarding use of their solar incentives that would allow appropriate comparisons across states. Of the 29 states with income tax incentives in December 2008, for instance, only four states published both the number of claimants and the amount of money spent on the incentive programs for more than a year or two. In many cases, state tax expenditures reflect estimated expenditures, impeding analysis of actual program performance. In some cases, the tax expenditures data did not differentiate between renewable technologies, precluding an analysis of solar-specific use (i.e., in Montana and Oregon).

Ten states were selected with enough available information on their solar incentive programs to examine further. Because the states were selected based on data availability, the results may not be representative of all solar incentive programs. Even so, the results help to highlight potential issues with incentive design and impact and to identify areas for further research.

The ten selected states currently offer a range of income tax and cash incentives for purchase and use of solar technology (see Table 1). Program information are available for twenty-three incentives in these states, subdivided where possible by eligible sector (i.e., residential vs. non-residential) or by technology (i.e., solar electric vs. solar heating). Thus, this analysis considers seven income tax incentives across five states, one grant program, and fifteen rebate incentives in six states.

Table 1. Selected State Financial Incentive Programs for Evaluation

State	Incentive Type	Eligible Sector	Eligible Technology	Current Incentive Amount	Available data
Arizona	Personal income tax credit	Residential	Solar electric and heating	25% of the installed cost ($1,000 maximum credit)	1995-2004
California	Rebate	Non-residential	Solar electric	$2.50-$3.50/W (maximum 50 kW in 2008-09; 30 kW in 2010 and after)†	2006-2009
California	Rebate	Residential	Solar electric	$2.50-$3.50/W for single-unit residential; $3.30-$4/W for multi-unit residential	2006-2009
Connecticut	Grant	Non-residential	Solar electric	$3.50-$4.75/W; $5/W for governments and nonprofits (minimum 10 kW; maximum 200 kW)	2005-2008
Connecticut	Rebate	Residential	Solar electric	$1.75/W for first 5 kW, $1.25/W for next 5 kW (maximum $15,000)	2004-2008
Delaware	Rebate	All	Solar electric	Delmarva customers: 25% installed cost (maximum $31,500 single-unit residential; $250,000 non-residential)‡	2002-2009
Delaware	Rebate	All	Solar heating	Delmarva customers: 25% installed cost (maximum $2,000 residential; $250,000 non-residential)	2002-2009
Hawaii	Personal income tax credit#	All	Solar electric and heating	35% installed cost (single-unit residential maximum: $5,000 for PV; $2,500 for heating; multi-unit residential maximum: $350 per unit)	1994-2005
Maine	Rebate	All	Solar electric	$2/W (maximum 1 kW; $2,000)	2006-2008
Maine	Rebate	All	Solar water and space heating	25% of installed cost (maximum $2,000)	2006-2008
Minnesota	Rebate	Residential	Solar electric	$1.75/W (5 kW maximum) + $0.25/W for using certified installers	2002-2008
New Jersey	Rebate	Commercial	Solar electric	$1.80-$4.10/W (maximum 20 kW)	2001-2008
New Jersey	Rebate	Other	Solar electric	$1.80-$4.10/W (maximum 20 kW)	2001-2008
New Jersey	Rebate	Residential	Solar electric	$1.80-$4.10/W (maximum 20 kW)	2001-2008
New Jersey	Rebate	Residential	Solar electric	$1.55/W (maximum 10 kW) + $0.20/W if perform energy audit	2009-2009
New Jersey	Rebate	Non-residential	Solar electric	$1/W (maximum 50 kW)	2009-2009
Oregon	Personal income tax credit	Residential	Solar electric and heating	$3/W ($6,000 maximum credit for PV or 50% project cost; $1,500 maximum for other solar)	2003-2008
Oregon	Corporate income tax credit	Commercial	Solar heating	50% of system cost (maximum $10 million)	2003-2008
Oregon	Rebate	Residential	Solar electric	$2-$2.25/W (maximum $20,000)	2003-2008
Oregon	Rebate	Commercial and industrial	Solar electric	Up to 30 kW: $1-$1.25/W; 30-200 kW: $0.5-$1/W for Pacific Power customers and $0.75-$1.25/W for PGE customers; more than 200 kW: $0.75/W; site maximum for less than 200 kW: $100,000 for Pacific Power and $600,000 for PGE	2003-2008
Oregon	Rebate	Residential	Solar heating	$0.07-$0.40/kWh saved and $1.50-$6.00/therm saved ($1,500 maximum for water heating, $1,000 maximum for pool heating; 1st year only)	2003-2008

State	Incentive Type	Eligible Sector	Eligible Technology	Current Incentive Amount	Available data
Utah	Income tax credit	All	Solar electric and heating	Residential: 25% of the installed cost (maximum $2,000); Commercial: 10% (maximum $50,000)	1994-2008

Notes: † This analysis considers only the California Solar Initiative. Customers can claim the upfront cash rebate, described here, or claim a 5-year performance-based incentive of $0.39/kwh for the electricity produced by the solar installation. ‡ This analysis considers only rebates utilized by customers of Delmarva Power, the state's investor-owned utility. Technically, the state's rebate program is also available to customers of municipal or cooperative utilities, although no data were available on rebate usage by these customers. # A similar corporate tax credit was enacted in 1990 for commercial, residential, and multi-family residential installations, up to $250,000 for solar thermal and $500,000 for PV installations. Very few credits have been claimed and thus are not evaluated here.
Source: Database of State Incentives for Renewables and Efficiency (DSIRE).

The income tax credits examined here are calculated as a share of the total installed cost, ranging from 25 to 50 percent of the installed cost, with varying limits on the amount that can be claimed. Delaware's rebate program is also cost-based. The other incentives are calculated based on the size of the solar electric installation, ranging from $0.75 per Watt (W) to $5/W. Most of the capacity-based rebates impose limits based either on size of the installation or on the maximum incentive that can be claimed. All of the incentives can be claimed on top of the current federal investment tax credit of 30 percent of the installed cost.

EVALUATION TOOLS

This report employs a two-pronged approach to evaluating the impact of current state incentives. Impact is judged by the extent to which programs achieve three important objectives: (1) encouraging consumer adoption of solar technology; (2) reducing consumer demand for conventional energy; and (3) reducing environmental impacts from energy consumption, such as from air pollution (Webber, 1985).

The first approach estimates the impact of existing incentive designs on the financial viability of photovoltaic (PV) systems to potential consumers. Such an approach simulates the adoption decision made by a consumer who is considering a solar technology purchase.

The analysis uses the Solar Advisor Model (SAM), which was developed by the U.S. Department of Energy to estimate the financial viability of installing a system given inputs about location, the customer's financial situation (i.e., financing characteristics, relevant tax rates), and size, type, and performance of the PV system. Thus, the analysis employs location-specific information on solar availability, electricity prices, tax rates, and available state incentives.

SAM produces two metrics of interest: the net present value (NPV) of the installed system and the levelized cost of energy (LCOE). A positive NPV indicates that the customer's investment would generate enough energy savings over a 30-year analysis period to recoup the initial investment cost. A negative NPV indicates that the customer would lose money over the lifetime of the investment. Customers are not expected to install PV systems without being able to generate a positive NPV. The LCOE is the cost to produce electricity from the solar system (in cents per kilowatt). The LCOE can be directly compared to current electricity rates in the customer's location and to the LCOE of alternative policies, such as weatherization or efficiency programs.

Incentives are identified as potentially effective at stimulating consumer adoption of solar technology if their addition brought the NPV above zero and the LCOE below current electricity prices. Note that the impact of state incentives was evaluated on top of the federal income tax investment tax credit, which is currently set at 30 percent of the installed cost of the system.

The second prong of the evaluation focuses on the observed behavioral response to the availability of state incentives. In general, programs that have experienced a strong response are judged more effective than those that have seen a weaker response.

The question is how to best evaluate response to the incentive. This analysis employs multiple metrics to inform the evaluation. None of the metrics individually is sufficient to gauge impact. Taken together, however, the metrics highlight programs that appear to be performing well and programs that could likely be strengthened.

The first metric evaluated is participation in the program. Which state programs have had the most participants? Participation is difficult to evaluate across states without some benchmark, given that larger states are likely to have more participation, all else equal. For residential programs, cumulative participation is standardized by the total number of housing units in the state as of the latest year program data was available. Similarly, cumulative participation in non-residential programs is standardized by the total number of business establishments in the state as of the latest year program data was available or 2007 (the latest year establishments data was available). Higher participation rates indicate that programs are reaching a larger share of their target audience and are therefore more effective than programs with lower participation rates.

Participation is also evaluated in light of the average program expenditures per participant. Such average costs illustrate the efficiency of the program at delivering incentive benefits to its target recipients. Programs may be more effective than alternatives if they generate participation at a lower cost. The problem with this metric is that it conflates two processes: the efficiency of delivering the incentive and the generosity of the incentive.

Stern, et al. (1985) argued that states with similar incentive designs may have vastly different participation and cost-effectiveness due to differing administration or implementation. While a full analysis of incentive implementation is beyond the scope of this report, the analysis considers whether participation varies by the type of incentive offered, such as tax or cash incentives, which are implemented and funded differently. Participation is also evaluated in light of incentive design characteristics, such as the relative value of the benefits, the longevity of the program, or the class of recipients targeted for the program.

Second, programs are evaluated against the amount of solar technology installed, measured in square feet of collectors for solar thermal or kilowatts (kW) of installed electric capacity for photovoltaics. The impact of state incentives can be illustrated by examining program-related capacity-installed in the context of statewide capacity-installed. Programs that account for a large share of total statewide capacity-additions are effectively reaching motivated solar consumers within their states. The impact of incentives is also illustrated in light of the overall trend of annual statewide installations. Effective programs would produce a noticeable impact on the statewide trend.

Two additional metrics are also evaluated with respect to encouraging solar adoption. First, the average installation size is evaluated, such as the square feet of collectors or kW installed per participant. Second, capacity-installed is evaluated in terms of the expenditures required to achieve such capacity additions, such as the expenditures per Watt installed for the PV programs. These performance metrics should vary by incentive type and the effective value of the incentive to the consumer, as well as the administrative process that is used to provide the benefits.

Finally, programs are evaluated against the two remaining outcomes of interest: the energy savings generated from use of solar technology and the estimated environmental benefits from use of solar technology (such as from reduced air pollution and carbon dioxide emissions). Few programs reported these metrics, but estimates are constructed from available data for the cash incentive programs. The outcomes are assessed in aggregate, as above, as well as standardized by program costs to illustrate the average subsidy required to generate each unit of energy savings or emissions reductions. Such cost-effectiveness metrics can then be compared to alternative policies that achieve similar outcomes (e.g., weatherization programs).

The primary drawback to the analysis conducted here is that we cannot fully attribute all of the installations under the state programs to the presence of the state incentive. In some cases, the marketing of a state incentive successfully alerted consumers to the benefits of solar technology and thereby led directly to the purchase decision. In other cases, the presence of an incentive – possibly combined with other incentives or supportive policies – made the purchase financially viable for the consumer and successfully contributed to the purchase decision. In still other cases, the presence of the incentive had very little to do with the consumer's purchase decision. In the worst cases, the incentive operates as a "windfall" profit for the consumer who would have otherwise made the purchase (Rodberg & Schachter, 1980).

Indeed, other factors may be powerful motivators for consumers rather than incentives, such as the available solar resource, high or volatile energy prices, or the presence of alternative energy policies. Few states survey incentive claimants to determine whether the presence of the incentive accounted for their purchase. One recent evaluation for Wisconsin found that the state incentives successfully motivated a large share of the PV installations (Goldberg, Tannenbaum, Dunn, & Jones, 2009). However, the evaluation also found that a large share of the solar thermal installations, especially the ones displacing natural gas heating, would have been done without the incentive. Lacking similar survey data for each program here, this evaluation relies on inferences based on other empirical evidence or logical explanation in light of other possible motivations. The next section reviews possible motivations besides incentives that may influence program impact.

4 - FACTORS INFLUENCING SOLAR MARKETS

This section reviews the adoption of solar technology within the selected states, as well as factors besides incentives that likely influence variation in statewide adoption (see Table 2, Table 3, and Table 4). These factors are used both to provide context and because the factors may also influence the impact of program incentives, described later. The relationships outlined here were identified using simple statistics, including Pearson correlation coefficients and one-way analysis of variance (ANOVA) tests. The factors are considered in isolation and do not provide evidence of causation. Future analysis will employ a more robust, multiple regression model of statewide solar adoption over time as a function of incentives and the other factors described here.

The ten selected states include mature, underdeveloped, and weak solar markets (see Table 2). Arizona, California, Connecticut, Hawaii, New Jersey, and Oregon all rank in the top 10 states nationally for solar thermal shipments and grid-tied photovoltaic (PV) capacity installed.[1] (In many ways, California is an outlier because has substantially more solar market development and a much larger population than any of the other states in the analysis.) The other states have some combination of deployment across the two technologies, such as Delaware with less-developed solar thermal markets but stronger PV markets. Alternatively, Maine has a relatively strong solar thermal market when viewed on a per capita basis, but a less-developed PV market. Minnesota and Utah have moderate deployment of both solar technologies.[2] Major solar markets that are missing from the sample include Florida (strong for solar thermal) and Nevada (strong for PV).

Table 2. Installed Solar Capacity in the Selected States

State	Solar Thermal Shipments	Rank	Per Capita Solar Thermal Shipments	Rank	Cumulative Installed Grid-Tied PV	Rank	Per Capita Installed Grid-Tied PV	Rank
Arizona	9,087	3	1.40	4	25.3	5	3.89	6
California	52,804	2	1.44	3	528.3	1	14.37	1
Connecticut	2,426	10	0.69	7	8.8	8	2.51	7
Delaware	53	44	0.06	28	1.8	19	2.06	8
Hawaii	4,880	5	3.79	2	13.5	7	10.48	3

[1] Not all solar thermal shipments to the state may have been installed within the state, although systematic bias is not expected in the amount installed out-of-state.

[2] The author believes that the PV data for Utah is missing from 2003-2008, and thus the cumulative numbers understate the total amount installed in Utah. Statewide grid-tied PV adoption data was obtained from by personal communication with Larry Sherwood at the Interstate Renewable Energy Council. Sherwood's data shows no grid-tied PV installed in Utah since 2003, even though the state continued to receive PV tax credit claims in all years since 2003. It is possible that the earlier tax claims for PV were for grid-tied installations and none of the more recent claims have been. It seems more plausible that the grid-tied PV data for Utah are incomplete. Other states also appear to be missing PV data from recent years, including Idaho, Iowa, Michigan, New Hampshire, and Virginia. Such potential data problems limit statistical analysis using the Sherwood PV data and are one reason why the report recommends a more concerted effort by state energy offices to track solar installations by year. The EIA has begun to track photovoltaic shipments, as it does solar thermal, with complete data beginning in 2007.

State	Solar Thermal Shipments	Rank	Per Capita Solar Thermal Shipments	Rank	Cumulative Installed Grid-Tied PV	Rank	Per Capita Installed Grid-Tied PV	Rank
Maine	395	23	0.30	10	0.3	29	0.23	22
Minnesota	509	22	0.10	22	1.0	23	0.19	24
New Jersey	5,008	4	0.58	8	70.2	2	8.09	4
Oregon	3,401	6	0.90	6	7.6	9	2.03	9
Utah	129	35	0.05	34	0.2	31	0.07	29
U.S.	182,251		0.60		791.7		2.60	

Notes: State rankings listed in parentheses, with 1 indicating the state with the largest value of all 50 states and the District of Columbia, and 51 indicating the lowest value.
Sources: shipments of solar thermal collectors (thousands of square feet) from 1986 through 2007 from Yvonne Taylor, U.S. Department of Energy (data on shipments for 2008 should be published in November 2009); cumulative installed grid-tied PV capacity (MW) through 2008 from Larry Sherwood, Interstate Renewable Energy Council; per capita solar thermal shipments (square feet) and installed PV capacity (Watts) were calculated using the state's 2008 population from the Bureau of Economic Analysis, *Regional Economic Information System*.

The extent of solar development within a state depends in large part on its size (see Table 3). Larger states tend to have more solar thermal shipments and PV installations because they have more potential customers. The selected states vary in population size from nearly 37 million residents in California (by far the largest in the sample) to less than 1 million residents in Delaware. Because the relationship between adoption and population is so strong across the sample, program performance metrics are presented on an aggregate basis and standardized for households or incentive recipients.

Table 3. Population, Income, Energy Prices, and Energy Self-Sufficiency in the Selected States

State	Population	Rank	Per Capita Income	Rank	Average Electricity Price	Rank	Average Natural Gas Price	Rank	Energy Self-Sufficiency	Rank
Arizona	6,500,180	14	32,953	43	10.69	22	23.94	7	35%	26
California	36,756,666	1	42,696	12	14.91	12	9.41	50	34%	27
Connecticut	3,501,252	29	56,248	2	20.20	2	18.46	20	23%	33
Delaware	873,092	45	40,852	17	13.96	13	24.33	4	1%	50
Hawaii	1,288,198	42	40,490	18	22.91	1	40.09	1	5%	48
Maine	1,316,456	40	35,381	34	15.47	9	19.35	18	34%	28
Minnesota	5,220,393	21	42,772	11	10.06	29	10.27	49	17%	40
New Jersey	8,682,661	11	50,919	3	16.41	7	17.32	25	13%	43
Oregon	3,790,060	27	35,956	32	8.69	39	17.97	22	36%	25
Utah	2,736,424	34	30,291	50	8.50	42	9.15	51	135%	11
U.S.	304,059,724		39,751		11.55		14.84		70%	

Notes: State rankings scored from 1 for the state with the largest value of all 50 states and the District of Columbia, to 51 indicating the lowest value.
Sources: Population and per capita personal income ($) for 2008 from the Bureau of Economic Analysis, Regional Economic Information System; average electricity price (cents per kWh) for residential users for July 2009 from the Department of Energy, *Electric Power Monthly*; average natural gas price ($ per thousand cubic feet) for residential users for July 2009 from the Department of Energy, *Natural Gas Monthly*; energy self-sufficiency calculated as the ratio of the total energy produced in the state (trillion btu) to the total energy consumed in the state (trillion btu) in 2007 from the Department of Energy, *State Energy Data System*.

States with higher average incomes tend to have more solar deployment even without incentives because more people are able to afford the technology or because their governments have more capacity to support solar technology (see Table 3). The sample states span nearly the entire income spectrum, with average per capita incomes ranging from over $50,000 in Connecticut to $30,000 in Utah. Six of the selected states have per capita incomes higher than the national average, including

California, Connecticut, New Jersey, Minnesota, Delaware, and Hawaii. The relationship between income and solar deployment is more evident for PV than for solar thermal in this sample, which makes sense because PV systems are considerably more expensive than solar thermal systems.

States with higher electricity or natural gas prices tend to have more solar installations, due to the larger potential energy savings that might be obtained by installing a solar system in these states (see Table 3). Energy prices exhibited some of the strongest effects on solar deployment or energy conservation in previous impact studies (Lazzari, 1983). Average electricity prices for residential customers range from a high of 22.91 cents per kWh in Hawaii to a low of 8.50 cents per kWh in Utah. Average natural gas prices for residential customers also vary from a high of $40.09 per thousand cubic feet in Hawaii to $9.15 per thousand cubic feet in Utah. Six states have higher electricity prices than the national average and seven states have higher natural gas rates than the national average. Weak solar deployment in Utah and Minnesota likely reflects their low energy prices. California has an unexpectedly strong solar market given its low natural gas rates, although the size of its solar market is more in-line with what is expected from its higher electricity rates. California's strong solar market may also be expected if one considers its high peak electricity prices rather than average electricity prices, or takes into account high costs for transmission and distribution (Borenstein, 2008).

States that need to import energy tend to have stronger solar deployment (Sawyer, 1984) (see Table 3). Indeed, only Utah produces more energy than its residents consume and the state has weak solar deployment even on a per capita basis. The remaining states all must import energy to meet their needs. Delaware and Hawaii are both severely reliant on energy imports and thus may be the most susceptible to supply disruptions and price fluctuations. Connecticut, New Jersey, and Minnesota also produce less than 20 percent of the energy consumed in their states. Minnesota has a smaller solar market than might be expected given its dependence on imports, although likely in keeping with its colder and wetter weather (which are not good conditions for solar).

States with better solar resources have more solar installations (see Table 4). It takes a smaller size solar system (i.e., a cheaper system) in these states to generate the same amount of energy as in locations with less solar resources. Solar resources are also stronger in states with higher demand for pool heating, such as in Florida and the American Southwest, which can be offset by relatively inexpensive solar thermal pool heaters. Arizona has the best average solar resource in the sample, followed by California, Hawaii, and Utah.[3] New Jersey, California, Hawaii, and Arizona all have stronger solar markets than might be expected based on their solar resources alone. Deployment in California, Hawaii, and Arizona all make more sense when also considering their milder climates (California and Hawaii) and

[3] The solar resource is classified according to the average amount of solar radiation received per unit area. Alaska is classified as "moderate," receiving less than 3,000 Watt-hours per meter-squared (Wh/m^2) of radiation. Thirty-four states are classified as having "good" resources and receive between 4,000 and 4,999 Wh/m^2. Fourteen states have "very good" resources, receiving between 5,000 and 5,999 Wh/m^2. Only two states have "excellent" resources (Arizona and New Mexico) with levels greater than 6,000 Wh/m^2. Southern California also has excellent solar resources, but the state as a whole averages lower. http://www.nrel.gov/gis/solar.html

pool heating demand (Arizona). Conversely, Utah has less solar deployment than expected given its "very good" solar resource.

Table 4. Solar Resource and Supportive Policies in the Selected States

State	Solar Resource	Adopted Net Metering	Adopted Renewable Portfolio Standard (RPS)	RPS Design	RPS Solar-Specific Provisions
Arizona	Excellent	2008	2006	15% by 2025 (investor-owned utilities)	4.5% from distributed resources by 2012
California	Very Good	1995	2002	20% by 2010	None
Connecticut	Good	1998	1998	20% by 2020 (Class I)	None
Delaware	Good	1999	2005	20% by 2019	2.005% solar by 2019 (1.2% by 2010); multiplier for customer-sited PV
Hawaii	Very Good	2001	2004	40% by 2030	None
Maine	Good	1998	1999	40% by 2017(10% new Class I)	None
Minnesota	Good	1983	1994	30% by 2020 (Xcel); 25% by 2025 (others)	Not to exceed 1% RPS requirement
New Jersey	Good	1999	1999	22.5% by 2021	2.12% solar by 2004
Oregon	Good	1999	2007	25% by 2025 (large utilities)	0.04% solar by 2013; multiplier for solar RECs
Utah	Very Good	1999	2008	Non-binding goal of 20% by 2025	None

Sources: solar resource category from the National Renewable Energy Laboratory; DSIRE.

States with net metering should have stronger PV markets than states without net metering. Only six states nationwide do not offer net metering, and all six states have very weak solar deployment (Alabama, Alaska, Kansas, Mississippi, South Dakota, and Tennessee). Net metering allows the customer to receive a payment from their utility for the excess electricity produced (i.e., production net of consumption) from renewable technology such as PV. All of the sample states have adopted some form of net metering (see Table 4). Minnesota adopted net metering in 1983, many of the states adopted 1996-1999, with Arizona adopting most recently in 2008. While we expect that states with net metering in effect for a longer period would have stronger PV markets, such a relationship is weak in the sample.

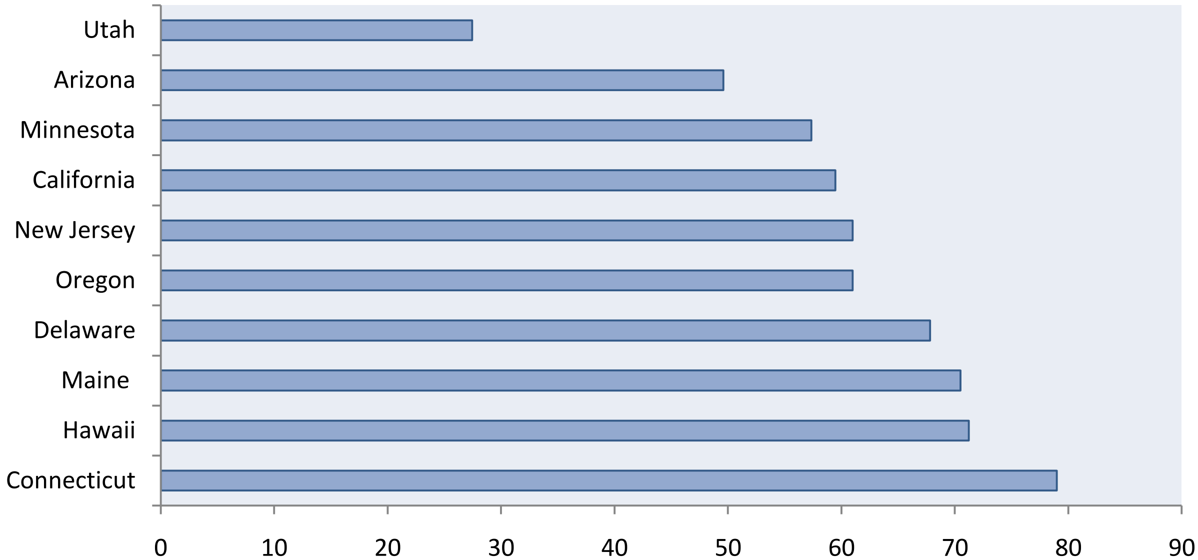
The impact of net metering on solar deployment may have much to do with its design. A few states pay customers directly each month based on the excess produced (i.e., Minnesota pays its customers the retail rate for electricity; Michigan pays its consumers the wholesale rate; Ohio, New Mexico, and North Dakota pay its customers the amount it would have cost the utility to produce an equivalent amount of power). The remaining states with net metering allow the customer to roll-over any excess electricity produced onto later bills. A problem arises when the amount rolled-over is not consumed by the end of the year, such as when the customer consistently produces more than it generates. In several states in the sample, the customer forfeits the excess without receiving compensation (i.e., California, Delaware, Hawaii, Maine, Utah), proving to be a disincentive for customers consistently generating excess electricity.

States with a renewable portfolio standard (RPS) that has a specific solar provision should also have stronger solar deployment than states without a solar-specific RPS. An RPS requires utilities to obtain a portion of their electricity sales from renewable sources, including solar technologies, by a designated date. All of the sample states have some form of RPS (see Table 4). The RPS provisions range from a non-binding goal in Utah up to binding requirements of 40% of electricity sales in Maine and Hawaii. Given the high costs of solar technology, utilities generally try to meet their RPS requirements with lowest-cost renewable resources, such as hydropower or wind. To encourage solar power despite its high cost, four of the selected states have provisions specific to solar technologies. Delaware and New Jersey both require about 2% of total electricity sales to come from solar resources, and Arizona and Oregon give extra credit for electricity produced by customer-sited solar installations.

Utilities typically satisfy their RPS requirements through renewable energy certificates (RECs; generally in 1 MWh increments). They can either produce the required amount themselves or purchase RECs from other generators. When utilities cannot produce or purchase enough renewable energy required by the RPS, they may meet their RPS requirements through alternative compliance payments (ACPs). In addition, utilities may pay the ACP if they cannot produce or purchase renewable energy at a cost that is less than the ACP. Thus, the RPS requirements are more likely to be met with new renewable capacity in instances where the ACPs are high. Some states with solar-specific provisions may also have higher ACPs for solar, such as in New Jersey with $50/MWh general ACPs and $711/MWh solar ACPs (2008-2009 compliance year).

Finally, interest in adopting solar technology (as well as solar supportive policy) may be driven also by the environmental consciousness or attitudes of the states' residents. Many measures of citizen attitudes have been developed. One promising measure estimates that ideological position of Congressional members from each state as well as all candidates running in state elections. The assumption is that the ideological position of candidates represents the ideological position of their supporters. Thus, this measure considers both the ideology of citizens voting for successful candidates and the ideology of citizens voting for unsuccessful candidates (Berry, Ringquist, Fording, & Hanson, 1998). Higher scores indicate more liberal ideology, which would be assumed to be more supportive of solar policy. Indeed, the states with some of the most generous solar incentives score high on this scale of citizen liberalism, with Connecticut the most liberal state in the sample (see Figure 1). Utah scored quite low by contrast, and has relatively weak solar deployment and small solar financial incentives despite its good solar resources.

Figure 1. Average Citizen Liberalism, 1960-2006



Source: Berry, Ringquist, Fording, and Hanson (1998); updated by Richard Fording, University of Kentucky (http://www.uky.edu/~rford/stateideology.html).

The above discussion indicates that different factors appear to drive solar deployment in different states. In a general sense, the factors discussed here intuitively account fairly well for the variation in solar market development across states. Consider the following states:

- Arizona has a well-established market that has steadily grown over time in pace with its population growth and with what might be expected in a location with excellent solar resources and with high natural gas prices. Such a strong market has developed despite the state's lower per capita income and citizen ideology scores.
- California and Hawaii have well-established markets, growing faster even than population and following what might be expected in locations with very good solar resources and high electricity prices. Consumers in Hawaii may have turned to solar technology to improve energy self-sufficiency, while consumers in California may have turned to solar to counterbalance price volatility in local electricity markets. Both states have strong incentives consistent with the factors presented here.
- Connecticut and New Jersey have relatively well-established solar markets with strong recent growth in keeping with high electricity prices, high per capita income, low in-state energy production, early and strong RPS provisions, and a liberal citizenry.
- By contrast, Minnesota and Utah do not have many conditions favoring solar power, and indeed have experienced weak solar deployment.

The remaining three states have stronger solar deployment than might be expected based on the factors presented here:

- Oregon has a stronger solar market than might be expected based on its average population size, average per capita income, low electricity prices, average natural gas prices, only moderate solar resource, relatively late RPS adoption, and moderate liberalism.
- Maine and Delaware have small solar markets but have experienced strong recent deployment on a per capita basis (Maine for solar thermal, Delaware for PV). Both states have higher than average electricity and natural gas prices and a liberal citizenry, but only moderate solar resources. Delaware's recent solar growth may reflect a desire to improve the state's energy self-sufficiency.

An important remaining question is how financial incentives contribute to a state's solar market development. Incentives may be one reason why Oregon, Maine, and Delaware have stronger markets than otherwise expected. Incentives may have worked in concert with other factors to drive market development in Arizona, California, Hawaii, Connecticut, and New Jersey.

5 - ILLUSTRATING THE INCENTIVE IMPACT ON PV FINANCIALS

Consumer choice theory suggests incentives should be designed to reflect the amount that is needed to make solar investments cost-effective for the consumer, given the price of solar technology, solar resource availability, and conventional energy prices. In reality, the incentives are also designed to reflect available financial resources and administrative capacity within the state to incentivize the production of energy from solar technology. Thus, it is not surprising that states have widely varying solar incentive designs as seen in Table 1. The question is whether the state incentives as currently designed are able to effectively incentivize consumer adoption of solar technology in their states.

This section examines the impact of incentives on the financial viability of two hypothetical PV systems installed in different locations throughout the country, evaluated using the Solar Advisor Model produced by the National Renewable Energy Laboratory. The analysis keeps all inputs the same except for variation due to location, local electricity prices, state income tax rates, and available incentives (see Table 5 for inputs). The analysis aims to determine the magnitude of the impact posed by incentives on the system's 30-year financial viability, as measured by the net present value (NPV) and levelized cost of energy (LCOE) of the investment. Note that this analysis is illustrative only and does not account for differences in installation costs, the availability of other incentives, or the unique financing or tax situations of potential customers.

Table 5. Inputs for Solar Advisor Model

Attribute	Value – Residential	Value – Commercial
System Nameplate Capacity	3.808 kW	199.021
Annual System Degradation	0.5%	0.5%
Availability	100%	100%
Array	Fixed	Fixed
Tilt	@ latitude	@ latitude
Radiation Model	Beam and diffuse	Beam and diffuse
Derate Factor	89.5%	88.5%
Module Output	95.2 W	99.76 W
Module Cost	40 units @ 0.1 kW/unit @ $2.87/W	1995 units @ 0.1 kW/unit @ $2.65/W
Inverter Cost	1 unit @ 4 kW/unit @ $0.56/W	50 units @ 4 kW/unit @ $0.44/W
Total Direct Cost	$18,288.96	$925,406.18
Total Installed Cost	$24,768.96	$995,406.18
Average Installed Cost	$6.50/W	$5/W
Annual Operation & Maintenance Costs	$50/kW-yr	$35/kW-yr
Analysis Period	30 years	30 years
Inflation Rate	2%	2%
Discount Rate (real)	4%	4%
Federal Taxes	28%/yr	35%/yr
State Taxes	Marginal tax rates for personal filers (married filing jointly) with income of $150,000	Marginal tax rates for corporate filers at maximum tax bracket * 65% (Wiser et al., 2009)
Property Taxes	0%/yr	0%/yr

Attribute	Value – Residential	Value – Commercial
Sales Taxes	0%	0%/yr
Insurance	0%	1%
Depreciation		MACRS Mid-Quarter Convention
Financing Terms	100% debt-financed via mortgage at 6% interest for 10 years	100% debt-financed via standard loan at 6% interest for 10 years

This analysis assumes that the upfront installation cost is financed entirely rather than paid in cash, as the financing option is a better buy for the consumer. (Thus, in general, cash-financed systems would need much larger incentives to be cost-effective.) The analysis assumes that the system produces energy that is consumed on-site and no excess electricity is sold back to the grid.

The analysis assumes an installation cost of $6.5/W for the residential system and $5/W for the commercial system. These costs are lower than the total installation costs for many PV installations supported by incentives in 2009, although they reflect the informed judgment of the project's funder (K. Zweibel, personal communication, October 17, 2009).

This analysis uses many of the same financial assumptions employed in Wiser et al. (2009). For residential incentive recipients (assumed to be filing personal tax returns), state cash incentives were assumed to be non-taxable but to reduce the basis for the federal investment tax credit. Cash incentives for commercial recipients were assumed to be taxable by both the federal and state governments but not to reduce the federal investment tax credit basis. State investment tax credits were assumed to be federally taxable income for both personal and corporate filers.

The analysis assumes no property or sales taxes would be due on either the residential or commercial investment. Thus, the results include implicit property and sales tax incentives, especially for states that do require sales or property taxes be paid on solar investments. Future analyses will account for the individual impacts from such property and sales tax incentives.

A comparable tool has not been developed for residential and commercial solar thermal systems. Thus, the analysis is only able to evaluate the impact of incentives on the financial viability of residential and commercial PV installations.

Finally, the results presented here are highly sensitive to the choice of analysis period, inflation and discount rates, and other input parameters. The choices on input values reflect a realistic scenario for a private consumer. Calculations of social net benefits would require different inputs and a useful discussion on social valuation of PV is reported elsewhere (Borenstein, 2008).

SUPPORTING RESIDENTIAL PV

Several states have incentivized the purchase so that it would be financially viable for rational consumers (see Table 6). The most effective residential solar subsidies are offered by California, Connecticut, and Hawaii. The addition of the state incentive to the current federal tax credit in these states pushed the financials well into the black, plus pulled the levelized cost of energy (LCOE) below the current average electricity prices in their states. One would expect the presence of the incentive to be an important motivating factor for consumers in these states.

Note that in California, both the upfront rebate program and the performance-based incentive program generate positive results. In Connecticut, the system is cost-effective both with current incentive levels and previous incentive levels, justifying the state's decision to drop the incentive to $1.75/W (at least for systems costing $6.5/W to install, as modeled here). In Hawaii, however, the residential system would be cost-effective for the consumer even without the state incentive, and thus may represent a "windfall" profit for recipients in the situation modeled here. Even so, the LCOE for the modeled residential system in Hawaii utilizing the federal and state tax incentives is over 20 cents per kWh, which is quite high.

Table 6. Solar Advisor Model Results for Hypothetical Residential System

Location	Average Electricity Prices (cents/kWh)	Capacity Factor (%)	Incentive	Net Present Value ($)	Levelized Cost of Energy (LCOE; cents/kWh)
AZ-Phoenix	10.51	20.2	1-None	-14,402	29.47
AZ-Phoenix	10.51	20.2	2-FITC	-7,397	21.44
AZ-Phoenix	10.51	20.2	3-FITC + SITC (25% up to $1,000)	-6,718	20.67
CA-Los Angeles	14.91	18.4	1-None	-10,826	32.00
CA-Los Angeles	14.91	18.4	2-FITC	-3,821	23.20
CA-Los Angeles	14.91	18.4	**3-FITC + rebate @ $3.50/W**	**+4,377**	12.90
CA-Los Angeles	14.91	18.4	**4-FITC + PBI @ $0.39/kWh for 5 years**	**+6,142**	10.68
CT-Hartford	20.19	14.6	1-None	-9,930	40.62
CT-Hartford	20.19	14.6	2-FITC	-2,926	29.54
CT-Hartford	20.19	14.6	**3-FITC + rebate @ $1.75/W up to $15,000 [current level]**	**+1,232**	22.97
CT-Hartford	20.19	14.6	**4-FITC + rebate @ $5/W [previous level]**	**+8,952**	**10.76**
DE-Wilmington	13.96	15.6	1-None	-14,006	37.97
DE-Wilmington	13.96	15.6	2-FITC	-7,002	27.60
DE-Wilmington	13.96	15.6	3-FITC + rebate @ 25% up to $31,500 [Delmarva customers]	-3,151	21.89
DE-Wilmington	13.96	15.6	4-FITC + rebate @ 33.3% up to $15,000 [municipal and cooperative utility customers]	-1,872	20.00
HI-Honolulu	22.91	18.0	1-None	-3,261	32.71
HI-Honolulu	22.91	18.0	**2-FITC**	**+3,544**	23.72

Location	Average Electricity Prices (cents/kWh)	Capacity Factor (%)	Incentive	Net Present Value ($)	Levelized Cost of Energy (LCOE; cents/kWh)
HI-Honolulu	22.91	18.0	**3-FITC + SITC (35% up to $5,000)**	**+6,938**	**19.38**
ME-Portland	15.47	16.1	1-None	-12,194	36.57
ME-Portland	15.47	16.1	2-FITC	-5,189	26.53
ME-Portland	15.47	16.1	3-FITC + rebate @ $2/W up to $2,000	-3,955	24.76
MN-Minneapolis	10.06	16.2	1-None	-16,822	36.37
MN-Minneapolis	10.06	16.2	2-FITC	-9,785	26.35
MN-Minneapolis	10.06	16.2	3-FITC + rebate @ $2/W	-5,111	19.69
NJ-Newark	16.41	14.9	1-None	-12,603	39.80
NJ-Newark	16.41	14.9	2-FITC	-5,598	28.93
NJ-Newark	16.41	14.9	3-FITC + rebate @ $1.55/W [current level]	-1,922	23.23
NJ-Newark	16.41	14.9	**4-FITC + rebate @ $4.10/W [previous level]**	**+4,125**	13.85
OR-Portland	8.69	12.9	1-None	-19,483	45.55
OR-Portland	8.69	12.9	2-FITC	-12,478	33.03
OR-Portland	8.69	12.9	3-FITC + SITC ($3/W up to $6,000)	-8,406	25.75
OR-Portland	8.69	12.9	4-FITC + SITC + rebate @ $2.25/W up to $20,000	-3,131	16.32
UT-Salt Lake City	8.50	17.5	1-None	-17,656	33.85
UT-Salt Lake City	8.50	17.5	2-FITC	-10,651	24.58
UT-Salt Lake City	8.50	17.5	3-FITC + SITC (25% up to $2,000)	-9,294	22.79

Notes: FITC = federal investment tax credit (30% of the installation cost, no maximum); SITC = state investment tax credit; PBI = performance-based incentive.

Although New Jersey's current rebate is too small to generate positive net benefits, the previous level that the state offered ($4.1/W) would have been enough to make this a good investment for the consumer and to bring the LCOE below current electricity prices. It is not surprising the state could no longer afford to maintain such generous rebates, but in the absence of such large incentives residential consumers may have difficulty affording solar PV systems in New Jersey.

None of the other state incentives were large enough to make the hypothetical residential system a financially viable investment. Utah and Arizona currently offer the smallest state incentives, leaving the largest financial burden on the consumer. With such small incentives, the consumers in these states that do install PV systems of this size must be making decisions based on other factors besides the current state incentive. For instance, consumers may make up the difference using a utility-sponsored rebate. In Arizona, utility-sponsored incentives have so far supported nearly 1,500 installations of almost 10 MW of PV capacity, at an average installed cost of $7.3/W.[4]

SUPPORTING COMMERCIAL PV

Six of the states successfully incentivized the hypothetical commercial installation evaluated here, including California, Connecticut, Hawaii, Maine, New Jersey, and Oregon (see Table 7). Hawaii is the only state that successfully finances incentives of this size out of tax expenditures; the other state incentives are paid out of public benefits funds or through the private sale of solar renewable energy credits (SRECs), as in New Jersey (described in more detail below). In Hawaii, the commercial installation would also be a good investment even without the state incentive and may represent a "windfall" profit to consumers purchasing systems under the conditions modeled here. By contrast, Oregon also has a state tax incentive, although installations in Portland of this size would only be cost-effective with the addition of the state rebate to the federal and state tax incentives.

Table 7. Solar Advisor Model Results for Hypothetical Commercial System

Location	Average Electricity Prices (cents/kWh)	Capacity Factor (%)	Incentive	Net Present Value ($)	Levelized Cost of Energy (LCOE; cents/kWh)
AZ-Phoenix	9.22	19.6	1-None	-421,300	16.57
AZ-Phoenix	9.22	19.6	2-FITC	-189,074	11.33
AZ-Phoenix	9.22	19.6	3-FITC + SITC (10% up to $25,000 per building)	-173,755	10.98
CA-Los Angeles	13.54	17.7	1-None	-311,994	18.02
CA-Los Angeles	13.54	17.7	2-FITC	-80,781	12.25
CA-Los Angeles	13.54	17.7	**3-FITC + PBI @ $0.22/kWh for 5 years**	**+92,920**	**7.93**
CT-Hartford	15.67	14.1	1-None	-349,682	22.93
CT-Hartford	15.67	14.1	2-FITC	-117,793	15.65
CT-Hartford	15.67	14.1	**3-FITC + grant @ $3.50/W up to $850,000**	**+250,013**	**4.10**
DE-Wilmington	12.07	15.0	1-None	-412,380	21.25
DE-Wilmington	12.07	15.0	2-FITC	-181,168	14.45
DE-Wilmington	12.07	15.0	3-FITC + rebate @ 25% up to $250,000	-51,355	10.64
HI-Honolulu	20.46	17.4	1-None	-117,122	18.69
HI-Honolulu	20.46	17.4	**2-FITC**	**+115,357**	**12.80**
HI-Honolulu	20.46	17.4	**3-FITC + SITC (35% up to $500,000)**	**+328,833**	**7.38**

[4] Data on utility-supported PV installations were obtained from the National Renewable Energy Laboratory's Open PV Project (http://openpv.nrel.gov/).

Location	Average Electricity Prices (cents/kWh)	Capacity Factor (%)	Incentive	Net Present Value ($)	Levelized Cost of Energy (LCOE; cents/kWh)
ME-Portland	12.75	15.5	1-None	-384,157	20.59
ME-Portland	12.75	15.5	2-FITC	-153,028	14.00
ME-Portland	12.75	15.5	**3-FITC + PBI @ $0.10/kWh for 20 years**	**+28,668**	**8.82**
MN-Minnesota	7.92	15.6	1-None	-506,475	20.29
MN-Minnesota	7.92	15.6	2-FITC	-275,853	13.76
MN-Minnesota	7.92	15.6	3-FITC + SITC ($2/W up to $20,000)[5]	-265,532	13.47
NJ-Newark	14.50	14.4	1-None	-365,537	22.20
NJ-Newark	14.50	14.4	2-FITC	-134,493	15.08
NJ-Newark	14.50	14.4	**3-FITC + SREC @ $0.47/kWh for 15 years (falling 2.5% each year)**	**+451,703**	**-2.96**
OR-Portland	7.89	12.5	1-None	-558,695	25.76
OR-Portland	7.89	12.5	2-FITC	-326,975	17.57
OR-Portland	7.89	12.5	3-FITC + SITC (50% cost up to $10,000,000)	-22,010	6.78
OR-Portland	7.89	12.5	**3- FITC + SITC + rebate @ $0.50/W up to $100,000 [Pacific Power customers]**	**+30,375**	**4.93**
OR-Portland	7.89	12.5	**4- FITC + SITC + rebate @ $0.75/W up to $600,000 [PGE customers]**	**+56,568**	**4.01**
UT-Salt Lake City	7.01	16.8	1-None	-538,216	19.56
UT-Salt Lake City	7.01	16.8	2-FITC	-304,977	13.44
UT-Salt Lake City	7.01	16.8	3-FITC + SITC (10% up to $50,000)	-274,339	12.64

Notes: FITC = federal investment tax credit (30% of the installation cost, no maximum); SITC = state investment tax credit; PBI = performance-based incentive; SREC = solar renewable energy credit.

Connecticut and New Jersey currently offer incentives that could generate large net benefits and a cost-competitive LCOE. Such high incentive levels are unlikely to continue in the future. Both states have already cut back their incentives substantially this year. Note that the Connecticut grant is a typical capacity-based incentive of $3.50/W up to $850,000, while the New Jersey incentive is delivered through the new SREC program described in more detail below. The incentive value used here is based on current 2009 SREC prices of $0.49/kWh, and assumes prices will fall by 2.5% each year over the 15 years that customers can participate in the program. This approach likely overestimates the incentive value, as the customers do not sign contracts for power production at current levels for the full 15 years.

[5] Minnesota's commercial incentive is intended for small systems below 10 kW, although larger systems are eligible.

Instead, credit for the solar production is issued as it is generated, and would be subject to SREC prices at that time. Presumably, prices will fall over time as more solar generation technology comes on-line.

Maine proposed a new community-based performance-based incentive (PBI) of a maximum of $0.10/kWh for 20 years, which is currently under consideration. Such a PBI would be sufficient to make this large commercial installation a good investment for rational consumers, indicating that the state has likely set an appropriate PBI level. The challenge will be if the state can afford to pay out such generous benefits for 20 years, which requires a sustained funding commitment (as in California) as opposed to the more common rebates or tax incentives.

The remaining states do not currently offer large enough state incentives to make this large commercial installation a viable investment. In Minnesota and Utah, the 30-year net costs to the customer are more than $200,000. In Arizona, net costs reach almost $100,000 despite the state’s excellent solar resources, which generates a high capacity factor of 19.6 percent (i.e., the amount of electricity produced from the technology’s rated capacity). Rational consumers are only likely to invest in this hypothetical commercial system in these states if they could find other financial incentives to make up the difference (such as rebates offered by utilities).

Note that consumers may have many other reasons for investing in solar systems besides earning a return on their investment, such as the desire to “go green.” In general, however, consumers are not expected to invest in an expensive technology like solar unless the benefits that they derive – financial or otherwise – would be sufficient to overcome the high upfront costs of the system.

6 - INCENTIVE IMPACT ON CONSUMER ADOPTION

One of the primary goals of solar incentive programs is to encourage consumer adoption of solar technology. This section reviews key performance metrics regarding program participation to illustrate the impact on consumer adoption, on the assumption that at least some of the participants in the program are making purchase decisions in response to the program incentive. The metrics are considered in light of key attributes of incentive design, funding, or implementation. Program performance is also considered in light of the maturity of solar markets and other factors that likely influence solar deployment, as discussed above.

PROGRAM PARTICIPATION

Participation has been increasing annually for most of the studied programs, with notable gains in participation in recent years in several of the programs. Even so, these incentives reach very few consumers. For instance, only three state programs have more than 10,000 participants overall and 1,000 annual participants (California's rebate, and Arizona's and Hawaii's tax credit).[6] Together, all of the studied programs have reached 80,000 consumers, of which 97 percent were for residential installations (see Table 8). The programs with the most participants were all residential programs and were in states with well-established solar markets.

Table 8. Cumulative Participation, Expenditures, and Average Expenditures in Selected State Incentive Programs

State	Incentive	Eligible Sector	Eligible Technology	Cumulative Participation	Cumulative Expenditures†	Average Expenditures per Recipient
AZ	Income tax	Residential	All	17,066	$7,662,536	$449
CA	Rebate	Nonresidential	PV	1,306	$431,100,000	$330,092
CA	Rebate	Residential	PV	20,754	$191,800,000	$9,242
CT	Grant	Nonresidential	PV	78	$41,368,585	$530,366
CT	Rebate	Residential	PV	529	$11,925,483	$22,543
DE	Rebate	Nonresidential	PV	49	$5,607,188	$114,432
DE	Rebate	Residential	PV	184	$3,741,926	$20,337
DE	Rebate	Residential	Water heating	16	$40,815	$2,551
HI	Income tax*	Residential	All	26,239	$61,373,176	$2,339
ME	Rebate	All	PV	76	$410,128	$5,396
ME	Rebate	All	Space heating	23	$18,928	$823
ME	Rebate	All	Water heating	347	$621,749	$1,792
MN	Rebate	All (73% residential)	PV	228	$1,718,589	$7,538
NJ	Rebate	Commercial	PV [previous]	430	$104,381,633	$242,748
NJ	Rebate	Nonresidential	PV [current]	24	$439,188	$18,300

[6] 2007 was the latest year that the majority of programs reported participation. These counts do not include income tax programs in Arizona or Hawaii, which both had more than 1,000 annual participants as of the latest year that data was available (2004 for Arizona, 2005 for Hawaii).

State	Incentive	Eligible Sector	Eligible Technology	Cumulative Participation	Cumulative Expenditures†	Average Expenditures per Recipient
NJ	Rebate	Other non-residential	PV [previous]	279	$70,050,525	$251,077
NJ	Rebate	Residential	PV [current]	244	$3,106,243	$12,731
NJ	Rebate	Residential	PV [previous]	3,242	$117,522,671	$36,250
OR	Rebate	Nonresidential	PV	239	$4,978,997	$20,833
OR	Rebate	Nonresidential	Water heating	47	$149,292	$3,176
OR	Rebate	Residential	PV	675	$5,488,676	$8,131
OR	Rebate	Residential	Water heating	655	$703,630	$1,074
UT	Income tax	All (94% residential)	All	583	$1,227,360	$1,598#
ALL	ALL	ALL	ALL	73,313	$1.1 billion	$14,533

Notes: † all expenditures adjusted to 2008 dollars using the Consumer Price Index – Urban. ‡ Unable to estimate; tax credit maximum is $500 and it looks like most recipients are claiming the full credit. # for single-family residential only. * Solar-only participants and expenditures were estimated backwards for 1994-2003 using data that separated claims by technology from 2004-2005 (67% of participants and 74% of expenditures).
Sources: State budget and program documents; author's calculations.

Income tax incentives had greater participation than the grant/rebate programs (approximately 44,000 and 30,000 participants, respectively). Income tax incentives tend to be easy to claim for the consumer and are processed using the existing tax apparatus within states, making them relatively easy to implement administratively. In addition, income tax incentives do not require explicit annual budgeting as do most cash incentive programs, and thus tend to be more stable in design and funding levels from year-to-year.

The income tax incentives also are reaching a larger share of potential consumers in the state than the cash incentives, although this result appears to be due to strong participation in Hawaii and Arizona. Hawaii's income tax credit program has had the most extensive participation of any studied incentive, with an estimated 26,000 solar claimants from 1994-2005. These claimants represent 5 percent of the households in Hawaii in 2005, by far the largest share of the studied programs (see Table 9). Hawaii's success owes in part to the fact that the tax incentive has been in place in some form since 1976 and is one of the longest, consistently offered tax incentives among the selected states.

Table 9. Participation in Selected State Residential Incentive Programs

State	Incentive Type	Incentive Data	Cumulative Participants in State Incentive Programs*	Share of State's Households#
Arizona	Income tax	1997-2004	17,066	0.70%
California	Rebate‡	2006-2009	20,754	0.15%
Connecticut	Rebate	2004-2008	529	0.04%
Delaware	Rebate	2006-2009	200	0.05%
Hawaii	Income tax	1994-2005	26,239	5.34%
Maine	Rebate	2005-2007	446	0.06%
Minnesota	Rebate	2002-2009	228	0.01%
New Jersey	Rebate	2001-2009	3,486	0.10%
Oregon	Rebate	2003-2008	1,330	0.08%
Utah	Income tax	1994-2008	583	0.06%

Notes: * program participation compiled across all technologies; # households determined as of the last year incentive data was available (i.e., 2004 for Arizona), assumes each participant represents one household; ‡ includes only participants with completed systems as of July 2009 under California Solar Initiative's rebate program for existing homes.
Sources: state budget and program reports; U.S. Census Bureau, *Annual Population Estimates*.

Program longevity is not the whole story, however, when it comes to participation. Utah's personal income tax incentive, for instance, had far less participation than might be expected given the program's longevity (since 1980) and the "very good" solar resources available in Utah. Instead, the program had just 568 participants from 1994-2008, representing 0.06 percent of Utah's households.

Although adopted more recently, Arizona's income tax program has also generated more participation than all of the other state programs excepting Hawaii's tax program. Even so, Arizona's tax incentive has only been claimed by 17,000 households, which is less than 1 percent of the state's current households. All of the other state incentive programs studied have so far reached far less than 1 percent of their state's households or businesses. Indeed, even the rapidly-growing California Solar Initiative rebate program, with the highest participation of the studied grant and rebate programs (over 20,000 participants since 2006), has reached just 0.15 percent of California households.[7]

By contrast, each state in the sample had at least 1 percent of its federal tax filers claim the federal residential energy investment tax credit (FRETC) in both 2006 and 2007 (see Table 9). Many of the FRETC claims were likely for less expensive energy-saving improvements than for solar technologies. Even so, the share claiming the FRETC plausibly represents the group of motivated, energy-conscious consumers that might invest in solar technology within the state. Only Hawaii's tax credit looks to be reaching its target population to any substantial degree.[8]

Table 10. State Claimants of Federal Energy Tax Credit

State	Claimants of Federal Residential Energy Tax Credit (2007)†	Share of State's Federal Tax Filers (2007)
Arizona	59,842	2.06%
California	267,401	1.52%
Connecticut	82,491	4.42%
Delaware	20,342	4.47%
Hawaii	8,407	1.21%
Maine	27,666	3.79%
Minnesota	117,878	4.31%
New Jersey	173,629	3.79%
Oregon	42,623	2.23%
Utah	38,748	3.26%

Notes: † federal tax credit in 2006-2007 set at 10% of the cost of energy-efficiency improvements up to $500 and 30% of solar investments up to $2,000 (with no credit available for solar pool heating).
Sources: U.S. Internal Revenue Service, *Tax Statistics*.

Similarly, any recent response to state incentives should appropriately be attributed to the combined impact of the state incentive with the federal investment tax credit, rather than to the state incentive by itself. Starting in January 2006, the federal government reinstated an investment tax credit for

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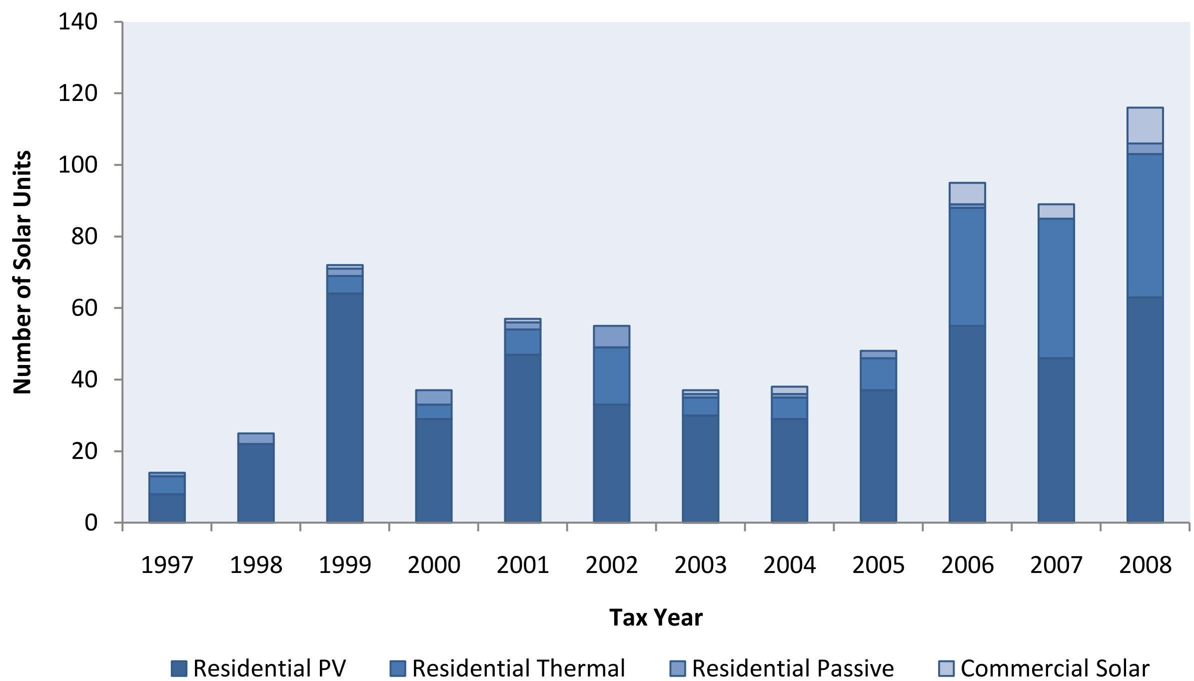
[7] Admittedly, the California Solar Initiative rebate program studied here is only the latest in California's long history of policy experimentation with solar incentives (Margaret Taylor, 2008). For instance, the state had an income tax credit in place for several years just prior to the start of this rebate program and also has had other rebate programs, such as the Self-Generation Incentive Program (which supported PV from 2001-2006).

[8] The average federal tax credit claimed by Hawaii residents in 2007 was $900 (indicating an average installation cost of approximately $3,000), which was much higher than the average claim from residents in all other states.

residential solar installations and raised the maximum allowable credit for non-residential solar systems. In general, projects supported by the state incentives in 2006 and after would also be eligible for the federal incentive. Support for this conclusion also comes from inspection of program participation and solar technology adoption trends within states from 2006 onward.

Consider Utah, which first adopted a renewable energy tax credit in 1980 (see Figure 2). Claims increased noticeably starting in 2006 for both residential and commercial installations. Claims also stayed higher from 2006-2008 than in previous years. Utah's increase from 2006-2008 especially in claims for solar thermal installations makes sense: solar thermal technology is cheaper to install than PV and thus the addition of the federal incentive to the state incentive was likely enough to push motivated consumers into purchasing solar thermal systems. By contrast, the two incentives together were not large enough to make the hypothetical PV system a sound financial investment in Utah, as described above, thus accounting for the smaller response in PV installations. While the state has many fewer commercial claims than residential claims, a clear response in commercial installations can also be seen in 2006-2008 over previous years.

Figure 2. Claims for Utah's Renewable Energy Tax Credit by Technology and Sector, 1997-2008



Source: Utah Geological Survey

As in Utah, participation in all of the state residential programs increased noticeably in 2006 onward. In addition, participation appears up again in the states reporting preliminary data for 2009, which may be a response to the removal of the maximum credit for residential installations. The previous modeling exercise suggested that solar installations would only be financially viable in some of the states after accounting for both the state incentive and the federal incentive.

COST-EFFECTIVENESS AT GENERATING PARTICIPATION

Expenditures on state solar incentive programs vary dramatically across states (see Table 8).[9] For instance, Maine's space heating rebate program spent less than $20,000 over the three years it has been in place, while California's non-residential rebate program spent more than $430 million in just three and a half years.[10] Four rebate programs in the sample spent more than $100 million (both residential and non-residential rebates in California and New Jersey). The largest tax incentive program (in Hawaii) spent approximately $74 million during 1994-2005. Annual expenditures range from less than $10,000 to more than $100 million per year.

Together, the incentive programs have invested more than $1 billion to incentivize purchase of solar systems, of which 60 percent was for non-residential installations. All of the higher spending cash incentive programs were funded through public benefits funds, which get their revenue from surcharges on electricity bills, rather than from state general funds or state "tax expenditures" (avoided tax revenues).

While the income tax incentives had higher total participation than the cash incentives, the tax incentives typically spent far less for each participant than the cash incentives (see Table 8). For instance, average expenditures from the residential tax credits in Arizona fell below $500 per recipient. Average expenditures on residential tax credits were higher in Hawaii and Utah, at around $2,000 per recipient, similar to average rebates for water heating in Maine, Delaware, and Oregon. Almost all the other cash incentive programs were designed for PV systems and had high average expenditures, with Connecticut, Delaware, and New Jersey spending more than $20,000 per residence through their rebate programs. The non-residential incentives in California, Connecticut, Delaware, and New Jersey all averaged more than $100,000 per claim.

Consider if technology costs and purchase behavior were to stay the same as in the past. In that case, the income tax incentives would likely fund substantially more participants than the cash incentive programs. For instance, the residential tax credits in Arizona could fund more than 2,000 recipients with an expenditure of $1 million, while the non-residential rebates in California, Connecticut, and New Jersey could fund fewer than 5 applicants each for the same $1 million expenditure.

Difficulties admittedly plague such a simple exercise. Expenditures are closely tied to the type and size of system installed (i.e., solar thermal vs. PV; residential vs. commercial or industrial). Programs with smaller average expenditures are likely funding smaller and less-expensive systems, such as solar water heaters. Smaller and cheaper systems may be easier to incentivize than larger and more expensive systems. Thus, smaller average expenditures may indicate a smaller amount of solar capacity-installed, not necessarily a more efficient program.

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[9] For more information on the impact of state incentives on the installed cost of PV, see Wiser et al. (2009).

[10] All values in this report are adjusted for inflation to 2008 dollars using the Consumer Price Index- Urban from the Bureau of Economic Analysis.

Technology costs are also declining rapidly, making it difficult to estimate future behavior based on data from previous years. Declining technology costs mean that a consistent level of funding should fund more systems in the future than today, especially with respect to PV systems. Whether expenditures fund more systems in the future, however, depends also on the future stability of the state's incentive design and funding structure.

Economic theory suggests that the value of subsidies should decline as technology prices fall and demand for solar technology naturally increases. The challenge for incentive administrators is to determine when to reduce the incentive value. If the incentive is reduced too fast, the change may inadvertently dampen future adoption of solar technology. On the other hand, the more expensive programs may be unable to continue spending such large sums on each installation as their solar markets develop. Several of these programs have already exhausted available funds and have scaled back availability or maximums on their incentives (e.g., Connecticut, New Jersey). In addition, states like California and New Jersey have tied their future incentive levels to the amount of solar technology installed within the state. Such an approach may work well for states with well established solar markets but work less well in places that have weaker deployment.

CAPACITY INSTALLED

Solar capacity installed is a more direct measure of the extent to which the programs encourage consumer adoption of solar technology than participation. Capacity installed can also be used to construct metrics that evaluate achievement of the other two primary goals of solar incentives: reducing conventional energy demand and reducing the environmental impact of energy use. Unfortunately, capacity installed was not reported for any of the tax incentives and only for one solar thermal incentive.

Delaware's water heating rebate was the only heating incentive to report solar capacity installed. Participants in the Delaware program installed approximately 1,000 square feet of solar collectors from 2006-2009. The majority of these installations were made in 2008 and 2009, reflecting a large increase in installations over 2006 and 2007. While the recent growth shows promise, the capacity installed in 2006-2007 as part of the program comprised just 0.3 percent of the state's solar thermal capacity installed in those years, suggesting the rebate was not reaching many of the state's solar thermal customers in 2006-2007.[11]

The PV incentives all reported capacity installed, allowing more detailed analysis. Together, approximately 363 megawatts (MW) of installed PV capacity was associated with the incentive programs (see Table 11). Installed capacity through the incentive programs ranged from less than 0.5 MW in Maine and New Jersey's new non-residential rebate program to 171 MW in California for its non-residential program and 267 MW when including its residential program. Presumably, the 341 MW of

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[11] 2007 was the latest year with available statewide data on solar thermal shipments. Data for 2008 was expected from the Energy Information Administration in October 2009, but has not been published yet.

PV capacity installed under the studied incentives since 2006, or 97 percent of the total, would also have been eligible for the federal investment tax credit. This means that the impact of the state incentive programs in 2006 and after must be attributed to the combination of the state incentive and the federal tax credit.

Table 11. Cumulative Capacity Installed and Related Metrics for Selected PV Incentive Programs

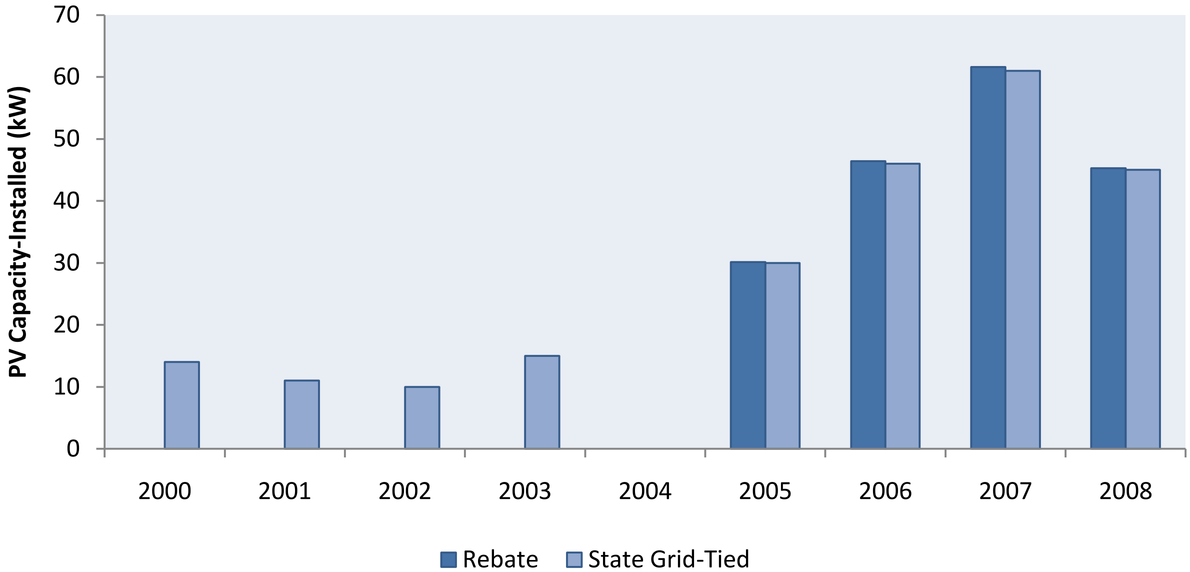
State	Incentive	Eligible Sector	Program Cumulative Capacity Installed (MW)†	Capacity Installed per Recipient (kW)	Average Incentive ($/W)
CA	Rebate	Nonresidential	170.8	130.78	$2.52
CA	Rebate	Residential	96.4	4.64	$1.99
CT	Grant	Nonresidential	10.2	131.27	$4.04
CT	Rebate	Residential	2.8	5.32	$4.23
DE	Rebate	Nonresidential	1.5	31.16	$3.67
DE	Rebate	Residential	1.1	6.16	$3.30
ME	Rebate	All	0.2	2.41	$2.23
MN	Rebate	All (73% residential)	0.9	3.87	$1.95
NJ	Rebate	Commercial	27.1	63.04	$3.85
NJ	Rebate	Nonresidential	0. 4	18.29	$1.00
NJ	Rebate	Other	21.2	76.00	$3.30
NJ	Rebate	Residential	1.8	7.35	$1.73
NJ	Rebate	Residential	23.5	7.26	$5.00
OR	Rebate	Nonresidential	3.0	12.43	$1.68
OR	Rebate	Residential	1.6	2.42	$3.35

Notes: † capacity-installed includes partial data for 2009 for California, Delaware, Minnesota, and New Jersey.
Source: State budget and program documents; author's calculations.

As expected, the average installation size was larger for the non-residential PV programs than for the residential programs (see Table 11). The non-residential programs in California and Connecticut yielded the largest installations, at more than 130 kW per recipient on average. The smallest non-residential installations were in Oregon, at around 12 kW per recipient on average. The largest residential installations were in New Jersey, at around 7.3 kW per recipient, while the smallest residential installations were in Maine and Oregon at 2.4 kW per recipient each. In general, programs with larger average installations are more effectively incentivizing larger systems, and thus more total capacity-installed.

Consumers are responding well to the presence of the state incentives when installing solar systems. For instance, all of the PV capacity installed in 2005-2008 in Maine was associated with the state's rebate program (see Figure 3). The state experienced steady increases in participation and capacity-installed through January 2008, when the state dropped the maximum allowable incentive from $7,000 to $2,000 to accommodate the maximum number of interested participants (Maine State Energy Program, 2009). Even with the drop in incentive available, customers in Maine installed more grid-tied PV in the first half of 2008 than in the full years prior to the incentive.

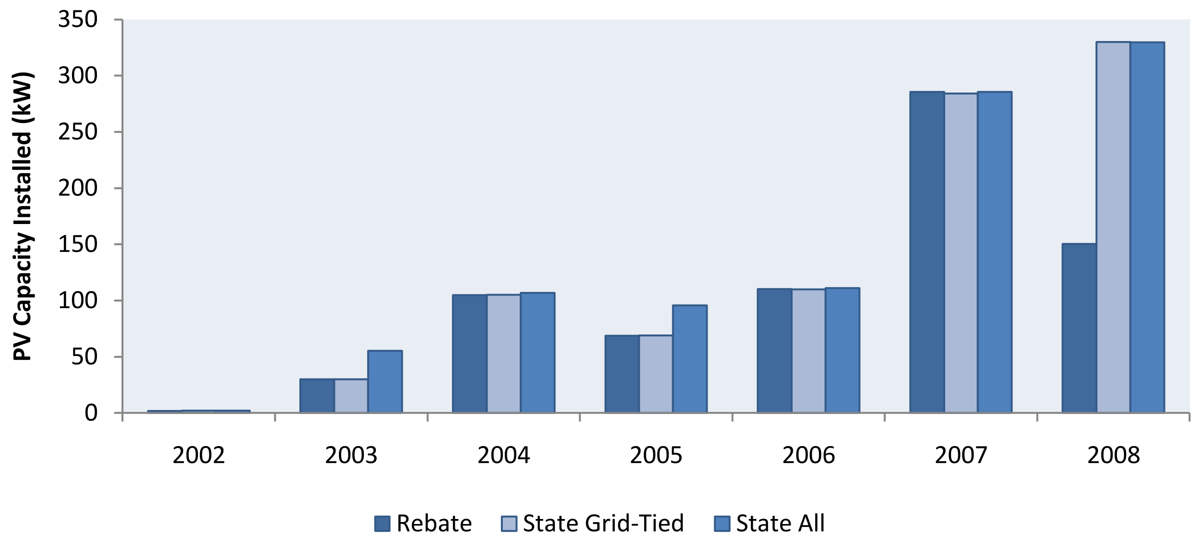
Figure 3. PV Capacity-Installed in Maine, 2000-2008



Note: Data from the rebate program were reported on a fiscal year basis, while grid-tied PV capacity installed was reported on a calendar year basis. The rebate data was adjusted by splitting the installations across the two calendar years (i.e., FY 2006 data split between 2005 and 2006). Therefore, the data for calendar year 2008 reflects only installations from January 1-June 30, 2008.
Sources: Maine State Energy Program; state grid-tied capacity-installed from Larry Sherwood, personal communication, 2009.

The response to the new PV incentives in Minnesota was similarly positive. In fact, program-related PV installations represented the entire state's grid-tied PV capacity-installed in 2002-2007 (see Figure 4). The capacity boost in 2007 reflected larger installations by business and non-taxable entities over previous years. The program ran out of money in 2008 before the full demand for rebates could be met (Minnesota Office of Energy Security, 2009). As successful as the program was in Minnesota, the state did experience notable off-grid PV installations in 2003 and 2005, which were not supported by the rebate. In this case, however, the presence of the rebate program may have indirectly facilitated the off-grid installations due to its effect on growing the number of solar dealers and installers within the state (Mike Taylor & Wolter, 2006).

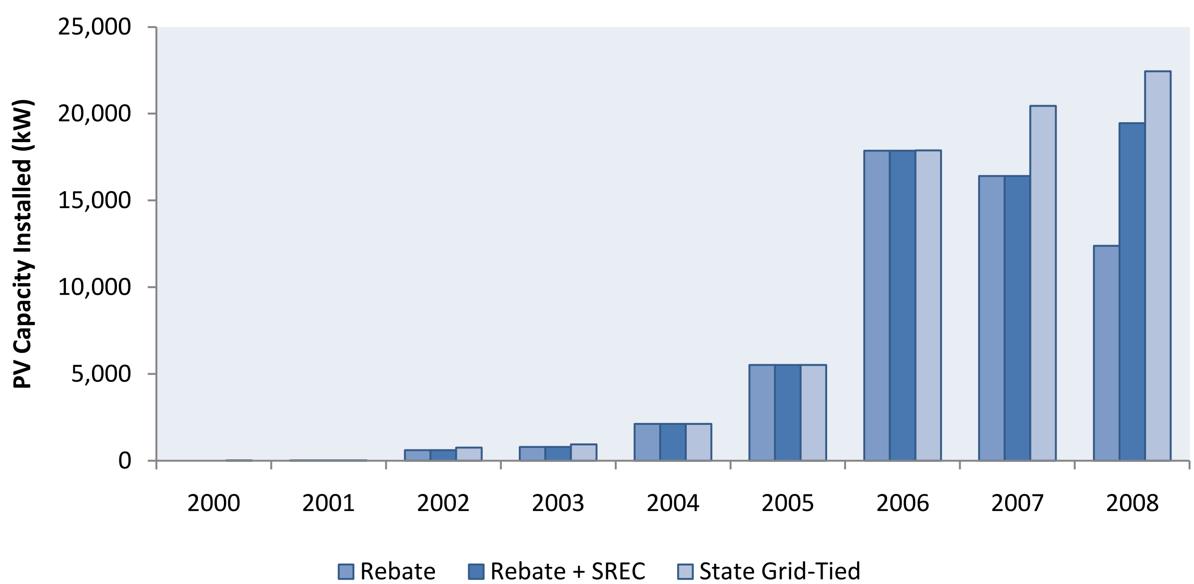
Figure 4. PV Capacity Installed in Minnesota, 2002-2008



Sources: Minnesota Office of Energy Security; state grid-tied from Larry Sherwood, personal communication, 2009.

New Jersey has been extremely successful at stimulating solar deployment, with nearly exponential growth in statewide capacity-installed since it began offering rebates in 2001 (see Figure 5). The state experienced a dramatic jump in rebate applications in 2006, when the combined value of the state rebate and the federal investment tax credit together equaled almost the entire installation cost of the system. The state could not continue to pay out rebates at such high levels in 2007 and 2008, and the amount installed under the rebate program dropped relative to the total capacity-installed statewide.

Figure 5. PV Capacity Installed in New Jersey, 2000-2008

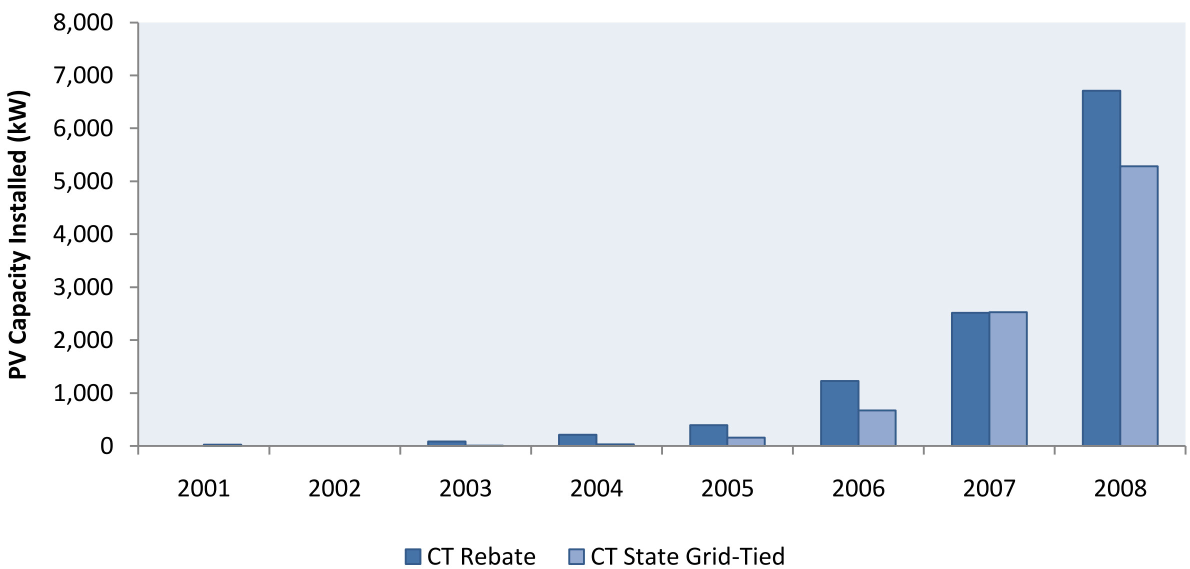


Sources: New Jersey Clean Energy Program; state grid-tied capacity-installed from Larry Sherwood, personal communication, 2009.

New Jersey began to shift away from rebates in late 2007, focusing instead on a new financing arrangement known as solar renewable energy credits (SRECs). SRECs are certificates for solar power that can be traded in a market setting. Residences or businesses producing excess solar power can obtain SRECs and sell them to utilities or other entities. The SRECs are then used to meet the state's strict requirements under its renewable portfolio standard (RPS) that 2.12 percent of electricity sold each year come from solar resources. By fostering a new market for SRECs, the state is able to reduce its financial commitment (as the SRECs are paid by purchasers, not the state) while still benefiting from an increase in solar deployment statewide. Installations associated with SRECs and rebates in 2008 together accounted for 86 percent of the statewide grid-tied PV capacity-installed. Much of the remainder came from 3.5 MW of electricity generation capacity that was installed from 2006-2008 at the Pennsauken Solar Plant in Camden, NJ and at the Atlantic City Convention Center.[12]

PV capacity also grew nearly exponentially in Connecticut after the state began offering generous rebates in 2003 (see Figure 6). The rebate program funded more capacity-installed than the state reported for grid-tied capacity in all years excepting 2007, indicating that some of the rebates were funding off-grid installations (which are not tracked systematically by state). Such strong growth suggests that the Connecticut rebates have been highly successful at stimulating PV deployment.

Figure 6. PV Capacity Installed in Connecticut, 2001-2008



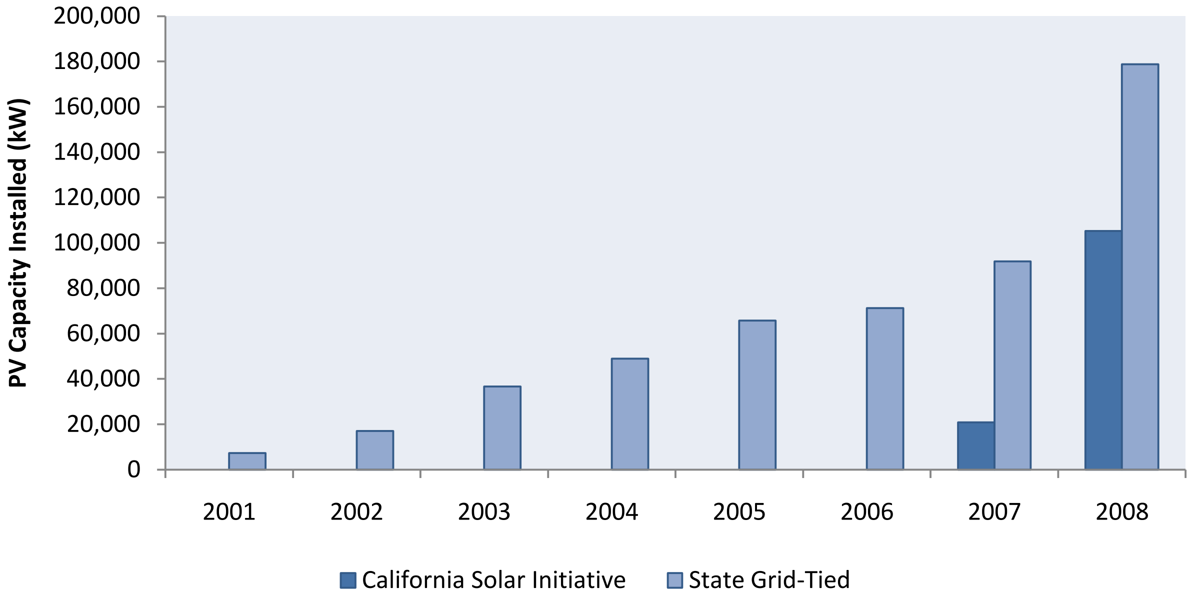
Sources: Connecticut Clean Energy Fund; state grid-tied from Larry Sherwood, personal communication, 2009.

The other states with PV cash incentives also have seen a relatively strong response to their incentives, with at least half of their statewide capacity installed through incentive programs, except in California. California is unique because it has the most mature solar market in the U.S. and has effectively

[12] Energy Information Administration, "Existing Electric Generating Units in the United States, 2008 (by Energy Source)," available at http://www.eia.doe.gov/cneaf/electricity/page/capacity/capacity.html.

incentivized solar deployment for decades. The adoption of the California Solar Initiative had only a small impact on statewide deployment in 2007, the first year the rebate was available, given previous trends (see Figure 7). However, more capacity was installed through the program in 2008 than was installed statewide in 2007. Thus, while the California Solar Initiative was not responsible for much of the cumulative statewide capacity-installed in California, the program appears to have been an important driver of solar deployment in 2008. Similarly, another 148 MW was installed under the program from January through September 2009. Such strong growth in a state with an already mature market suggests that the incentive has been extremely effective at stimulating additional deployment.

Figure 7. PV Capacity-Installed in California, 2001-2008



Sources: California Solar Initiative; state grid-tied capacity-installed from Larry Sherwood, personal communication, 2009.

The big increase in PV capacity-installed seen in California and Connecticut in 2008 were also seen in other states, including Arizona, Hawaii, and Oregon. In Minnesota, Florida, Nevada, and Washington, the large increase happened in 2007.[13] Such consistent trends across multiple states suggest that factors other than the studied incentives were also at work in encouraging strong deployment in 2007 and 2008. Several factors besides incentives that might account for the recent deployment trends were discussed above, including rising real energy prices and recent adoptions of RPS policies. Recent trends may also reflect greening of the public consciousness with respect to climate change and clean energy.

[13] In Nevada, most of the state's grid-tied PV capacity installed in 2007 was from the Nellis Solar Plant in Clark County, with a combined nameplate capacity of 14 MW. An additional 64 MW of solar thermal generating capacity was also installed at the Nevada Solar One plant in 2007.

COST-EFFECTIVENESS AT GENERATING CAPACITY

The PV incentives spent between $1/W and $5/W (2008$), on average, to incentivize the adoption of solar technology (see Table 11). In general, smaller average expenditures per Watt indicate a more cost-effective program. That is, public monies are used more efficiently when average costs are lower, all else equal.

The problem is that all else is not typically equal across states. For instance, installation costs in states with more established solar markets may be lower, meaning that incentive programs in these states may not have to spend as much to incentivize adoption (Wiser, et al., 2009). For instance, average installation costs in Arizona in 2008 were approximately $7.3/W as opposed to $10.3/W in Minnesota. Such a difference makes solar systems in Minnesota a lot less affordable. Similarly, installation costs tend to vary by size of the installation, where small installations cost the most. Nationwide, installation costs run from $9.2/W for installations less than 2 kW to approximately $6.5/W for installations larger than 500 kW (Wiser, et al., 2009).

The variation in average incentive cost also reflects the potential output from solar systems, determined by the available solar resource. Consider California and Connecticut, which had similar average installation sizes of around 5 kW for residential systems and 130 kW for their non-residential incentives. Yet the average incentive paid was $4.2/W and $4/W in Connecticut but only $2/W and $2.5/W in California, for residential and non-residential programs respectively. Connecticut may need to offer larger incentives than in California to account for its weaker solar resource (i.e., 14.6% capacity factor for residential PV in Hartford, CT vs. 18.4% in Los Angeles, CA).

Consider also the small system rebates in Maine and Oregon, which both supported an average PV installation of 2.4 kW. Yet, Maine spent $2.23/W to support PV and Oregon spent $3.3/W, on average, to support PV installations. Oregon also has a state income tax credit for solar installations, making the total state incentive expenditures even higher than in Maine for a similar amount of capacity-installed. Yet, Oregon may need to offer larger incentives to properly incentivize solar than Maine, given its weaker solar resource (i.e., 12.9% capacity factor for residential PV in Portland, OR vs. 16.1% in Portland, ME).

In other cases, the variation in cost-effectiveness can be attributed to the generosity of the incentive, raising questions of efficiency. For instance, New Jersey used to offer incentives of $5/W up to 50% of the installation cost for residential systems under its CORE rebate program. Some households were still filing CORE incentive applications at the beginning of 2009 for late 2008 installations and averaged incentives of approximately $3.8/W in 2009. Households installing in 2009 under the state's new rebate program averaged incentives of only $1.9/W (through the end of September 2009). The difference stems only from the generosity of the incentive. Participants in both programs had comparable total installation costs for early 2009, and response was still good to the new rebate level. Thus, the current rebate level appears more cost-efficient for the state than the previous rebate level, justifying the drop in incentive level.

Future costs for PV programs are expected to fall as the recent cost reductions in module prices and other non-module costs are reflected in program-related installations (Wiser, et al., 2009). Thus, if states maintain their current expenditure levels, the programs could likely support more capacity-installed in the future.

7 - INCENTIVE IMPACT ON ENERGY DEMAND AND AIR POLLUTION

The previous analysis focused on the extent to which the state incentive programs impacted consumer adoption of solar technology – one of the major goals of solar incentive programs. This section reviews the impacts of solar incentives on two additional outcomes of interest: reduction of consumer demand for conventional energy and reduction in environmental impacts from conventional energy.

Solar installations produce energy that can offset consumer demand for conventional energy, such as electricity or natural gas. Thus, the impact of solar incentives can be evaluated in light of the energy savings that the installed systems produce and the associated air pollution emissions that would be avoided through use of the solar technology.

Lifetime electricity savings (in megawatt-hours, MWh) were estimated using different approaches, depending on the data that was available. All calculations assumed a conservative 20 year lifetime for operation of the technology. Maine directly estimated the 20-year energy savings for their solar electric and heating incentives in British Thermal Units (Btu), which could be easily converted to MWh using a standard conversion factor of 3,413 Btu per kWh.

Connecticut and Oregon reported first-year energy savings from the solar installations funded by their incentives. For the PV systems, the annual energy savings were reported in kWh and were projected out 20 years. The solar thermal systems in Oregon's incentive program displaced both electricity and natural gas, requiring a two-step process. Lifetime electricity savings were projected forward as above. Lifetime savings from the displaced natural gas were calculated by converting first-year natural gas savings (in therms) to MWh-equivalent using standard conversion factors of 1 therm per 100,067 Btu and 3,413 Btu per kWh and projecting out 20 years. Lifetime electricity savings and natural gas savings were then summed for Oregon's solar heating incentives. The approach does not account for declining annual energy production as the solar systems age, which could be as much as 1 percent of original capacity per year (Borenstein, 2008).

For Delaware's solar thermal incentives, lifetime electricity savings were computed by multiplying the capacity installed (in ft^2) by a standard conversion factor of 10.76 ft^2/m^2 by the state's daily solar resource (in MWh/m^2) by 365 days per year by 50% (for efficiency) and by 20 years. For the rest of the PV cash incentives, lifetime electricity savings were computed by multiplying the capacity installed (in MW) by the state's average daily solar resource (in MWh/m^2) by 365 days per year by 80% (for efficiency) and by 20 years. The efficiency levels assume that the systems do not generate maximum power during all possible sunlight hours, and the levels reflect current system ratings. Note that the total electricity savings estimated with this methodology was within 10 percent of the estimated electricity production (Wh/W) produced by the Solar Advisor Model.

Emissions avoided were then calculated by multiplying the estimated 20-year lifetime electricity savings under the program (in MWh) by the state's annual non-baseload output emissions rates (in lb/MWh) for carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur dioxide (SO_2).[14] Similarly, the CO_2 emissions avoided from natural gas savings were calculated by multiplying the lifetime therms saved by 11.7 pounds per therm, which is the national average CO_2 emission rate for customer use of natural gas. The emission rate for natural gas does not vary much by state. Emissions in pounds were then converted to metric tons using a standard conversion factor of 2204.6 pounds per metric ton.

The methodology could not be applied to any of the income tax incentives, as none of these programs reported capacity installed. Reliable estimates of capacity-installed also could not be made based on available program data. Thus, the environmental benefits from the solar incentive programs in the ten states are underestimated.

Together, the technology installed under the cash incentive programs studied here resulted in approximately 11.8 million MWh of electricity savings over 20 years, at an average incentive cost of approximately $84/MWh (see Table 12). Such electricity savings would prevent an estimated 6.1 million metric tons of carbon dioxide (CO_2) emissions over 20 years, at an average incentive cost of $163 per ton. The electricity savings would also prevent 3,500 metric tons of nitrogen oxides (NO_x) and 4,900 metric tons of sulfur dioxide (SO_2) emissions over a 20-year period.

Table 12. Estimated Lifetime Electricity Savings and Avoided Emissions from Incentive Programs

State	Sector	Technology	Electricity Savings (MWh)	Incentive Cost for Future Electricity Savings ($/MWh)	Avoided Emissions of Carbon Dioxide (metric tons)	Incentive Cost for Avoided Emissions ($/metric ton CO_2)	Avoided Emissions of Nitrogen Oxides (metric tons)	Avoided Emissions of Sulfur Dioxide (metric tons)
CA	Nonresidential	PV	5,876,328	73	2,828,402	152	751	144
CA	Residential	PV	3,316,616	58	1,596,358	120	424	81
CT	Nonresidential	PV	215,283	192	144,403	286	113	134
CT	Residential	PV	59,202	201	39,710	300	31	37
DE	Nonresidential	PV	41,700	134	36,843	152	59	129
DE	Residential	PV	30,940	121	27,337	137	44	96
DE	Residential	Water heating	1,527	27	1,349	30	2	5
ME	All	PV	5,345	77	2,495	164	3	6
ME	All	Space heating	2,427	8	624	30	2	3
ME	All	Water heating	49,526	13	13,297	47	32	59
MN	All	PV	22,399	77	21,365	80	52	61

[14] Emissions rates were produced by the U.S. Environmental Protection Agency, available at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html. Latest available rates are for 2005. Non-baseload rates were chosen because solar will most likely displace non-baseload power, such as from inefficient fossil fuel power plants. If the methodology had used average rates across all electricity production with the state, the estimated emissions reductions would be less.

State	Sector	Technology	Electricity Savings (MWh)	Incentive Cost for Future Electricity Savings ($/MWh)	Avoided Emissions of Carbon Dioxide (metric tons)	Incentive Cost for Avoided Emissions ($/metric ton CO_2)	Avoided Emissions of Nitrogen Oxides (metric tons)	Avoided Emissions of Sulfur Dioxide (metric tons)
NJ	Commercial [previous]	PV	718,757	145	477,557	219	706	1,480
NJ	Nonresidential [current]	PV	11,640	38	7,734	57	11	24
NJ	Other [previous]	PV	562,245	125	373,567	188	553	1,158
NJ	Residential [current]	PV	47,542	65	31,588	98	47	98
NJ	Residential [previous]	PV	623,693	188	414,394	284	613	1,284
OR	Nonresidential	PV	85,334	58	38,697	129	39	44
OR	Nonresidential	Water heating	20,418	7	4,517	33	9	11
OR	Residential	PV	46,977	117	21,303	258	21	24
OR	Residential	Water heating	75,207	9	18,747	38	34	39
ALL	**ALL**	**ALL**	**11,813,107**	**84**	**6,100,287**	**163**	**3,545**	**4,915**

Note: New Jersey began a new rebate program in 2009; thus the data is presented both for the previous rebate and for the current rebate.
Source: author's calculations.

The incentive programs in California are associated with the largest electricity savings and avoided air pollution emissions, while the rebate programs in Delaware and Maine are associated with the smallest electricity savings and emissions reductions. Such results follow directly from the capacity-installed under the different programs.

To illustrate the relative energy and emissions reductions, the savings were standardized by the incentive expenditures for each program. Thus, the metrics indicate the public subsidy in today's dollars per MWh of electricity savings or per metric ton of air pollution emissions avoided over the estimated lifetime of the technology (20 years). When viewed this way, the solar thermal incentives in Delaware, Maine, and Oregon all required the smallest public subsidy per unit of energy savings of all of the cash incentive programs. In Oregon and Maine, the subsidy was less than $10 per MWh-equivalent of estimated electricity savings. The subsidies would likely be even smaller if a higher efficiency rating was used in the estimation methodology.

New Jersey's current non-residential incentive required the smallest subsidy per unit of electricity saved of all of the PV programs, at $38/MWh. By contrast, Connecticut (both sectors) and New Jersey (residential; previous level) spent the most to achieve energy reductions in their states from their PV incentives, at almost $200 per MWh of estimated electricity savings. Note that these values do not reflect the full cost to produce energy from solar technology, which would include other subsidies and private expenditures.

For instance, the state subsidies should be put in context with current federal subsidies for solar technologies. The subsidies include direct expenditures on solar incentives such as the federal investment tax credit, plus expenditures for research and development, which the state incentives evaluated here do not include. Even so, the Energy Information Administration (2008) estimates that solar electricity generation is currently subsidized by the federal government at around $28/MWh (adjusted to 2008 dollars). Likewise, federal solar subsidies not related to electricity production, such as for solar thermal systems, are estimated to cost $11/MWh.[15] Thus, most of the state solar thermal incentive programs appear to be spending similar amounts as the federal government to subsidize solar thermal systems. The state incentives for solar electric production are generally much higher than the federal subsidies on a per-unit basis.

The question is whether the state solar subsidies are the most efficient way to generate energy savings within these states. Other policies would be more economically efficient if they could produce comparable savings for less cost. Solar advocates cite several reasons for why the public should subsidize solar, even at its high cost, including the social benefits that solar power delivers, such as from reduced environmental impact of energy production and increased energy security. Thus, it is possible that solar subsidies properly account for the direct and indirect (i.e., social) costs associated with energy production, and thus could be appropriate even if they cost more than doing something else.

It is worth considering, then, how much these programs cost on average to achieve each unit of carbon dioxide (CO_2) emissions reductions. Carbon dioxide is one of the most important contributors to global climate change and is an environmental externality not properly priced in U.S. energy markets today. The solar incentives together spent on average $163 per estimated metric ton of CO_2 avoided. The most effective programs produced emissions reductions at around $30/ton avoided (in Delaware and Maine through water heating incentives). At the high end, Connecticut, New Jersey (previous level), and Oregon all spent more than $250/ton avoided on their non-residential programs. States like Oregon and California are challenged to produce cost-effective CO_2 reductions because their electricity is already quite clean (i.e., Oregon uses hydropower and California uses natural gas). Thus, these states have to invest more to achieve the same amount of CO_2 reductions as in a state with much more polluting electricity.

The cost-effectiveness of state solar incentives at achieving CO_2 emissions reductions depends, in part, on the magnitude of the economic benefits such reductions generate. These economic benefits are difficult to estimate and more than 200 estimates have so far been made (Tol, 2008). Tol finds that the median estimate is around $20/ton of carbon, or about $73/ton of CO_2, which is what carbon is trading at currently on the European Exchange. In this light, several of the state incentive programs appear to generate cost-effective CO_2 reductions, including the solar thermal incentives and the PV incentives in Minnesota and New Jersey (non-residential; current level).

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[15] This value was computed by converting estimated solar Btu savings from the Energy Information Administration into MWh-equivalent, as described above.

More programs may appear cost-effective if we assume that the full social benefits of carbon reduction go beyond current trading prices. For instance, one can argue that we are still in the early stages of learning how to make cost-effective carbon reductions, and thus there may be some benefit to stimulating the market. The side effect of solar investments as a CO_2 reduction strategy may be to improve the technical efficiency or drive down the cost of solar technology to a point where it is more cost-comparable to conventional energy sources, which is an additional societal benefit.

8 - DATA COLLECTION RECOMMENDATIONS

In general, the analysis was severely limited by data availability. All but two states offered some kind of tax incentive for solar technology at the end of 2008. Yet many tax incentive programs do not report sufficient information on participation to conduct an analysis of performance, as was possible with data from the cash incentive programs. States are highly encouraged to track, on an annual basis, the following information:

- number of participants (broken down by sector- i.e., residential, commercial);
- program expenditures (also broken down by sector);
- amount of technology supported (broken down by sector and technology, if necessary- i.e., square feet for solar thermal collectors; peak Watts installed for PV)

Additional analyses can be then conducted with this information, as was done above. Minnesota Office of Energy Security (2009, Appendix) used a simple table to report most of this information.[16] One recommended change to this model is to break out annual program expenditures by sector so that the average incentive cost per year or per Watt installed could be computed separately by sector. Some programs also report the total installation cost for each installation so that you could estimate the share of the installation cost provided by the incentive, which can be a useful when comparing programs in states with different installation costs.

Some of the best data on program participation and use is currently reported by California, New Jersey, and Connecticut. These data are available in spreadsheet form with detailed information on each installation funded through the program, including the installation date, location, sector, technology, amount funded, and total installation cost.

Reporting efforts may be easier for cash incentive programs due to the more extensive applications process typically involved. Even so, most states could require a short form be completed to obtain the tax incentive, in which the claimant had to report information on the sector for which the installation was made (residential, commercial, industrial, etc.), the type of system installed (solar heating or PV), and the total installation cost of the system. It is important for tax incentive programs to report information separately by technology if the incentive covers other renewable technology, so that the use of solar-specific incentives can be tracked properly. At a basic level, this information should be aggregated and reported as for the Minnesota program above. In the best case, this information would be made available to the public by installation as in California, New Jersey, or Connecticut.

An additional effort needs to be made to consolidate available program information across states, in an accessible and publicly-available format that allows comparative analysis. The *Database of State*

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[16] See http://www.state.mn.us/mn/externalDocs/Commerce/MN_Solar_Electric_Rebate_Report_040809051301_MinnesotaSolarElectricRebateProgram.pdf

Incentives for Renewables and Efficiency (DSIRE) is an invaluable source for information about the design and availability of current incentives. What is needed is a centralized place that tracks state incentives participation, spending, and impact back in time, as was attempted here. DSIRE has begun to do so for some of the rebate programs, but a large number of programs remain unstudied due to a lack of accessible or comparable information.

Additional effort is also needed to track the expansion of solar capacity by state over time. The U.S. Energy Information Administration (EIA) has successfully tracked annual shipments of solar thermal collectors by state back to 1985. The EIA only began to track PV shipments from manufacturers by state in 2007. Larry Sherwood at the Interstate Renewable Energy Council (IREC) currently maintains the most comprehensive dataset of state grid-tied PV installations by year back to 1996, although this analysis reveals the likelihood of missing information for several states in recent years. Future efforts are needed to fill in gaps before rigorous statistical analysis on PV deployment can be attempted.

Researchers from the Lawrence Berkeley National Laboratory have built a dataset of individual PV installations, which they estimate includes 71 percent of the grid-tied capacity-installed through 2008 (Wiser, et al., 2009). Such a dataset was designed to answer different questions than here, and thus would need to be reconfigured to report the amount of program participation, incentive spending, and output by state and by year. Similarly, researchers from the National Renewable Energy Laboratory have recently made available data on individual PV installations throughout the country at http://openpv.nrl.gov. Open PV is extremely useful for tracking installations across space and time, and will become more useful as its coverage is expanded to currently missing states such as Utah, Montana, Maine, and Illinois. Even so, the Open PV effort does not directly track the amount spent on incentives for each installation, precluding performance analysis for particular incentive programs.

Finally, researchers should not neglect to track solar thermal shipments, which still remain an important part of the residential solar market. According to the above analysis, solar thermal is easier and cheaper to support by states and so far yields more cost-effective electricity savings and emissions reductions than PV. Even so, most reported data on incentives and installations focus on PV installations rather than solar thermal installations. A comparable tool to the Solar Advisor Model used above would be useful for solar thermal, as would a centralized dataset of solar thermal installations along the lines of the Wiser et al. (2009) effort and the Open PV Project.

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