# State and Utility Solar Energy Programs: Recommended Approaches for Growing Markets

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# Executive Summary

The U.S. solar electricity industry is growing. In some jurisdictions, solar installations are thriving. A few jurisdictions are already approaching solar grid parity, which means solar electric power can be produced and delivered at prices equal to or lower than power generated from traditional fuel resources. That is especially true in a few markets where high electricity prices, combined with generous financial incentive policies, result in solar investment opportunities with reasonably rapid paybacks and increasingly competitive rates of return on investment. Full grid parity is sometimes defined to mean that solar electricity prices, without any special financial incentives, are matching traditional resource prices, but all energy markets are complicated by policies that influence prices. Pragmatically, many investors act as if grid parity exists when solar energy investments achieve an attractive return within a reasonable time frame.

In any case, solar power policies designed and implemented many years ago might not be ideal for larger, gradually maturing markets in the present or future. In the initial stages, policy makers probably implemented some programs specifically because solar power was uneconomical or only marginally economical: Solar therefore needed a boost to help meet policy objectives for diversifying energy supplies and increasing the use of this indigenous renewable energy resource. Most U.S. States enacted multiple policies supporting solar energy. The most commonly adopted policies include net metering, solar-access property rights, special financing and loan programs, direct cash incentives, and renewable energy portfolio standards or goals. Although the majority of states have enacted at least a few of these policies, solar electricity production still remains very small in all but a few jurisdictions.

Now, however, solar installations are proving economical in some markets, given the continuing improvements in solar energy conversion technologies and economies in manufacturing and system design and installation, coupled with the array of existing financial incentives and other supporting policies. This shift leads some observers to recommend reducing or eliminating solar incentives and rolling back other supporting policies. In particular, some utilities allege that net metering allows participating customers to use the electric grid system without paying their fair share of costs and results in cross-subsidies from non-participating to participating customers. Some observers also claim that existing state and federal solar incentives might now be too generous.

An alternative viewpoint held by some solar advocates is that utilities, fearing sales losses to self-generation at the same time sales growth has stalled due to other reasons, are exaggerating the costs and other potential problems that might be associated with net metering.

Multiple researchers are trying to assess accurately the full spectrum of costs and benefits associated with increasing solar power generation and with net metering in particular. Some analyses show positive net benefits from net metering in several states, thus reflecting cross-subsidies in the opposite direction, from participating to non-participating customers. Some observers point out that addressing these issues now is not particularly important, given the low rates of existing net metering participation in most jurisdictions, the general simplicity and relatively low cost of net metering program administration, and program caps that effectively limit the amounts of any lost sales and cross-subsidies that might exist.

At least some solar advocates fear that policymakers might overreact to perceived problems associated with current policies, in ways that will ultimately thwart progress just now appearing on the horizon after decades of concerted efforts to initiate viable solar power markets. From that perspective, policymakers should consider reducing or removing supporting policies only when it can be demonstrated that the solar industry can readily compete without them. As previous energy policy changes have sometimes demonstrated, removing supporting policies prematurely can result in major disruptions. However, many states are considering legislative or regulatory changes already, whether to address utility concerns or to expand existing or introduce new solar energy opportunities. In any case, policymakers ought to consider refining or replacing existing policies whenever it becomes clear that improved approaches can achieve the same or better results at lower cost and with fewer negative side effects.

This paper explores the different policies used to promote solar energy with a primary emphasis on net metering. Included is a timeline showing the year that net metering was adopted, by state, along with the years that major amendments were made and the general subjects of those amendments. Also included is a table of state and U.S. territory net metering and other solar incentive policies, highlighting major similarities and differences in these policies.

The paper also offers some ideas about how existing policies might best be reviewed and then adjusted, if revisions are needed. The major question explored in this paper is whether and how policies might best be adjusted, when necessary, to reflect maturing and expanding markets for solar energy, so that state policy objectives or requirements can be met at the lowest practical cost while minimizing or avoiding altogether any unintended negative side effects.

Four recommendations are provided for policymakers that are considering changes to existing state solar energy policy supports:

(A) To proceed with caution and on the basis of thorough analysis when revising solar energy policies;

(B) To model and consider establishing specific Public Utilities Regulatory Policy Act (PURPA) avoided cost rates for solar or for all distributed generation, depending on the state's other existing solar energy policies;

(C) To continue growing the solar industry by maintaining and further developing programs that leverage voluntary contributions and non-ratepayer funding; and

(D) To consider changes in public utility regulatory incentives to better accommodate increasing reliance on distributed energy resources.

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# I. Introduction

In the United States, more than a dozen types of policies to promote solar energy, including net metering, a variety of tax incentives, direct cash grants, and many other kinds of financial incentives, are used by various jurisdictions.[1] Most already have enacted multiple policies supporting solar energy. Some have been in place for decades already, but the total number of policies and the depth of support has grown in recent years. These policies include net metering in at least 43 states plus four U.S. territories; solar-access property-rights laws in 40 states and the U.S. Virgin Islands; special financing and loan programs in approximately 35 states; direct cash incentives in 23 states plus the District of Columbia and Puerto Rico; a variety of other financial incentives in another 23 states and the U.S. Virgin Islands; and incentives for the solar industry in 21 states and Puerto Rico. There are also existing renewable energy portfolio standards in 29 states, the District of Columbia, and two U.S. territories and renewable energy portfolio goals in eight more states and two territories. All of these include solar electricity generation as an eligible technology. Additionally, renewable energy standards in 16 of those states plus the District of Columbia explicitly support solar and/or distributed generation (DG), through special policy carve-outs or by providing extra credits for solar electricity.

At least partly as a result of these agglomerations of policies, solar electricity production is increasing rapidly in some jurisdictions, sometimes associated with what some observers perceive to be growing pains. In particular, some policies are designed so that total solar program costs to taxpayers or ratepayers are increasing as solar production grows. That can be the effect of growth in aggregate solar production, even if cash incentives are declining, in concert with reductions in the price of solar installations, on a per-installation or per-unit-of-production basis. (Barbose, Darghouth, & Wiser, 2012). The same result has also occurred in many states and countries with feed-in tariff (FIT) policies. There, the financial obligations of long-term FIT contracts sometimes grew rapidly, to perhaps higher-than-anticipated amounts (Grinlinton & Paddock, 2010; Jacobs, 2012; Mendonca, Jacobs, & Sovacool, 2010).

Electric utility net metering programs are attracting increasing numbers of customers. There are reports that net metering program caps are being reached in some jurisdictions and individual solar system size caps are preventing potentially cost-effective installations in others (Keyes, 2013). As the number of net metering participants increases, so does the total dollar value of the solar energy produced, associated net metering credits, and other financial incentives. That means any perceived inequities associated with solar policies are growing in importance, too. Many interested parties are sounding alarms, and some utilities and others are expressing heightened concerns about the fairness of net metering and questioning the wisdom of continuing or expanding solar support policies. (Asmus, 2013a; Berst, 2013; Burr, 2013; Cardwell, 2012; Chernova, 2013; Curry, 2013; Gilliam, 2013; Mahrer, 2013; Matz, 2012; Tempchin, 2013). Some researchers and observers are referring to renewable and distributed energy resources in general and sometimes solar PV specifically as potentially “disruptive” technologies (Kind, 2013; Manyika, Chui, et al., 2013; Nelder, 2013). Some even question whether PV and other distributed energy resources represent “an ‘existential threat’ to the business model of utilities” (Goldman, Satchwell, et al., 2013). Tweed (2013) quotes a utility

[1] In this paper, jurisdictions of the U.S. include states, territories, and the District of Columbia.

executive who says, "Regulators and utility executives have been talking about this issue for years, but it is now coming to a head."

With respect to net metering policies in particular, two important issues are being raised. One is that net metering could allow customers to avoid paying their fair share of costs for the services they obtain from the electric grid, especially for the embedded costs of the electricity distribution system. A second and related concern is that costs not paid by presumably more affluent net metering customers, to the extent they do exist, will be shifted to the more moderate- and low-income customers who can least afford them (Cardwell, 2012).

Cardwell (2012) summarizes the situation:

> The net metering benefit, which is available to residential and commercial customers with renewable energy systems in more than 40 states and has helped spur a boom in solar installations, is at the heart of a battle. Utilities, consumer advocates and renewable energy developers across the country are fighting over how much financial help to give to solar power and, to a lesser extent, other technologies. Regulators are in the middle, weighing the societal benefits of renewables as well as how best to spread the costs.
>
> Net metering has been so popular that several states are rapidly approaching regulatory limits on how many systems are eligible, meaning new customers have no assurance they can reap the same rewards. The solar industry, which is growing in size and influence, has been pressing to raise those limits to continue to encourage rooftop installations, while the utilities have generally been opposed.

During the infancy of markets for solar photovoltaic (PV) systems and other forms of DG, policy makers might reasonably have postponed closer scrutiny of, or even temporarily ignored, the problems some observers now ascribe to net metering. Curry (2013) explains, "Incentives that might have been appropriate when DG was a fledgling business, with insignificant market penetration, now threaten consequences that, if not addressed by regulators, will harm the public interest." Strong interest already exists among some parties, however, in reconsidering the details of net energy metering programs and how customer costs and benefits are treated in related utility tariffs (Mahrer, 2013). A preliminary project description from Lawrence Berkeley National Laboratory (personal communication with G. Barbose and A. Satchwell, May 2013) states:

> Fierce debates surrounding the impact of net metering have surfaced in some of the larger state solar markets and will only become more pronounced and widespread as solar costs decline and deployment accelerates, especially as states approach statutory caps on the allowed amount of net metered PV. Utilities are concerned about revenue erosion and reduced shareholder returns when net metered customers are able to offset charges for fixed infrastructure costs, while customer groups are correspondingly concerned about potential cost-shifting between solar and non-solar customers.

As Chernova (2013) reports, solar presently produces only "a drop in the bucket" of total U.S. power production. But Chernova also quotes a utility executive who tells a *Wall Street*

*Journal* conference that "distributed solar is a mortal threat" to utilities under current business and regulatory models. In any case, some state legislatures and utility commissions are already being pressed by some utility interest groups to take what the groups consider to be corrective actions, especially by modifying or possibly replacing net metering policies. These actions are proposed in order to rectify what the interest groups perceive to be problems of the present or the foreseeable future that they believe are likely to result from continuing rapid growth in the spread of distributed solar generation.

Offsetting these concerns are the values that solar power can provide to the electric grid. Some studies report values that exceed retail rates, and some forecast even higher values would result from more carefully targeted, strategic resource deployment. Several related studies are discussed in Part IV of this paper.

Solar advocates might view the current situation as a harbinger of the outcome that they have long desired and anticipated, that is, the breaking down of solar PV market barriers and obstacles to allow the industry to approach and eventually achieve full, widespread cost-parity. From this perspective, policy supports should be reduced or removed only when they are demonstrably no longer needed, meaning that the emerging solar industry can readily compete without them.

Some observers point out that addressing these issues now is not particularly important, given the low rates of existing net metering participation in most jurisdictions, the general simplicity and relatively low cost of net metering program administration, and program caps that effectively limit the amounts of any lost sales, lost revenues, and cross-subsidies that might exist. However, many states are actively considering legislative or regulatory changes already, whether to address utility concerns or to introduce new or expand existing net metering opportunities. In any case, policymakers ought to consider revising or replacing existing policies whenever it becomes clear that new approaches can achieve the same or better results at lower cost and with fewer or no negative side-effects.

This paper briefly summarizes the recent growth in solar installations and the state policy context in Part II. Then, Part III reviews the history and current status of state policies for the support of solar energy with special attention to net metering programs. Part IV reviews and summarizes several studies that attempt to analyze net metering benefits and costs and the value-of-solar energy. Part V recommends preliminary approaches for reviewing and adjusting policies in response to rapid growth in solar installations, and explores how decision makers might best change existing policies as solar technologies and markets evolve and eventually mature. Part VI provides a brief conclusion to this report.

# II. Solar Growth and the State Policy Context

Solar PV installed capacity in the U.S. roughly doubled between 2007 and 2009 and then continued doubling again each year since 2009 (Barnham, et al., 2013; Gilliam, 2013, p. 2; Goldman, Satchwell, et al., 2013, p. 6; Sherwood, 2012). Taken as a whole, the available data shows rapid growth in solar PV installations at all scales from small residential systems to large, multi-MW commercial- and utility-scale systems.

Although solar production in the U.S. is growing rapidly, it is from a small base. Therefore, although the totals are increasing, solar PV still represents small percentages of installed capacity and energy in all jurisdictions. As reported in Table 1, Column 3, Hawaii leads the U.S. in the percentage of residential (2.34%) and commercial (1.09%) customers who are net metering using solar PV. The next closest states are California for residential customers (with about 0.9%) and Colorado for commercial customers (with a bit more than 0.5%). For residential solar PV net metering customers, 31 states report fewer than 0.1%, and only 8 states report more than 0.25% (Arizona, California, Colorado, Hawaii, New Jersey, New Mexico, Oregon, and Vermont). For commercial, 33 states report less than 0.1%, and only four states (Colorado, Delaware, Hawaii, and New Jersey) report more than 0.25%.[2]

Prices for solar photovoltaic crystals, films, and modules have dropped rapidly in the last several years as manufacturing has ramped up and worldwide competition for market share has heated up (Gilliam, 2013, p. 3). Total installed costs have been dropping fairly rapidly as all parties in the solar energy supply chain are gaining experience and benefiting from systematic, focused efforts to reduce costs and increase system performance. Such efforts have helped to achieve cost reductions through improvements in practices for siting and permitting, in balance-of-system (BOS) components, and in the manufacturing and assembly of solar modules themselves (see, for example, USDOE, 2013d).[3] Installed prices have continued to drop for larger-capacity systems, albeit with diminishing returns to scale. Innovative financing techniques are also reducing initial out-of-pocket costs and simplifying the purchasing process for increasing numbers of customers. However, average prices in several other countries remain lower than in the U.S., reflecting the existence of a variety of policy drivers and structural differences (Barbose, Darghouth, & Wiser, 2012).

[2] Based on 2011 data from USEIA, 2012a and 2012b. Accurate data on the exact number of customers eligible for net metering in each state is not readily available. The data used here about eligible customers per state comes from USEIA reports (2012a) of the total number of residential and commercial customers in each state, at year-end 2011. This data source results in under-reporting the percentage of eligible customers participating in several states where not all utilities offer net metering service; those states are known to include at least Alabama, Colorado, Idaho, Illinois, Massachusetts, Michigan, Mississippi, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, and Utah.

[3] Some other solar technologies are already fully cost-effective in many applications. Examples include solar space and water heating, solar-powered air conditioning, and solar daylighting. However, these technologies have not received the same level of policy attention and support as more expensive solar PV and concentrating solar power technologies for making electricity. Non-electricity-producing solar technologies do deserve policy attention where it can be demonstrated that they are available to apply as cost-effective energy-efficiency measures.

Increasing numbers of brand-name commercial and manufacturing customers, especially those with ample open space on flat-roofed buildings and with facilities in many states and utility territories, are already flocking toward solar PV. With increasing frequency, customers such as Costco, FedEx, IKEA, Johnson & Johnson, McGraw Hill, and Walmart are adding megawatt-scale installations for on-site, behind-the-meter use. These installations are supported by the positive consumer relations the companies earn by investing in renewable energy, and by the economic values these companies associate with using solar PV to reduce their operating costs and mitigate the risk of price volatility by fixing at least a percentage of their electricity costs (SEIA, 2012).

Data on solar installations shows:

- The U.S. was home to a total of about four GW of installed PV capacity by 2011 (Barbose, Darghouth, & Wiser; 2012; USEIA, 2012c).

- Several states experienced even higher rates of growth (in total PV installations, not exclusively net metering) between 2010 and 2011, including Arizona (352%), New York (217%), New Mexico (199%), New Jersey (131%), Hawaii (119%), and California (110%) (Sherwood, 2012, p. 8).[4]

- A small number of states and utilities account for most solar installations. Sherwood (2012, pp. 9-11) reports that, by number of systems, just three states—California, New Jersey, and Pennsylvania—are home to more than 80% of all solar PV installations in the U.S. from 1998 through 2011. Also, Kind (2013, p. 4) reports that "70% of [DG] activity is concentrated within 10 utilities."

- In the five years from 2007 to 2011, for which net metering data has been collected and reported by the U.S. Energy Information Administration (USEIA, 2012b), the national net metering growth rate averaged nearly 50% per year.

- Solar energy represents a vast majority of total net metering participation by number of customers. The data for 2011 shows that over 98% of all net metering customers in 11 states use solar PV. These states include several states with the largest numbers of participating net metering customers, including Arizona, California, Colorado, Hawaii, New Jersey, and New York. Another 17 states report that more than 90%, and 15 more states report over that two-thirds, of all net metering customers use solar PV.

- In terms of installed solar PV net metering capacity, the leading states based on 2010 data are California (48% of the U.S. total), New Jersey (12%), and Colorado, Arizona, and Nevada (5% each) (Keyes & Wiedman, 2012, p. 3).

[4] In this data, 100% annual growth represents a doubling of installed capacity.

- Capacity of installed systems in the U.S. is widely distributed among small residential-scale systems of less than 2 to as many as 10 kW (about 20% of cumulative installed capacity by 2011), commercial systems ranging from 10 to 1,000 kW (a bit more than 50% of cumulative installed capacity by 2011), and large commercial or industrial scale facilities larger than 1,000 kW (1MW; equal to about 20% of installed capacity by 2011).

- Although slightly more than half of all the grid-connected solar PV capacity in the U.S. is now generated by utility-scale systems, a reported 93% of all U.S. PV grid-connected installations are net metered distributed commercial and residential systems, collectively "accounting for more than 3,000 MW-dc of new generating capacity" (Keyes, Fox, & Wiedman, LLP, 2013, pp. 2-3, footnote omitted).

- Utility-scale systems, defined as 2MW or larger, are also rapidly growing, with "90% of this capacity distributed across eight states (California, New Jersey, New Mexico, Nevada, Colorado, Arizona, Florida, and Texas)" (Barbose, Darghouth, & Wiser, 2012).

## III. Summary of State Net Metering and Solar Incentive Policies

Figure 1 presents a timeline of state net metering legislation and rules, and Table 1 summarizes information about state net metering and other solar-incentive policies. The most important points to glean from Figure 1 and Table 1 are:

(1) Many states' net metering policies have already been amended, some more than once, and nearly all of those amendments, one way or another, expanded program eligibility and increased the consumer benefits from net metering.

(2) Twenty-five states cap the maximum load allowed to net meter, for example to a maximum percent of utility sales or in a couple of states to a maximum number of MW, but based on year-end 2011 data (USEIA, 2012a and 2012b) no states are close to reaching those limits.

(3) During the past several years (2008 through June 2013), 20 states expanded their net metering programs and nine of the 20, plus two others, added provisions for meter aggregation or group net metering; 16 states presently include meter aggregation, group net metering, or both.

(4) Twenty-three states have RPS policies that include either solar carve-outs, some kind of extra credit for solar generation or for all DG, or both.

(5) Almost every state, even some states without any legislated or regulated net metering policy, provides one or more types of solar incentives.

In Figure 1, the listings above the timeline indicate the year in which each state first enacted a net metering policy. In the three decades depicted in this timeline, eight states first enacted net metering between 1982 and 1991, 17 more states and the District of Columbia added programs in the next decade, and 18 more states started programs in the third decade. Listings below the timeline in Figure 1 indicate the years when significant amendments were made in net metering laws or rules. Four major types of amendments, by category, are coded below the timeline.[5]

In Figure 1, states are listed below the timeline multiple times, if amendments in a given year include more than one of the types listed and also if the state's program has been amended in multiple years. For example, Massachusetts amended its net metering program in 1997, including increases in both individual system size limits and the prices credited for net excess generation.

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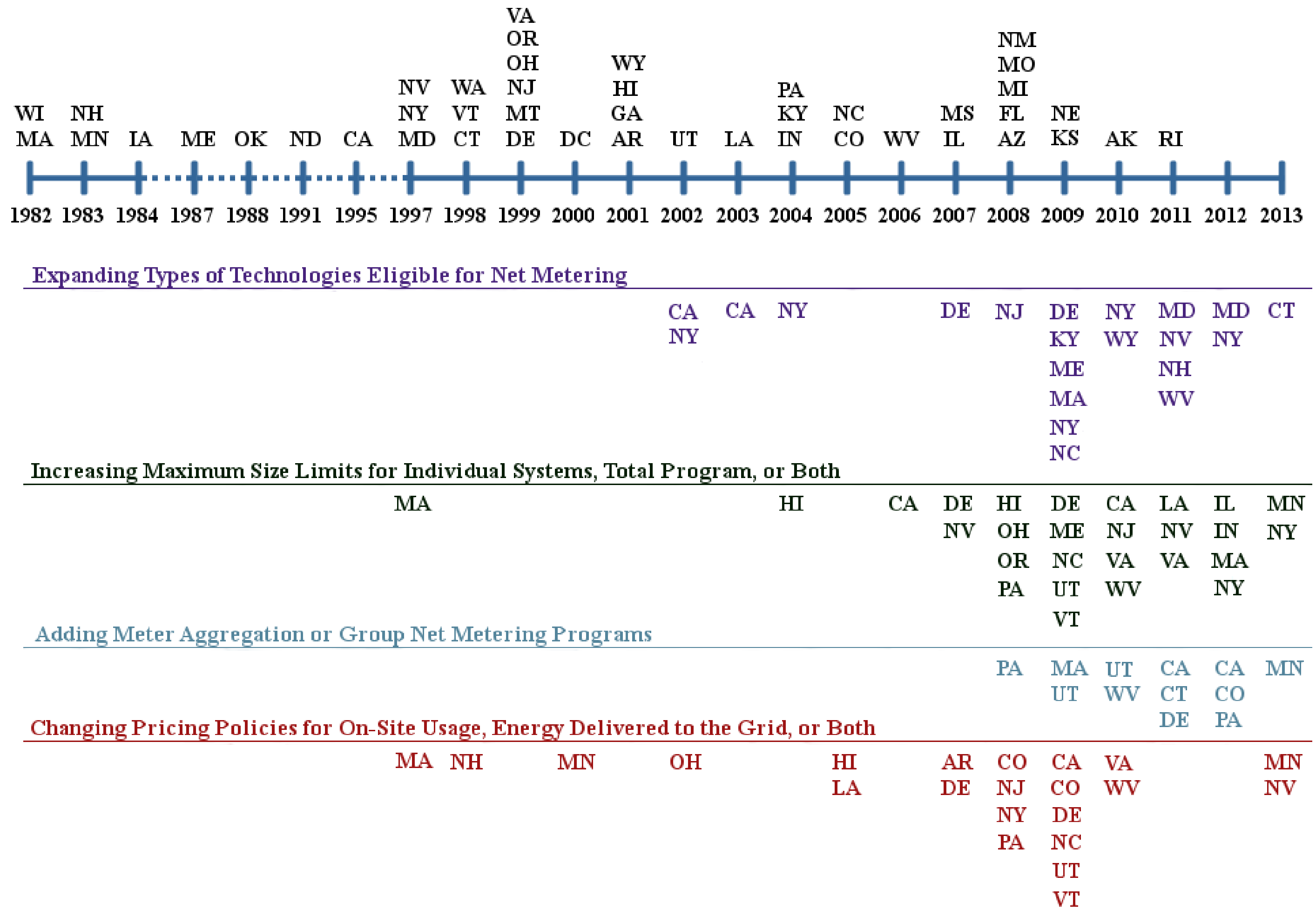
[5] Amendments for purposes other than those listed are not encoded in Figure 1. Not included in Figure 1 are amendments changing liability rules or insurance requirements (Arkansas, 2012; Kansas, 2010; Missouri, 2009; and New Hampshire, 2001), opening net metering to customers of cooperatives (Montana, 2001) or municipal utilities (Wyoming, 2003), adjusting customer class eligibility (Kentucky, 2009), changing contract requirements (Maine, 2000), adding time-of-use rate provisions (Vermont, 2012), and making changes specific to only one utility (Wisconsin, 2011).

**Figure 1: Timeline of U.S. State Net Metering Rules (years of first enactment and of major amendments, by type of amendment)**




Source: Author's construct using information from *Database of State Incentives for Renewables & Efficiency* (www.dsireusa.org) . Compiled by D. Phelan, NRRI.

Table 1 summarizes information about U.S. state and territory net metering and nine other solar support policies. Program details differ widely, though, and some programs have been changing fairly frequently. As shown for state net metering programs in Figure 1 (and also reported in Table 1, Column 2), California net metering has been amended seven times already; New York six times; Colorado, Delaware, and Hawaii three times each; and a few other states twice. The presentation in Table 1 is also complicated by the fact that individual utilities in several states are self-implementing solar PV programs voluntarily, not in response to state legislation or state public utility commission regulatory decisions. In those situations, a state might not be listed as including a specific policy type, even though that policy is being implemented by one or more utilities. For example, Florida is not indicated (in Column 10) as having a feed-in tariff (FIT) policy, but Gainesville Regional Utilities (2013) was the first in the U.S. to offer this type of solar incentive, and its program has received much publicity (see, for example, Galbraith, 2009). Thus, Figure 1 and Table 1 should be understood as giving a high-level indication of policy types and readers should consult each specific program's enabling legislation or rules to understand the program in detail.[6]

All state net metering programs are similar in some ways. As Gilliam (2013, p. 5) explains:

> Net metering is a billing mechanism that credits [customers for] electricity exported onto the electricity grid. Under the simplest implementation… a utility customer's billing meter runs backward as solar electricity is generated and exported to the electricity grid and forward as electricity is consumed from the grid.

State net metering programs differ in six major ways, as listed in Table 1, Columns 4 through 9. Included are differences in (1) the maximum total amounts of allowed net metering, either by utility or statewide; (2) the maximum size limits for individual customers' net metering facilities; (3) the treatment of and price credited or paid for net excess generation delivered to the utility grid; (4) whether third-party ownership of net metered systems is allowed; (5) whether group net metering is allowed; and (6) special benefits or extra credits for solar or other DG in state renewable portfolio standards. Another difference, whether or not renewable energy certificates or credits (RECs) associated with either gross or net production accrue to the benefit of net metering customers, is encoded as "RECs" in Column 10, along with listings of other incentive programs.

Years (in Column 2) indicate when each state first enacted net metering, and years that follow in parentheses indicate when major net metering amendments were passed, if any. For example, Arkansas first enacted net metering in 2001 and then amended its program first in 2007 and again in 2012.

Column 3 presents the estimated percentages of residential and commercial customers reported as net metering, based on 2011 data.[7] For example, in California, 0.89% of the state's

[6] Readers aware of any missing or incorrect data in Figure 1 and Table 1 are requested to notify the author.

[7] See footnote 2 on page 4 for an explanation about these estimates.

residential customers (89 of each 10,000 customers) and 0.025% of commercial customers (25 of each 100,000) are reported as net metering.

The “Program Limit” (Column 4) generally reflects how much of each utility’s total load, or sometimes the state’s total load, is eligible for net metering. Twenty-five states have caps that limit total net metering participation. “Individual System Limit” (Column 5) indicates the maximum size generator any one net metering customer can install. In many programs, though, the maximum size has two constraints: (1) generator capacity (e.g., number of kW or MW per customer), and (2) the customer’s annual energy usage (e.g., frequently, not to produce more than 120% of the net metering customer’s total annual electricity needs). For example, the total enrollment eligible in Alaska (Col. 4) is limited to 1.5% of each participating utility’s retail sales from the previous year, and the maximum size for a net-metered generator (Col. 5) is 25 kW.

Table 1, Column 6 attempts to summarize what is often rather detailed and complex information about how each state treats rate offsets for power produced and used on-site and bill credits for net excess generation. In almost all net metering programs, a customer’s billing-period exports to the grid are subtracted from usage, thus calculating the “net” amount of energy, either used or exported. Credits up to the point where billing-period exports are greater than usage (that is, when the energy bill would be zero or a credit owed the customer) are usually valued at the customer’s full retail variable energy-use rate. The price that applies is called the “rate offset” (Power Pundits, LLC, 2013, p. 18). Many state programs are encoded as “retail, avoided cost” (7 states), “retail, granted” (9 states), or “retail, indefinite” (10 states). The first word, “retail,” means customers are credited for energy delivered to the utility at the full retail variable energy-use rate, at least up to the point where their total net monthly bill for energy use would be zero. Other first words used frequently in Col. 5 include “avoided-cost” (6 states) and “varies” (4 states). In this context, “avoided-cost” means that rate offsets are priced at a commission-determined avoided cost, and “varies” means that decisions are made by type or size of utility or in individual utility rate cases.

The subsequent words in Column 6 (after the commas) indicate how customer bill credits for net excess generation are priced, above and beyond the customer’s usage, usually for each 12-billing-month period or calendar year.[8] Some state programs are encoded “indefinite,” meaning excess generation credits are allowed to carry over without ever expiring. Another common treatment credits customers at a commission-approved “avoided cost,” usually at the end of each 12-month period. A few other states reconcile customer credits monthly, so there is no 12-month reconciliation. Other states, encoded “granted,” simply turn over to the utility company the value of any excess generation at the end of each 12-month period and reset the customer’s account back to zero. In this context, Keyes and Wiedman (2012, p. 4) note:

> Perpetual rollover of excess generation...avoids possible federal regulatory issues related to wholesale sales and addresses concerns that [net energy metering (NEM)] might produce incentives for customers to oversize their systems. As well, the Internal Revenue

[8] Perkins (2010, p. 104) reports, “FERC declines to assert [wholesale price-setting] jurisdiction even if the on-site generator participates in net metering, so long as the site never generates more than it consumes [See MidAmerican Energy Co., 94 F.E.RC. 'II 61,340, at 62,263 (2001)].”

Service has indicated in at least one private letter ruling that payment for excess generation is taxable income. … Treatment of annual excess generation is an issue for the odd year when generation was higher than expected or consumption was lower than expected. Perpetual rollover of excess generation avoids the administrative burden of an annual reconciliation and gives the customer an assurance of credit for all energy delivered to the utility.

Column 7 indicates whether states explicitly allow or disallow third-party ownership of net metered systems (before the slash) and purchase power agreements (PPAs) between solar suppliers and individual retail customers (after the slash). Thirty states explicitly allow third-party ownership of net metered generators (encoded "y" for yes), and seven states explicitly disallow it (encoded "n" for no). The other state laws or rules do not clearly explain whether third-party ownership is allowed (encoded "-" to indicate uncertainty). Another factor of increasing importance for solar business models is whether states allow solar developers to enter into purchase power agreements (PPAs) covering sales to retail customers of solar-produced electricity. Using the same coding system, 22 states and Puerto Rico reportedly allow such PPAs, at least for some types of customers, and a half-dozen other states treat electricity sales to retail customers as an option available only to regulated public utilities and thus prevent solar dealers and customers from entering into this type of arrangement (USDOE, 2013e). Thus, solar business models in those states can allow developers to sell or lease solar panels to retail customers, but disallow contracts for the sale of the generated electricity, per se.

Column 8 lists 16 states offering some kind of group net metering provisions. Group net metering typically allows a generator to be owned by multiple, unaffiliated customers. These systems are most often not located on the roof or at the site of a home or business, and have more in common with small utility-scale installations than with conventional individual net metered systems. Each owner receives credit for their prorated share of the metered output of the group-owned generation, and that energy is treated for billing purposes just as if their share was produced by a net-metered generator located on the customer's premises. That program option is known as Solar Gardens in Colorado, and it is also variously called group, neighborhood, or virtual net metering in different states. Another variation on net metering, called aggregated net metering, allows a single customer to have the output of a generator attached to one meter to be netted against multiple billing meters, all on the same or adjacent customer premises.

As shown in Column 9, special RPS carve-outs are provided for solar or more generally for DG, special solar renewable energy credits (SRECs), or extra RECs, usually double (marked 2X) or triple (3X) RECs, are granted for solar or DG, in 21 states. Many states include more than one of these policies. These factors typically apply to apply to solar-powered merchant or utility plants but often apply to solar net metering customers, too (see Bird, Heeter, & Kreycik, 2011). Colorado, Delaware, Michigan, and Pennsylvania provide extra credits for renewable energy certificates or credits (RECs), and Delaware, Maryland, Massachusetts, Nevada, New Jersey, Pennsylvania make provisions for separate pricing for solar renewable energy certificates (SRECs), which have extra value by virtue of state renewable energy portfolio carve-outs. Connecticut terms its offerings the "Low Emissions Renewable Energy Credit (LREC) and Zero Emissions Renewable Energy Credit (ZREC) Program." In Connecticut, solar PV qualifies for ZRECs. In most of these circumstances, there are explicit provisions in laws or rules (indicated

"RECs" in Column 10) for these RECs or specialized RECs to accrue to the benefit of customers that host on-site solar PV systems.

The last column in Table 1, Column 10 indicates other solar support policies that states use frequently, separate from but mostly in addition to net metering. As Bird, Reger, and Heeter (2012, p. 3) report, "[N]et metering is available in most (if not all) utility service territories where solar incentive programs are in place." The codes in Column 10 (generally based on USDOE, 2013a) have the following meanings:

**EC:** **Equipment Certification** means the state provides for solar components or systems to be tested and certified, so that consumers can know ahead of time that specific systems will qualify for net metering and other incentives. Three states and Puerto Rico specifically provide for equipment certification. In some other states, however, utilities cooperate with recognized certification programs and maintain lists of qualifying equipment, even though there is no explicit provision for that in state solar laws or rules. It is also common for building and electrical code inspectors to seek confirmation of equipment testing and certification by recognized national laboratories before approving installation permits.

**FIT:** **Feed-In Tariff** programs, listed as available in eight states and the District of Columbia, usually establish a long-term fixed price for utility purchases. In most circumstances these are alternatives to net metering, and customers have a choice of participating in one program or the other, but not both. Feed-in tariffs are usually available to a limited amount of capacity, for systems that become operational in a particular, limited time period.

**IS:** **Industry Support**, available in some form in 21 states and Puerto Rico, means that the state provides financial incentives for the solar industry. These programs are mainly targeted at solar manufacturing plants, but are sometimes also available to other solar businesses, such as dealers and installers. These programs usually work under the auspices of the state's economic development agency.

**PTI:** **Property Tax Incentives** are available in 27 states, District of Columbia, and Puerto Rico. These variously include exemptions, exclusions, abatements, and credits.

**RECs:** **Renewable Energy Certificates** are generally tradable financial instruments that represent the production of one MWh of renewable electricity. In 21 states and the District of Columbia, customers self-generating solar electricity are credited with tradable renewable energy certificates for either gross or net energy produced. Some states, as indicated in Column 9, have rules that provide for specific solar renewable energy credits (SRECs). Eleven other states, also indicated "RECs" in Column 10, allocate RECs to net metering customers, without providing any special benefits or extra credit for solar or DG. Most states that offer extra credits, use SRECs, or have explicit carve-outs for solar or DG also have policies that explicitly allocate RECs to customers that self-generate using PV. The exceptions, where the REC policy for customer-sited systems is not explicitly articulated but the state has special RPS provisions for solar or DG, include Maryland (with SRECs), Texas and West Virginia (with extra credit multipliers), and Missouri, Ohio, New Mexico, New York, and North Carolina (with carve-outs).

**RSGP: Required Supplier Green Power** offerings apply in eight states that direct suppliers to offer customers one or more green pricing options. These are typically premium-price utility or competitive supplier rate offerings that include extra, sometimes as much as 100%, energy generated from renewable power sources. As reported by the U.S. Department of Energy (USDOE, 2013c), however, only some of these special products include solar energy.

**SA:** **Solar Access Laws**, on the books in 41 states and the U.S. Virgin Islands, are property rights that are intended to ensure that construction or vegetation on a neighbor's property will not shade a customer's solar panels.

**SF:** **Special Financing** means grants, loans, or rebates available for solar installations. Such programs are available in 25 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. Many of these programs are not continuously available: Sometimes limited amounts of funding are provided in a program tranche, and once those funds are expended the program is suspended until additional funds are allocated.

**STE:** **Sales Tax Exemptions**, available in 22 states, provide exemptions from or rebates of state sales taxes.

**TIC:** **Tax Incentive Corporate** includes credits and deductions that apply to state corporate taxes. These are available in 21 states and Puerto Rico.

**TIP:** **Tax Incentive Personal** includes credits or deductions that apply to state personal income taxes. These are available in 19 states and Puerto Rico, and 15 of those states and Puerto Rico offer tax incentives for both corporate and personal taxes.

**Table 1: Summary of Net Metering and Solar Incentives for U.S. States and Territories**

| (Col. 1) State/ Territory | (Col. 2) Year Net Metering Enacted (Amended) | (Col. 3) Residential / Commercial (% of eligible customers) | (Col. 4) Program Limit | (Col. 5) Individual System Limit | (Col. 6) Net Excess Generation Treatment[1] | (Col. 7) 3rd-Party Owners/ PPAs (-/y/n)[2] | (Col. 8) Group Net Metering | (Col. 9) Solar or DG Special RPS Provisions | (Col. 10) Supporting Policies[3] |
|---|---|---|---|---|---|---|---|---|---|
| Alabama | | 0.0012%/ <0.01% | | | | -/- | | | |
| Alaska | 2010 | 0.014%/ 0.02% | 1.5% | 25 kW | Non-firm power, indefinite | y/- | | | PTI, SA, SF |
| Arizona | 2008 | 0.44%/ 0.016% | None | 125% of customer annual usage | Retail, avoided-cost | y/y | | 4.5% DG by 2025 | EC, IS, PTI, RECs, SA, STE, TIC, TIP |
| Arkansas | 2001 (2007, 2012) | 0.014%/ <0.01% | None | 25 kW (Res), 300 kW | Retail, granted | -/- | n | | IS, RECs |
| California | 1995 (2002, 2003, 2006, 2008, 2010, 2011, 2012) | 0.89%/ 0.025% | 5%, 1,940 MW of PV | 1 MW (Privately owned), 5 MW (Publicly owned) | Retail, indefinite | y/y | y | | FIT, IS, PTI, RECs, SA, SF, STE |
| Colorado | 2005 (2008, 2009, 2012) | 0.58%/ 0.053% | None | 120% of customer annual usage | Retail, indefinite | y/y | y | 3% DG by 2020; 3X RECs | PTI, RECs, RSGP, SA, SF, STE |
| Connecticut | 1998 (2011, 2013) | 0.17%/ 0.024% | None | 2 MW | Retail, avoided-cost | -/y | y | ZRECs | IS, PTI, RECs, SF, STE |
| Delaware | 1999 (2007, 2009, 2011) | 0.23%/ 0.026% | 5% | Varies | Retail, indefinite | y/y | | 3.5% PV by 2026; 3X RECs; SRECs | RECs, SA, SF |
| See Table Notes at end of Table, on page 21. | | | | | | | | | |

**Table 1 (continued): Summary of Net Metering and Solar Support Policies for U.S. States and Territories**

| (Col. 1) State/ Territory | (Col. 2) Year Net Metering Enacted (Amended) | (Col. 3) Residential / Commercial (% of eligible customers) | (Col. 4) Program Limit | (Col. 5) Individual System Limit | (Col. 6) Net Excess Generation Treatment[1] | (Col. 7) 3rd-Party Owners/ PPAs (-/y/n)[2] | (Col. 8) Group Net Metering | (Col. 9) Solar or DG Special RPS Provisions | (Col. 10) Supporting Policies[3] |
|---|---|---|---|---|---|---|---|---|---|
| District of Columbia | 2000 (2008) | 0.18%/ 0.011% | None | 1 MW | Retail or generation, indefinite | y/y | | 2.5% solar by 2023 | FIT, PTI RECs, SF |
| Florida | 2008 | 0.045%/ 0.05% | None | 2 MW | Retail, avoided-cost | n/n | | | EC, RECs, SA, STE, TIC |
| Georgia | 2001 | 0.0084%/ 0.02% | 0.2% | 10 kW (Res), 100 kW | Pre-determined, reconciled monthly | n/n | | | SA, TIC, TIP |
| Hawaii | 2001 (2004, 2005, 2008, 2011) | 2.34%/ 1.09% | 15% | 50 kW for Kauai, 100 kW for others | Retail, granted | -/y | | | FIT, SA, SF, TIC, TIP |
| Idaho | * | 0.0031%/ 0.02% | | | | -/- | | | SA, SF, TIP |
| Illinois | 2007 (2012) | 0.0099%/ 0.02% | 5% | 2 MW | Retail, granted | y/y | y | 1.5% PV, 0.25% DG by 2025 | IS, PTI, RECs, SA, SF |
| Indiana | 2004 (2011) | 0.0087%/ 0.02% | 1% | 1 MW | Retail, indefinite | -/- | | | PTI, SA, SF, STE, TIP |
| Iowa | 1984 | 0.0059%/ <0.01% | None | 500 kW | Retail, indefinite | -/n | | | PTI, RSGP, SA, SF, STE, TIC, TIP |
| Kansas | 2009 (2010) | 0.0063%/ 0.01% | 1% | 25 kW (Res), 200 kW | Retail, granted | y/- | | | IS, PTI, SA |
| See Table Notes at end of Table, on page 21. | | | | | | | | | |

**Table 1 (continued): Summary of Net Metering and Solar Support Policies for U.S. States and Territories**

| (Col. 1) State/ Territory | (Col. 2) Year Net Metering Enacted (Amended) | (Col. 3) Residential / Commercial (% of eligible customers) | (Col. 4) Program Limit | (Col. 5) Individual System Limit | (Col. 6) Net Excess Generation Treatment[1] | (Col. 7) 3rd-Party Owners/ PPAs (-/y/n)[2] | (Col. 8) Group Net Metering | (Col. 9) Solar or DG Special RPS Provisions | (Col. 10) Supporting Policies[3] |
|---|---|---|---|---|---|---|---|---|---|
| Kentucky | 2004 (2009) | 0.011%/ <0.01% | 1% | 30 kW | Retail, indefinite | n/n | | | IS, RECs, SA, SF, STE, TIC, TIP |
| Louisiana | 2003 (2005, 2011) | 0.065%/ 0.02% | 0.5% | 25 kW (Res), 300 kW | Retail, indefinite | y/- | | | PTI, SA, TIC, TIP |
| Maine | 1987 (2000, 2009) | 0.097%/ 0.011% | None | 660 kW (IOUs), 100 kW (others) | Retail, granted | y/- | y | | FIT, RSGP, SA, SF |
| Maryland | 1997 (2011, 2012) | 0.11%/ 0.09% | 1,500 MW | 2 MW or 200% of customer annual usage | Retail, commodity energy | y/y | y | 2% solar by 2020; SRECs | PTI, SA, SF, STE, TIC, TIP |
| Massachusetts | 1982 (1997, 2009, 2012) | 0.14%/ 0.02% | 3% | Varies | Varies | y/y | y | 400MW PV by 2020; SRECs | IS, PTI, RECs, SA, SF, STE, TIC, TIP |
| Michigan | 2008 | 0.018%/ 0.03% | 0.75% | 150 kW | Retail/power supply, indefinite | y/y | | 3X RECs | IS, PTI, RECs, SF |
| Minnesota | 1983 (2000, 2013) | 0.027%/ 0.04% | None | 40 kW, 120% or 1MW (IOUs) | Avoided cost, reconciled monthly | y/- | y | | FIT, EC, PTI, SA, SF, STE |
| Mississippi | | 0.0003%/ <0.01% | | | | -/- | | | IS, SF |
| See Table Notes at end of Table, on page 21. | | | | | | | | | |

**Table 1 (continued): Summary of Net Metering and Solar Support Policies for U.S. States and Territories**

| (Col. 1) State/ Territory | (Col. 2) Year Net Metering Enacted (Amended) | (Col. 3) Residential / Commercial (% of eligible customers) | (Col. 4) Program Limit | (Col. 5) Individual System Limit | (Col. 6) Net Excess Generation Treatment[1] | (Col. 7) 3rd-Party Owners/ PPAs (-/y/n)[2] | (Col. 8) Group Net Metering | (Col. 9) Solar or DG Special RPS Provisions | (Col. 10) Supporting Policies[3] |
|---|---|---|---|---|---|---|---|---|---|
| Missouri | 2007 (2009) | 0.002%/ 0.05% | 5% | 100 kW | Avoided-cost, granted | y/- | | 0.3% solar by 2021 | PTI, SA, SF |
| Montana | 1999 (2001) | 0.14%/ 0.02% | None | 50 kW | Retail, granted | -/- | | | IS, PTI, RSGP, SA, SF, TIC, TIP |
| Nebraska | 2009 | 0.004%/ <0.01% | 1% | 25 kW | Avoided-cost, avoided-cost | y/- | | | RECs, SA, SF, TIC, TIP |
| Nevada | 1997 (2007, 2011) | 0.16%/ 0.022% | 2% | 1 MW or 100% of customer annual usage | Retail, indefinite | y/y | | 1.5% solar by 2025; 2.4X–2.45X PV RECs | PTI, RECs, SA, SF, STE |
| New Hampshire | 1983 (1994, 2001, 2011) | 0.097%/ 0.09% | 50 MW | 1 MW | Retail, avoided-cost | y/y | | 0.3% solar by 2014 | PTI, RECs, SA, SF |
| New Jersey | 1999 (2008, 2010) | 0.37%/ 0.05% | None (BPU may limit to 2.5%) | 100% of customer annual usage | Retail, avoided-cost | y/y | y | 4.1% solar by 2028; SRECs | IS, PTI, RECs, SA, STE |
| New Mexico | 2008 | 0.35%/ 0.2% | None | 80 MW | Avoided-cost, avoided-cost | y/y | | 4% solar, 0.6% DG by 2020 | IS, PTI, RSGP, SA, STE, TIC, TIP |
| See Table Notes at end of Table, on page 21. | | | | | | | | | |

**Table 1 (continued): Summary of Net Metering and Solar Support Policies for U.S. States and Territories**

| (Col. 1) State/ Territory | (Col. 2) Year Net Metering Enacted (Amended) | (Col. 3) Residential / Commercial (% of eligible customers) | (Col. 4) Program Limit | (Col. 5) Individual System Limit | (Col. 6) Net Excess Generation Treatment[1] | (Col. 7) 3rd-Party Owners/ PPAs (-/y/n)[2] | (Col. 8) Group Net Metering | (Col. 9) Solar or DG Special RPS Provisions | (Col. 10) Supporting Policies[3] |
|---|---|---|---|---|---|---|---|---|---|
| New York | 1997 (2002, 2004, 2008, 2010, 2012, 2013) | 0.12%/ 0.01% | 3% | 25 kW (Res), 2 MW | Retail, indefinite | y/y | y | 0.4092% customer-sited by 2015 | PTI, SA, SF, TIC, TIP |
| North Carolina | 2005 (2009) | 0.006%/ <0.01% | None | 1 MW | Retail, granted | n/n | | 0.2% solar by 2018 | IS, PTI, SA, SF, TIC, TIP |
| North Dakota | 1991 | 0.003%/ <0.01% | None | 100 kW | Avoided-cost, reconciled monthly | -/- | | | PTI, RECs, SA, STE, TIC |
| Ohio | 1999 (2002, 2008) | 0.018%/ 0.06% | None | None | Unbundled generation | y/y | | 0.5% solar by 2025 | PTI, SA, SF, STE |
| Oklahoma | 1988 | 0.007%/ <0.01% | None | 100 kW or 25,000 kWh/year | Varies | -/n | | | IS, SF, TIC |
| Oregon | 1999 (2007) | 0.28%/ 0.02% | 0.5% | Varies | Varies | y/y | y | 20MW PV by 2020; 2X RECs. | FIT, IS, PTI, RECs, RSGP, SA, SF, TIP |
| Pennsylvania | 2004 (2008, 2012) | 0.12%/ 0.01% | None | 50 kW (Res), 3 MW | Retail, price-to-compare | y/y | y | 0.5% PV by 2021; 3X RECs; SRECs | IS, RECs, SF |
| Rhode Island | 2011 | 0.042%/ 0.08% | 3% | 100% of customer annual usage | Avoided-cost, indefinite | n/y | y | | FIT, PTI, SA, SF, STE, TIC |
| See Table Notes at end of Table, on page 21. | | | | | | | | | |

**Table 1 (continued): Summary of Net Metering and Solar Support Policies for U.S. States and Territories**

| (Col. 1) State/ Territory | (Col. 2) Year Net Metering Enacted (Amended) | (Col. 3) Residential / Commercial (% of eligible customers) | (Col. 4) Program Limit | (Col. 5) Individual System Limit | (Col. 6) Net Excess Generation Treatment[1] | (Col. 7) 3rd-Party Owners/ PPAs (-/y/n)[2] | (Col. 8) Group Net Metering | (Col. 9) Solar or DG Special RPS Provisions | (Col. 10) Supporting Policies[3] |
|---|---|---|---|---|---|---|---|---|---|
| South Carolina | * | 0.008%/ <0.01% | | | | -/- | | | SF, TIC, TIP |
| South Dakota | | 0.002%/ <0.01% | | | | -/- | | | PTI, SA, SF |
| Tennessee | | 0.0006%/ <0.01% | | | | -/- | | | IS, PTI, SA, STE |
| Texas | * | 0.039%/ 0.04% | | | | -/y | | 2X RECs, 500MW goal for non-wind | IS, PTI, SA, SF, TIC |
| Utah | 2002 (2009, 2010) | 0.13%/ 0.014% | 20% (0.1% for co-ops) | 25 kW (Res), 2 MW | Varies | y/y | y | 2.4X RECs | IS, RECs, SA, STE, TIC, TIP |
| Vermont | 1998 (2009, 2012) | 0.38%/ 0.2% | 4% | 500 kW | Retail, granted | y/y | y | | FIT, PTI, SA, SF, STE, TIC |
| Virginia | 1999 (2010, 2011) | 0.031%/ 0.03% | 1% | 20 kW (Res), 500 kW | Retail, indefinite or avoided-cost | y/- | | | IS, PTI, RECs, RSGP, SA, SF |
| Washington | 1998 | 0.076%/ 0.07% | 0.5% | 100 kW | Retail, granted | y/- | y | 2X RECs for DG | FIT, IS, RECs, RSGP, SA, STE |
| West Virginia | 2006 (2010, 2011) | 0.017%/ 0.02% | 3% | Varies | Retail, indefinite | y/- | y | Extra RECs (varies) | SA, TIP |
| See Table Notes at end of Table, on page 21. | | | | | | | | | |

**Table 1 (continued): Summary of Net Metering and Solar Support Policies for U.S. States and Territories**

| (Col. 1) State/ Territory | (Col. 2) Year Net Metering Enacted (Amended) | (Col. 3) Residential / Commercial (% of eligible customers) | (Col. 4) Program Limit | (Col. 5) Individual System Limit | (Col. 6) Net Excess Generation Treatment[1] | (Col. 7) 3rd-Party Owners/ PPAs (-/y/n)[2] | (Col. 8) Group Net Metering | (Col. 9) Solar or DG Special RPS Provisions | (Col. 10) Supporting Policies[3] |
|---|---|---|---|---|---|---|---|---|---|
| Wisconsin | 1982 (2011) | 0.035%/ 0.07% | None | 20 kW | Retail | n/- | | | PTI, SA, SF, STE |
| Wyoming | 2001 (2003) | 0.069%/ 0.05% | None | 25 kW | Retail, avoided-cost | y/- | | | |
| U.S. Territories | | | | | | | | | |
| American Samoa | 2008 | | 5% | 30 kW | Retail, granted | -/- | | | |
| Guam | 2008 (2010) | | None | 25 kW (Res), 100 kW | Varies | -/- | | | |
| Puerto Rico | 2008 (2012) | | None | Varies | Retail | -/y | | | EC, IS, PTI, SF, TIC, TIP |
| U.S. Virgin Islands | 2009 | | 10 MW | 20 kW (Res), 100 kW | Retail, granted | -/- | | | SA, SF |
| See Table Notes at end of Table, on page 21. | | | | | | | | | |

**Table 1 (continued): Summary of Net Metering and Solar Support Policies for U.S. States and Territories**

| (Col. 1) State/ Territory | (Col. 2) Year Net Metering Enacted (Amended) | (Col. 3) Residential / Commercial (% of eligible customers) | (Col. 4) Program Limit | (Col. 5) Individual System Limit | (Col. 6) Net Excess Generation Treatment[1] | (Col. 7) 3rd-Party Owners/ PPAs (-/y/n)[2] | (Col. 8) Group Net Metering | (Col. 9) Solar or DG Special RPS Provisions | (Col. 10) Supporting Policies[3] |
|---|---|---|---|---|---|---|---|---|---|

Source: Database of State Incentives for Renewables & Efficiency (2013, www.dsireusa.org).

* Blanks in Col. 2, for Alabama, Mississippi, South Dakota, and Tennessee, indicate that there is no legislated or commission-regulated net metering program and no utility is publicly reporting a net metering offering, yet some net metering data (as shown in Col. 3) is reported to EIA. Asterisks (in Col. 2, for Idaho, South Carolina, and Texas) indicate there is no legislated or commission-regulated net metering program, but one or more utilities does offer net metering and reports data to EIA.

[1] Net Excess Generation is credited at either retail price or some other avoided-cost or non-firm power price. Many state programs allow for credits to be carried forward indefinitely. "Granted" means excess generation is credited to the utility. Several other utilities reconcile any credits monthly, usually valuing credits based on an estimate of wholesale avoided-cost.

[2] In this column, "y" means explicitly allowed, "n" means disallowed, and "-" means unknown, or not explicitly addressed in the state's related statute or rules. In each cell, the character before the slash reflects the status of 3rd Party Ownership and the second character, after the slash, reflects the policy regarding solar purchase power agreements (PPAs).

[3] Supporting policies listed in Column 10 include: EC–Equipment Certification; FIT–Feed-In Tariff; IS–Industry Support; PTI–Property Tax Incentives; RECs–Renewable Energy Certificates; RSGP–Required Supplier Green Power offerings; SA–Solar Access Laws; SF–Special Financing (grants and loans); STE–Sales Tax Exemption; TIC–Tax Incentive Corporate; and TIP–Tax Incentive Personal.

## IV. Analyzing Net Metering Benefits and Costs

Several studies analyze the benefits and costs of utility net metering programs. A dozen major modeling studies are summarized briefly in Table 2 (pp. 31-33). Table 2 depicts the rather broad scope of analysis involved in such assessments, listing the major categories of benefits and costs (with cost data shown in parentheses) that are most often included.

A few major observations drawn from reviewing these and other, similar studies include: (1) net utility system benefits sometimes equal or exceed retail rates, (2) situational differences affect costs and benefits, (3) costs and benefits change as adoption levels grow, and (4) achieving consensus on modeling and analysis techniques is difficult. Each of these observations is discussed in more detail, beginning on page 24.

The studies summarized in Table 2 and further described here represent several of the most extensive reviews completed to date, but none of them is fully exhaustive or conclusive. That is to be expected in this situation, where study parameters are still developing and modeling requirements are complex.

For example, in addition to the categories of benefits listed in Table 2, no benefits are included for the possible assistance that distributed solar PV generation could provide for: (a) blackout prevention, (b) outage recovery, (c) emergency dispatch, (d) managing load uncertainty, (e) retail price hedging, and (f) voltage and reactive power control (Keyes & Wiedman, 2012, pp. 6-9). Similarly, Burgos-Payán, Roldán-Fernández, et al. (2013) surmise that environmental benefits include greenhouse-gas reductions and estimated health-care cost avoidance, and propose considering benefits that accrue due to diversification of energy supply associated with downward pressure on wholesale prices, long-term supply security, import reductions, creation of a domestic industry, enhanced opportunities for regional and rural development, and job creation. Barnham, et al. (2013, p. 385-87) note the propensity of solar PV to help reduce peak power prices.

Nor do many of the studies attempt to consider any potential benefits from electricity storage associated with on-site solar PV. In addition, the studies by Perez et al. attempt to analyze the local economic development value associated with increased solar PV installations, estimating the value of "enhanced tax revenues associated with net job creation for solar versus conventional power generation" (Perez, Norris, & Hoff, 2012, pp. 45-47).

Similarly, the costs analyzed are not exhaustive. In addition to the cost categories listed, utilities often cite costs associated with grid interconnections for distributed generators, associated incremental distribution O&M costs, and standby costs. California Public Utilities Commission (2009) determines that standardized ratepayer impact measure (RIM) test costs are to include "reduced revenue from standby charge exemptions, lost revenue from non-bypassable charges, reduced T&D and non-fuel generation revenues, increased reliability costs for ancillary services and VAR support, cost of utility rebates or incentives, the cost of utility interconnection not charged to customer-generators" (Keyes & Wiedman, 2012, p. 10). The California E3 (Energy and Environmental Economics, 2010) study includes interconnection costs, which under

California law are not billed to net metering customers. In California and many other states, net metering customers are exempt from standby charges.[9]

In addition to the modeling studies listed in Table 2, other researchers have identified categories of solar-value benefits and costs, without necessarily quantifying their values. For example, Hoke and Komor (2012, pp. 56-61) identify a dozen already existing benefits from distributed PV, which include (1) reduced fuel costs; (2) reduced O&M costs; (3) reduced line losses; (4) reduced purchase-power costs; (5) generation and transmission investment deferral; (6) distribution investment deferral; (7) reduced land-use and rights-of-way issues; (8) capacity value; (9) differential time-value of energy; (10) reduced electricity demand; (11) multiplication of demand-response effectiveness; and (12) price stability/predictability. They also list as "emerging benefits" voltage regulation and other advanced control techniques. Hoke and Komor (2012, pp. 61-63) also itemize a half-dozen costs that could possibly be attributed to distributed PV, which include: (1) reduced utility revenues; (2) administrative costs; (3) operating reserve costs; (4) power quality costs; (5) possible PV curtailment costs; and (6) distribution equipment upgrades.

The Solar America Board for Codes and Standards (Solar ABCs) study, by Keyes and Wiedman (2012) reviews and comments on three of the other major studies: E3 (Energy and Environmental Economics, 2010), Austin Energy (Rábago, Libby, et al., 2011), and Arizona Public Service (APS study, by R.W. Beck and Associates, 2009). The Crossborder Energy (Beach and McGuire, 2012) study focuses on rate design issues and whether non-participating customers are subsidizing net metering customers. The Crossborder study also includes a review and comments on the E3 study and a related Lawrence Berkeley National Laboratory study (Darghouth, Barbose, & Wiser, 2010) which is not summarized in Table 2.

Similar Navigant studies are completed for Nevada (NV) Energy (Navigant Consulting, 2010) and for Arizona Public Service (APS) (Navigant Consulting, 2012). It should be noted that the NV Energy (Navigant Consulting, 2010) study is primarily devoted to answering questions about the technical and operational aspects of integrating increasing amounts of distributed solar PV into the grid, and focuses less on the specific economic and ratemaking impacts associated with net metering. The Navigant APS study is more directly focused on the reduction in utility revenues related to net metering, netting out the billed cost of fuel. That study's reported intent was to measure "cross-subsidies provided to APS customers with solar generation due to monthly bill savings and net metering" (Navigant Consulting, 2012, p. 1). Also, both Navigant studies (2010 and 2012) model PV as displacing an average on-peak and off-peak cost of energy, derived from the utility's integrated resource plan modeling, rather than hourly avoided cost.

Some of the studies listed in Table 2 (Austin Energy, APS, E3) attempt to systematically identify and calculate the value-of-solar (VOS) energy to the utility. In some cases, these studies

[9] Customers with variable-output generators, such as solar or wind, should not pay standby charges because: (a) on many rate structures they will pay demand charges that reflect their use of service; and (b) multiple customers with such generators effectively back up one another, so that their supplier of generation service does not bear any incremental cost for providing standby service to them. See Stanton, 2012, pp. 21, 30.

led to establishing a value-of-solar tariff (VOST) as an adjunct or alternative to net metering. Austin Energy explicitly calls its tariff VOST, while California refers to its as a FIT (California PUC, 2013). These studies model hourly solar PV production and hourly electricity prices. On that basis, it is not unusual to find that the total value-of-solar energy is equal to or greater than the retail rate.

Rabago, Libby, et al. (2012) calculated Austin Energy's 2008 levelized VOST to be 16.4¢/kWh, while the comparable residential rate was 11.47¢/kWh for consumption of more than 500 kWh/month from May through October (Keyes & Wiedman, 2012, p. 6). The E3 study (Energy and Environmental Economics, 2010) found minimal solar rate impacts, on the order of 0.1% impact on utility rates for each 1% contribution solar PV makes to meeting utility peak demand (Keyes & Wiedman, 2012, p. 12). Keyes and Wiedman (2012, pp. 12-18) explain that the E3 study likely overestimates rate impacts, though, because it overestimates certain costs and does not fully account for all known benefits that distributed solar is capable of providing.

### A. Net utility system benefits sometimes equal or exceed retail rates

Several recent studies of the value of distributed solar energy conclude that there is little, if any, subsidy to solar producers when solar electricity is valued at the customer's average retail price, which it is in many net metering programs. This is because solar PV production in many jurisdictions generally coincides with high-cost days and hours, thus displacing what would otherwise be above-average cost, marginal energy production, or purchases. In these cases, typical for utilities with peak demands related to air-conditioning loads, net metering does not result in cross-subsidies from non-participating to participating customers. On the contrary, where utility system benefits from solar PV production exceed retail rates, then net metering can be understood as actually under-compensating the participating customers. This happens both because the electric supplier's avoided energy production or purchases would have a value higher than average retail rates, and because net metering does not compensate producers for any additional distributed benefits.

Note that several of the studies listed in Table 2 indicate "+" in the row which denotes a finding of positive "net value-of-solar energy." That is basically because the hours of the day and months of the year when solar production is highest correspond quite well to air-conditioning loads and thus to high-usage and high-cost time periods. This means that the utility's avoided energy cost during the hours of solar production tends to be enough above average that it is not unusual for the aggregated value-of-solar production to equal or exceed the average retail price. That effect can occur even when the only value considered for solar PV is the hourly avoided energy cost, but it is even more likely when additional distributed resource cost savings are included in modeling a total value-of-solar. Under these circumstances, solar net metering customers are effectively producing benefits in excess of costs. This implies that cross-subsidies, if any, are from the participating customers to the non-participants.

This is not to say that net metering is necessarily an ideal way to assign the associated benefits and costs, based on long-standing cost-causation principles. Rather, it simply acknowledges that under current conditions in many markets there is presently little practical difference, for the utility and for non-participating customers, between current net metering practices and an alternative buy-all/sell-all arrangement, in which the customer purchases all their usage from the utility under standard tariff rates and sells the entire output from their solar panels to the utility at the utility's avoided hourly marginal cost. In theory, a utility would be indifferent between net metering and an alternative buy-all/sell-all arrangement, where a customer sells the entire output of their PV system to the utility at a rate equal to the full value-of-solar energy. An important difference for the participating customer, however, is that revenues from the sale of electricity will be treated as taxable income under a buy-all/sell-all arrangement, whereas net metering can avoid that concern (Keyes & Wiedman, 2012, p. 4).

### B. Situational differences affect costs and benefits

Several of the categories of benefits and costs can vary substantially from one utility to another, and for the same utility at different points in time. Since solar PV systems are typically expected to continue operating for 25 years or more, it is important to consider a fairly long-term time horizon when evaluating costs and benefits. And, of course, the farther into the future one attempts to model costs and benefits, the more uncertainty results.

Costs and benefits vary markedly depending on economic, market, and technical conditions in different states and utility service territories. The costs and benefits also vary over time in each jurisdiction as circumstances change.

At any rate, one prominent example of widely varying cost is RPS costs, which can be substantial for some utilities and minimal or non-existent for others. As Keyes and Wiedman (2012, p. 20) point out, utilities in states without an RPS are not likely to have savings equivalent to those in states that do have an RPS. Even in states with no RPS, however, solar renewable energy certificates (SRECs) can have value in voluntary markets or through sales to mandatory markets in other states. Another example is costs associated with capacity purchases. Those depend on electric industry market structure, on each utility's present and foreseeable future situation regarding the adequacy of existing capacity and reserve margins, and on the extent to which the utility's system peaks tend to match the general annual cycles of solar production, which are generally higher in the summer months and lower in winter, due to the variations throughout the year in the hours of daylight and timing of maximum solar radiation. A third example comes from reports of utility administrative costs to manage net metering and billing. In its review of California's investor-owned utilities, Energy and Environmental Economics (2010, pp. 9, 39-40) notes that one utility reports residential net metering billing costs of about \$3 a month, a second utility about \$6, and a third utility about \$18.

A major challenge in determining both utility and consumer benefits and costs is that rate structures vary markedly, especially in terms of fixed versus variable charges and the extent to which energy charges reflect average, time-of-use, or hourly prices. In many jurisdictions, residential electric rates are based on only two major billing determinants: (1) a fixed monthly customer charge, and (2) a variable energy use charge. Most commercial rates, however, have three components: (1) a fixed monthly customer charge; (2) a fixed demand-charge per kW, reflecting the highest amount of power used during any hour (or sometimes shorter-duration portion) of the billing period (or sometimes the highest usage measured over a longer previous time period); and (3) a variable energy-use charge, reflecting kWh use in the billing period. The impact from net metering on utility revenues is thus quite different for residential as compared to commercial customers. In theory, residential customers might produce enough net energy over the course of a year to drive their variable energy-use charges to zero, or close to it. That is what engenders the concern that such customers might not pay their fair share of embedded distribution-system costs. Commercial customers, on the other hand, pay fixed demand charges that do not change much, if at all, when variable-output generation, such as solar, is installed.

A further complication is that solar PV production, with or without thermal or electricity storage, could be usefully coordinated with consumer demand response, utility load management, and many varieties of energy-efficiency measures, so that the combined effects of groups of resources will best match utility-system peak loads. These capabilities remain to be verified through demonstration projects, however. (See footnote 10 on p. 29.)

Because of these kinds of situational differences among states, utilities, and specific locations on the utility grid, and across different periods of time, it is necessary to model, as accurately as is practical, the specific benefits and costs for each utility company and for various PV system sizes and locations. As the U.S. Department of Energy (USDOE, 2007, p. v) explains about analyzing the benefits of DG:

> Calculating DG benefits is complicated, and ultimately requires a complete dataset of site-specific operational characteristics and circumstances. This renders the possibility of utilizing a single, comprehensive analysis tool, model, or methodology to estimate national or regional benefits of DG highly improbable. However, methodologies exist for accurately evaluating "local" costs and benefits (such as DG to support a distribution feeder). It is also possible to develop comprehensive methods for aggregating local DG costs and benefits for substations, local utility service areas, states, regional transmission organizations, and the nation as a whole.

The reverse is also true: Comparing solar PV or any other DG to bulk energy and capacity costs is a gross oversimplification and is not good modeling practice. Rather, value-of-solar calculations should attempt to include all of the particular distributed benefits that solar PV can provide.

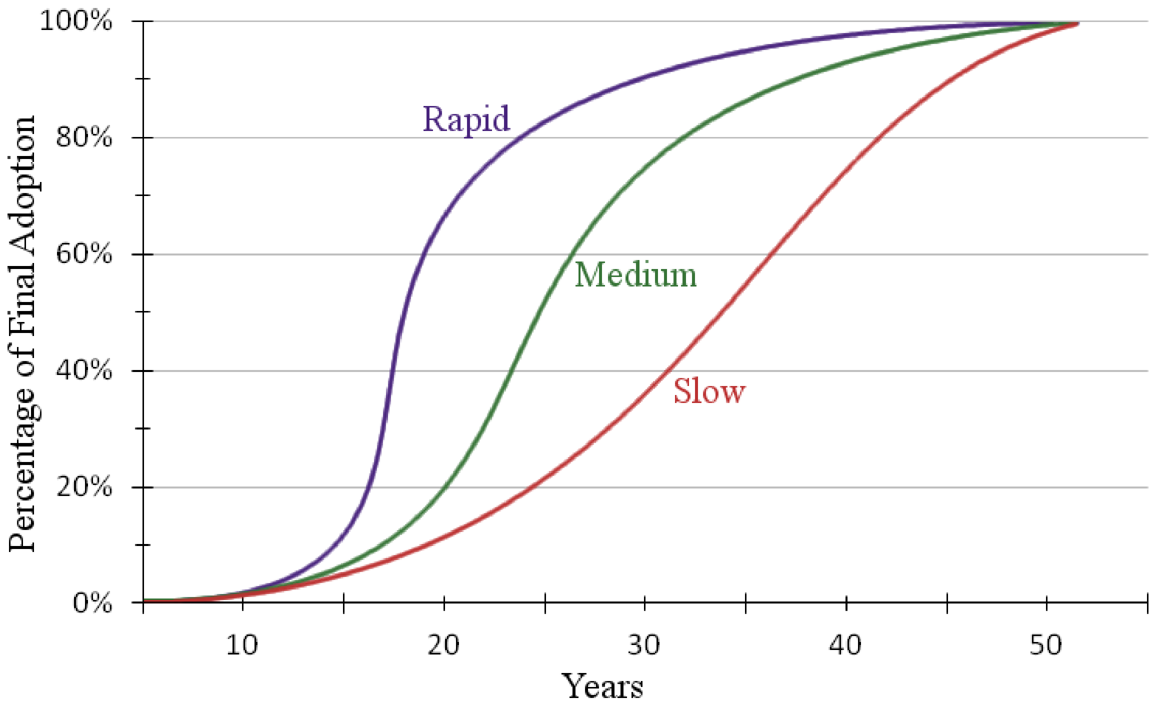
### C. Costs and benefits change as adoption levels grow

An additional complication for value-of-solar modeling is understanding how the costs and benefits change as more customers install, and more energy and capacity is supplied by, distributed solar PV systems. Modelers have to determine how large a population of solar PV and what time period to analyze.

The effects associated with growing populations of solar PV and varying durations of analysis are generally related to the fact that many utility infrastructure investments are lumpy. Being "lumpy" means utility investments are made in relatively large increments, which means they are also possibly avoidable or avoided in relatively large increments, too.

Some general trends that often apply to changes in benefits and costs are illustrated in Figure 2, which shows s-curves representing more rapid, medium, and slow growth rates. In Figure 2, “rapid” growth reaches about 80% of eventual market saturation in about 20 years, “medium” about 30 years, and “slow” about 40 years. Studies of many different kinds of new inventions and new products show a common tendency for innovations to take as long as 15 years or more to progress from a test-bench or laboratory setting to commercial viability (Rogers, 2003). In the case of solar photovoltaics, the phenomenon was first described in 1839, and the first photovoltaic cells were used in the U.S. space program in the mid-1950s. It took about 30 more years for PV cells to enter into widespread commercial production, and another 30 years passed before the solar PV market finally reached and started to pass the first s-curve inflection point, marking the point where industry growth started the current, rapid trend. (USDOE, no date).

**Figure 2: Representative, Generic S-Curves of New Product Market Growth**




Source: Author’s construct based on Rogers (2003).

Often, both benefits and costs accrue in typical s-curves, where effects are minor at first. For each category of benefit or cost, an inflection point is typically reached as the number and size of cumulative installations reaches some minimum threshold. Below the minimum, benefits and costs might both be small. Once some minimum size is reached for each benefit or cost analyzed, though, then a fairly direct relationship holds for each added increment of solar PV, up until some higher inflection point is reached. In those more vertical and generally flatter sections of an s-curve, additional increments produce added benefits or costs in a fairly steady relationship. After reaching some upper inflection point in the s-curve, the theoretically applicable tendency will be for each added unit of PV supply to result in reduced incremental benefits or increased incremental costs. However, accurately projecting the ultimate shape of such s-curves is fraught with difficulties and complexities. And, as discussed in Part II, PV production in all but a few jurisdictions is still at very modest levels, probably still remaining at or near the very bottom of their s-curves, while only a few jurisdictions might be experiencing growth already sufficient to reflect the start of a vertical sloping section.

A prominent example of variability in benefits and costs is associated with distribution system capital and O&M benefits and costs. At a minimal level, distributed solar PV will have a barely discernible effect, but as PV contributions rise on a particular distribution feeder, these values might increase fairly substantially. Then, eventually, PV contributions might conceivably increase to a level where incremental capital and O&M expenditures are required to manage energy flows and the variability of loads, thus adding to costs. Interconnection rules and standards frequently require distributed generators to pay some or all of these costs.

Another example is the value of avoided energy purchases. Distributed energy production can be modeled like demand reductions, which avoid marginal, highest-hourly-cost energy purchases. Solar PV production usually aligns fairly closely with utility-system load profiles, at least for those utilities with peaks that are highly influenced by air conditioning loads. Thus, solar PV starts to displace higher-cost marginal energy purchases. As that displacement increases, however, the marginal value starts to decrease stepwise with decreases in the marginal purchase prices (Olson & Jones, 2012). Darghouth, Barbose, and Wiser (2013, 2011) modeled this effect under a variety of utility supply scenarios, rates, and billing arrangements and found substantial differences in the value of customer bill savings. One of the most important preliminary findings from that analysis is that the value of bill savings under most circumstances is likely to decline as solar PV contributions increase to as much as 15% of total requirements. But at this point in time, no jurisdiction in the U.S. is close to this level of solar PV.

Similarly, in theory an influx of solar PV can put downward pressure on overall utility rates and on natural gas prices, but those effects will also proceed in an s-curve. There would likely be no discernible effect at the lowest levels of PV production, then increasing effects to a certain point, then diminishing effects once growth increases further.

The R.W. Beck study (2009, pp. 5-8–5-9) indicates that, from a system-planning perspective, solar PV production equal to more than just a few percent of peak demand will be associated with diminishing dependable capacity. That study refers several times to a "Law of Diminishing Returns" that can apply to many of the potential benefits of solar PV, as production increases. Perez, Norris, and Hoff (2012, p. 11) also anticipate there could be diminishing returns from increasing solar PV capacity because:

- The match between PV output and loads is reduced. As more PV is added to the resource mix, the system peak tends to shift toward non-solar hours, thereby reducing PV's ability to deliver power during the hours of peak demands.[10]

[10] Solar electricity in ample quantities could tend to shift peak loads to later in the day, after the angle of the sun starts to head toward the horizon, reducing the output from solar PV systems. A

- Line losses are related to the square of the load. Consequently, the greatest marginal savings provided by PV is achieved with small amounts of PV. Increasing quantities of PV will reduce line losses, but with decreasing results per unit of capacity.

- Similarly, energy and capacity market prices are non-linear and fairly lumpy, and small amounts of PV capacity are most effective in reducing market prices: As PV capacity grows, the marginal cost of energy and capacity displaced will eventually tend toward lower prices, eventually trending toward the average price.

Thus, a point of contention in solar value studies is where, on each benefit or cost s-curve, to model incremental solar installations. An important lesson from the existing studies is that detailed modeling of multiple scenarios is necessary to tease out reasonably reliable data on benefits and costs. As depicted in the R.W. Beck study for Arizona Public Service (2009, pp. 6-14), modeling can result in rather broad range of values. In that study, solar distributed energy is valued at a range from about 8 to 14 ¢/kWh. That study (Section 3) also depicts how PV benefits and costs depend on many details of the utility grid and customer loads.[11] In that example, distribution-system line losses and deferral of capital expenditures were modeled for almost two dozen specific feeders, resulting in widely varying ranges of values. Again, however, some declines in benefits will occur only after much growth in what are now small rates of PV production in U.S. markets.

### D. Achieving consensus on modeling and analysis techniques is difficult

The various interested parties do not necessarily agree on what categories of benefits and costs should be included, how to value them, and what time horizons to consider. Table 2 (pp. 31-33) illustrates some of these differences among studies conducted by different parties.

Solar PV in particular, and distributed generation and net metering in general, are potentially contentious subjects, where interested parties frequently have widely divergent perspectives. Thus, it can prove difficult to achieve consensus on modeling and analysis techniques. All three of the previously discussed issues play into this divergence, and a variety of other existing economic, institutional, and political circumstances will all affect the perspectives held by utilities, solar interest groups, and other ratepayers and ratepayer advocates. Potentially important variables that influence stakeholder perspectives include, for example:

- Market structure (especially whether or not utilities are vertically integrated and own and operate electric power generation);

- Existing regulatory incentives, especially those that determine how, and how much, utility profits are affected by reductions in electricity sales;

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counterpoint, not yet analyzed in detail, is that solar PV could work in conjunction with demand-response and energy-efficiency improvements so that increasing quantities of all three resources might be coordinated, with the combined effect of reducing peak loads.

[11] R.W. Beck (2009) also modeled solar domestic hot water systems and solar daylighting.

- Rate structures and differences between residential and commercial rates, especially differences in the extent to which fixed costs are recovered via variable use charges (Gilliam, 2013, p. 9);

- The relative maturity of the solar industry and solar businesses, and how close solar PV comes to achieving or bettering full cost parity (Barbose et al., 2012);

- RPS goals or requirements, including any carve-outs for solar or distributed generation;

- Ongoing rates of growth in utility sales and in energy and capacity savings due to demand-side management programs and measures;

- Interconnection standards (rules, regulations, procedures, and cost allocation);

- The availability of jurisdictional financial incentives for solar-system manufacturers, dealers and installers, and purchasers and users; and

- Locational differences in the electric transmission and distribution systems.

**Table 2: Summary of Net Metering and Value-of-Solar (VOS) Studies**

| | | | | | |
|---|---|---|---|---|---|
| **Study Name** | | Arizona Public Service (APS) | APS | APS | APS |
| **Author** | | R.W. Beck | Navigant | SAIC | Beach and McGuire |
| **Year** | | 2009 | 2012 | 2013 | 2013 |
| **State/Utility** | | Arizona/APS | Arizona/APS | Arizona/APS | Arizona/APS |
| **Benefit/Cost Tests Used[1]** | | UCT, RIM | UCT, RIM | UCT, RIM | RIM |
| **Generation Analyzed** | | Gross | Gross | Gross | Gross |
| **Benefits and Costs Analyzed (¢/kWh, if reported)** | **Energy purchases** | 7.1–8.2* | y | y | 6.4–7.5 |
| | **RPS costs** | | | | 4.5 |
| | **Capacity purchases** | 0.0–1.9 | y | y | 6.7–7.6 |
| | **T&D line losses** | 0.0–0.8* | y | y | 2.3–2.5 |
| | **T&D savings, capital & O&M** | 0.8-3.2 | | y | |
| | **Environmental benefits** | | y | y | 0.1 |
| | **Natural gas price hedge** | | | | |
| | **Ancillary services and VAR support** | y | | | 1.5 |
| | **Cost of bill credits** | N/A | (y)* | N/A | (13.7–15.3) |
| | **Administrative costs** | N/A | | N/A | (0.2) |
| **Calculated non-participant net cost** | | | y | | |
| **Value of Solar Energy (+/-)** | | + | – | + | + |

Source: Adapted from Keyes and Wiedman, 2012, and Mahrer, 2013 (unpublished manuscript).

[1] These refer to the Utility Cost Test (UCT), Ratepayer Impacts Measure (RIM), and Total Resource Cost (TRC) standardized benefit/cost tests, identified and described in the *California Standard Practices Manual* (California PUC, 2001).

* Asterisks indicate studies using different benefit/cost categories. R.W. Beck (2009) includes T&D line losses in its energy purchases category, and divides T&D expenses into separate categories for O&M and capital. And, Navigant (2010 and 2012) studies include several costs in addition to bill credits to customers.

**Table 2 (continued): Summary of Net Metering and Value-of-Solar Studies**

| | | | | | |
|---|---|---|---|---|---|
| **Study Name** | | Austin Energy | Crossborder | Energy and Environmental Economics (E3) | Nevada Energy |
| **Author** | | Rábago, Libby, *et al.* | Beach and McGuire | Constantine | Navigant |
| **Year** | | 2006, 2012 | 2012 | 2010 | 2010 |
| **State/Utility** | | Texas/Austin Energy | California | California | Nevada-PUC |
| **Benefit/Cost Tests Used**[1] | | UCT, RIM | UCT, RIM | UCT, RIM | UCT, RIM |
| **Generation Analyzed** | | Gross | Exports | Exports | Gross |
| **Benefits and Costs Analyzed (¢/kWh, if reported)** | **Energy purchases** | y | y | y | y |
| | **RPS costs** | | y | y | |
| | **Capacity purchases** | y | y | y | y |
| | **T&D line losses** | y | y | y | y |
| | **T&D savings, capital & O&M** | y | y | y | |
| | **Environmental benefits** | y | y | y | y |
| | **Natural gas price hedge** | y | | | |
| | **Ancillary services and VAR support** | y | y | y | |
| | **Cost of bill credits** | N/A | y | y | * |
| | **Administrative costs** | N/A | y | y | |
| **Calculated non-participant net cost** | | | y | y | |
| **Value of Solar Energy (+/–)** | | | + | – | – |

Source: Adapted from Keyes and Wiedman, 2012, and Mahrer, 2013 (unpublished manuscript).

[1] These refer to the Utility Cost Test (UCT), Ratepayer Impacts Measure (RIM), and Total Resource Cost (TRC) standardized benefit/cost tests, identified and described in the *California Standard Practices Manual* (California PUC, 2001).

* Asterisks indicate studies using different benefit/cost categories. R.W. Beck (2009) includes T&D line losses in its energy purchases category, and divides T&D expenses into separate categories for O&M and capital. And, Navigant (2010 and 2012) studies include several costs in addition to bill credits to customers.

**Table 2 (continued): Summary of Net Metering and Value-of-Solar Studies**

| | | | | | |
|---|---|---|---|---|---|
| **Study Name** | | NYSERDA &NYDPS | Perez | Perez | Solar ABCs |
| **Author** | | NYSERDA | Perez | Perez | Keyes and Wiedman |
| **Year** | | 2012 | 2011 | 2012 | 2012 |
| **State/Utility** | | New York | NYC area | New Jersey and Pennsylvania | |
| **Benefit/Cost Tests Used**[1] | | UCT, RIM | UCT, RIM, TRC | UCT, RIM, TRC | UCT, RIM |
| **Generation Analyzed** | | Gross | Gross | Gross | Exports |
| **Benefits and Costs Analyzed (¢/kWh, if reported)** | **Energy purchases** | y | 9–16 | y | y |
| | **PPS costs** | y | | | y |
| | **Capacity purchases** | y | 0–8 | y | y |
| | **T&D line losses** | y | 0–1 | y | y |
| | **T&D savings, capital & O&M** | y | y | y | y |
| | **Environmental benefits** | y | 3–6 | y | y |
| | **Natural gas price hedge** | | | | y |
| | **Ancillary services and VAR support** | | 2–3 | y | y |
| | **Cost of bill credits** | N/A | N/A | N/A | y |
| | **Administration costs** | N/A | N/A | N/A | y |
| **Calculated non-participant net cost** | | | | * | |
| **Value of Solar Energy (+/-)** | | + | + | + | + |

Source: Adapted from Keyes and Wiedman, 2012, and Mahrer, 2013 (unpublished manuscript).

[1] These refer to the Utility Cost Test (UCT), Ratepayer Impacts Measure (RIM), and Total Resource Cost (TRC) standardized benefit/cost tests, identified and described in the *California Standard Practices Manual* (California PUC, 2001).

* Asterisks indicate studies using different benefit/cost categories. R.W. Beck (2009) includes T&D line losses in its energy purchases category, and divides T&D expenses into separate categories for O&M and capital. And, Navigant (2010 and 2012) studies include several costs in addition to bill credits to customers.

## V. Recommended Policies and Conclusion

Given all of this information about the current state of solar PV policies and markets, questions facing state public utility commissions and other policymakers include: (1) Are changes in solar policies warranted? and (2) If yes, what changes should be considered?

In this context, the Federal Energy Regulatory Commission (FERC) acknowledges that state utility regulatory commissions can establish PURPA avoided-cost rates reflecting both (a) state law requirements for utility portfolios to include particular sources of energy and (b) specific values provided by different kinds of generators.[12] Bloom et al. (2011, p. 29) conclude:

> FERC held that [a state] could implement a multi-tiered avoided cost rate structure in accordance with PURPA and confirmed that the avoided cost calculation may include all actual costs of complying with state procurement and environmental laws.

Vermont Public Service Board (2013, pp. 12-13, footnotes omitted) summarize the essence of the related FERC rulings:

> FERC [in California Pub. Util. Comm'n, 132 FERC ¶ 61,047 (July 15, 2010) at ¶ 64]… concluded that, because states have certain delegated authority to set wholesale rates under the Public Utility Regulatory Policies Act ("PURPA") for at least some producers of wholesale power (referred to as "qualifying facilities"), there are circumstances in which a standard-offer program can withstand [FERC] preemption scrutiny. FERC's rules implementing PURPA require that states set the rates based on avoided cost… [and] that standard-offer rates [for utility purchases of power and energy from PURPA qualifying facilities] established under state law must not exceed the PURPA avoided cost. … FERC ruled that states may employ a "multi-tiered" avoided-cost structure in a standard offer program that takes into account such things as state-law requirements to purchase electricity from particular sources of energy. [Cal. Pub. Util. Comm'n, 133 FERC ¶ 61,059 (October 21, 2010) at ¶ 26. … See California Pub. Util. Comm'n, 134 FERC ¶ 61,044 (January 20, 2011) at ¶ 30 (noting that "states have the authority to dictate the generation resources from which utilities may procure electric energy… so an avoided cost rate may also reflect a state requirement that utilities purchase their energy needs, from, for example, renewable resources").] This ruling essentially permits a state to establish rates for specific categories of renewable projects, provided those rates are set at avoided cost rather than [based on] some other methodology.

The FERC rulings differentiate among three different state-policy situations: (1) states with no renewable portfolio standard (RPS); (2) states with an RPS, but no specific requirement for contributions from solar or distributed generation; and (3) states with both an RPS and a specific solar or DG requirement (commonly called a “carve-out”). In any of these circumstances, a state could develop a PURPA avoided-cost rate that reflects the benefits

[12] PURPA refers to the Public Utilities Regulatory Policy Act of 1978, as amended. The section about avoided costs for qualifying cogeneration and small power production facilities is found in 16 USC § 824a–3 - Cogeneration and small power production. http://www.law.cornell.edu/uscode/text/16/824a-3

provided by distributed generators. Keyes, Fox, and Wiedman (2013, pp. 2, 5-6, footnotes omitted) itemize many "as-yet-unquantified" distributed benefits which they say can be incorporated into a PURPA avoided-cost rate. These include:

- reduced line losses;
- ability to install smaller increments of capacity with shorter lead times;
- ability to avoid or defer T&D costs;
- value of PURPA qualifying facility (QF) capacity and energy;
- ability to dispatch QF output, including the expected or demonstrated reliability of the output;
- the usefulness of QF production during system emergencies;
- environmental benefits and renewable attributes of QF power; and
- the duration and enforceability of QF contracts.

Bloom et al. (2011, pp. 27-29) interpret the FERC rulings to mean that a state can design a feed-in tariff (FIT) in accordance with PURPA, which could include provisions covering:

- the facilities that qualify (potentially based on size, resource type, grid location, and other criteria);
- the length of term of the FIT; and
- the frequency at which prices are set during the term.

As Keyes, Fox, and Wiedman (2013, pp. 12-13) explain, state-commission ratemaking under the PURPA provisions conceivably provides a path for developing feed-in tariffs (FITs) that are cost-based, work to support community-based systems, work on either side of the utility meter with or without net metering, and potentially remove existing net-metering limits, which restrict customers to generating only as much energy as they use on-site. Perkins (2010, pp. 105-106) notes, "FITs have been a proven success… stabilizing renewable-energy markets, thus lowering the risk to investors and, as a result, the cost of renewable energy." Note also that there is a precedent for establishing PURPA rates that are fixed for the duration of typical terms of financing, and long-term fixed rates help to reduce financing costs and thus lower prices.

This is not to say that this approach avoids all problems, difficulties, and controversies (see Morton & Peabody, 2010). Bloom et al. (2011, pp. 30-33) further explain that the FERC guidance is general and leaves important questions to be determined, such as how "avoided congestion debottlenecking costs" might be incorporated and whether reverse-auction procedures could be employed in defining avoided cost. They suggest that FERC could helpfully provide more detailed “guidance on the approaches to defining avoided costs that it will accept as consistent with PURPA.” That would help resolve what Perkins (2010, p. 111) calls the currently existing “precarious legal situation.”

In any case, with or without with this PURPA approach, several major topics remain for state commissions to address. These include difficulties inherent in:

- arriving at a consensus on the values for each component of distributed benefit;

- deriving accurate long-term, fixed avoided-cost prices, and determining how frequently to adjust those prices as market conditions change;

- deriving appropriate standby rates for solar self-generation customers;

- enabling distributed energy systems and resources to provide service on both sides of the utility meter; and

- establishing appropriate utility or affiliated company roles in distributed resources development and deployment.

Here, four preliminary recommendations are proposed for commission consideration. The first is to proceed with caution, on the basis of thorough analysis, when changing current solar policy supports. The second is to model, and then consider establishing, specific Public Utilities Regulatory Policy Act (PURPA) avoided-cost rates that reflect state requirements for distributed solar installations, or for distributed energy in general. A third recommendation is to continue growing the solar industry by maintaining and further developing programs that leverage voluntary contributions and non-ratepayer funding. Examples include voluntary green-pricing programs and community-based solar projects. The fourth and final recommendation is for commissions to actively consider changes in regulatory incentives designed to better accommodate increasing reliance on distributed energy resources.

### A. Proceed with caution and on the basis of thorough analysis when revising solar energy policies

The gist of this recommendation is to avoid changes that will dismantle existing solar energy policies prior to completing a thorough analysis and modeling to ascertain, as best as possible, what the effects are of current policies, both positive and negative, and what changes in benefits and costs will be introduced by proposed policy changes or replacements. Values to utility companies, participating and non-participating customers, and society as a whole should be considered (R.W. Beck, 2009, p. 1-22). A corollary to this recommendation is that several contemporary studies indicate a net positive value-of-solar power for ratepayers, which suggests that current policies should be continued or even expanded in the near term while more detailed analysis is completed.

Commissions can help to prevent decision-making paralysis and continuing volleys of dueling benefit–cost studies by encouraging or leading multi-party analyses, and by providing guidance about what benefits and costs will be included in analyses along with instructions about how to incorporate that information. Arizona is presently engaging stakeholders in the start of just this type of exercise (Power Pundits, LLC, 2013). Many sources of policy guidance are available to support such activities. Detailed net metering, solar, and more general renewable energy policy recommendations have been published by the Interstate Renewable Energy Council (Fox & Varnado, 2010; IREC, 2013), National Renewable Energy Laboratory (Bird, Reger, & Heter, 2012; Coddington, Fox, et al., 2012; Doris & Krasko, 2012; Mendelsohn, 2012; Schwabe, Mendelsohn, et al., 2012), Solar Electric Power Association (Gibson & Taylor, 2013; Siegrist, Barth, et al., 2013), and others (Bradford & Hoskins, 2013; Grace, Donovan, & Melnick, 2011; Hempling, Stanton, & Porter, 2011; Rocky Mountain Institute, 2013; Sovacool, 2008; USDOE, 2011).

### B. Model and consider establishing specific PURPA avoided-cost rates for solar or for all distributed generation, depending on the state's other existing solar energy policies

The essence of this idea is for a state commission to model wholesale PURPA avoided-cost rates that reflect the full value-of-solar PV to the utility system. As some recent value-of-solar analyses predict, in at least some jurisdictions, PURPA rates for solar PV might approximate full retail rates (see Table 2 and the discussion on pages 22-30). In jurisdictions with ample avoided costs, PURPA rates could serve as an adjunct to or at least a partial replacement for net metering. As an alternative, at least knowing that an avoided-cost rate and retail rates are roughly equivalent will help justify continuing and possibly increasing net metering policies. As well, in some jurisdictions PURPA rates could support cost-effective solar PV investments with adequate rates of return, at current or near-future installed prices, in which case PURPA rates can function similar to FITs. In any of these circumstances, a PURPA avoided-cost rate accurately reflecting the full value of distributed solar PV could support additional solar development, while neither creating windfalls for developers nor resulting in ratepayer cross-subsidies (Verbruggen & Lauber, 2012).

In other jurisdictions, a PURPA avoided-cost rate could prove insufficient, by itself, to attract investments in distributed solar PV. In that event, policymakers who are intent on continuing to grow solar energy production can consider how best to tailor additional solar incentives to bridge the gap between an avoided-cost rate set on the basis of costs and the total payments necessary to attract investment (see Bird, Reger, & Heeter, 2012). Quite probably, solar financial incentives can be reduced over time to reflect continuing progress in the solar industry (Barbose, Darghouth, & Wiser, 2012, p. 32).

### C. Continue growing the solar industry by maintaining and further developing programs that leverage voluntary contributions and non-ratepayer funding

This recommendation acknowledges that solar is already growing in some ways that require no mandatory contributions from any utility ratepayers. Primary examples include voluntary green-pricing programs and community-based or crowd-funded solar installations (Bird, Holt, et al., 2010; Heeter & McLaren, 2012; USDOE, 2013b). Utility roles in such programs vary, depending on electric industry structure (i.e., vertically integrated monopoly or competitive choice of generation provider). In some of these circumstances, a state commission's role could be limited simply to approving a voluntary program, but sometimes rate structures, interconnection standards, and standby rates might also be implicated (see Bird, Swezey, & Cory, 2008).

These kinds of programs can represent important, virtuous cycle opportunities for additional solar power development: The resulting solar installations help to increase general familiarity with the technologies on the part of all market participants and observers. Plus, continuing growth is positively associated with a variety of efficiencies throughout the entire solar value chain—including manufacturing, system design, procurement and installation, financing, and more—all of which help lead to lower installed costs and prices.

Therefore, the basic recommendation is for commissions to keep abreast of best practices in each of these areas, and watch for opportunities to pursue improvements in such programs.

### D. Consider changes in regulatory incentives to better accommodate increasing reliance on distributed energy resources

This last recommendation reflects the need to consider how regulatory incentives interact with energy policy ideals. The recent flurry of interest in and concern about solar and net metering policy, as discussed in the introduction to this report (p. 6), is an indication of some unrest, but it reflects underlying issues that involve more than just solar energy and more than just net metering. The unrest raises questions about the present and future business models for public utilities, about regulatory incentives, and about ratemaking principles in general. Therefore, this recommendation is for state public utility commissions to consider a future public utility infrastructure that is much more reliant on distributed energy resources of all kinds. Of course, ongoing engineering and economic modeling is still needed to demonstrate that distributed resources are among the least-cost and greatest-benefit options for meeting future needs. To the extent that such studies show a growing role for distributed resources, though, it behooves commissions to continue to explore changes in regulatory incentives that will encourage regulated utilities to focus on the full deployment of such resources.

As Goldman, Satchwell, et al. (2013, p. 16-19) point out,

> There is a considerable amount of ongoing research and advocacy aimed at defining, analyzing, and promoting alternative utility business models… [including efforts on the part of] academia…, advocacy organizations…, utility industry associations…, consultants…, and national labs.

In this context, commissions are encouraged to consider their unique role in designing and implementing regulatory incentives and to watch for opportunities to help guide regulated utility companies toward business models that will most effectively serve the public interest.

### E. Conclusion

Solar policy in the U.S. states and territories presents something of a "good news, bad news" situation. The good news is that existing policies are working, some would say at long last, to increase the prevalence of solar energy installations. The bad news is that issues inherent in the existing constellations of policies are creating enough concern that some interested parties are actively seeking corrective actions. Different interest groups, though, have widely divergent ideas about what corrective actions are warranted, if any.

The issues are challenging, and they call out for attention. But, in spite of recent rapid growth rates, solar production still represents only a small fraction of electricity sales, even in the jurisdictions where the growth has been most notable.

Also, there is still much to learn about solar energy policy best practices. There is no definitive study of the differential effects of state policies on solar power development. Preliminary studies comparing different policies do point toward some helpful concepts, at least. Examples include: Bird, Reger, and Heeter (2012); Carley (2011); Coffman, Griffin, and Bernstein (2012); Krasko and Doris (2012); Millar (2013); Miller, Nobler, et al. (2012); and Zhai (2013). As discussed in Part III (p. 7), however, correlations are evident already, in a small number of states and utility service territories, between the sum-total effects of all available solar policies, including financial incentives, and more substantial growth.

One advocacy group (SolarPowerRocks.com, 2013) proffers a grading system and state rankings, giving each state "A" through "F" grades on each of about a dozen different policies. Primary among the factors this group uses for its scoring system are: available utility, state, and local government incentives and sales and property tax exemptions; the availability of performance-based incentives, such as SREC markets or FITs; the presence of an RPS and specifically RPS solar carve-outs; technical and administrative details about interconnection rules and standards; and customer-friendly net metering policies. The resulting state rankings, however, show little correlation to the percentages of net metering customers in each state, as reported in Table 1, Column 3. The mismatches between SolarPowerRocks.com ranks and existing solar adoption percentages suggest: (a) the assigned factor weights do not match how the factors affect solar sales; (b) there are other as yet unidentified factors accounting for the differences; or both.

De Martini, et al. (2012, p. 30, footnotes omitted) discuss the current challenge presented by today's limited understanding of the future electric utility industry and the lack of clarity and consensus about the best possible end states that could result from successful energy policies. They explain:

> [A]s tempting as it may be to describe the complete solution today, it is not possible given the nascent stage of many of the attributes discussed including control systems, market designs, architectures, related products and security. A number of exciting ideas and interesting demonstrations of new designs and technologies are occurring today… . Valuable lessons are being learned… . While these efforts are creating a significant foundation of knowledge about the 21st century electric system, there is much more to be learned and developed.

Policy analysis should consider not only basic technical and economic details but also solar industry business models. The need to understand the solar industry and business models has already been demonstrated (R.W. Beck, 2009, pp. 6-21–6-22; Huijben & Verbong, 2013; Kataoka, 2013). The U.S. *Sunshot Initiative* (USDOE, 2013d) is already engaged in identifying and pursuing opportunities to increase the efficiency and reduce the installed cost of solar PV systems, through technical improvements and improved business practices.

Berkhout et al. (2012, p. 109-111) explain that successful business models for innovative technologies like solar power are affected by complex combinations of multiple factors. They contend:

> [T]ransitions will… require some combination of economic, political, institutional and socio-cultural changes. … [P]rice alone does not fully explain the uptake of new technologies. Instead, a series of institutional, behavioral and cultural factors also play an important role… . There are two main reasons for this. The first is that energy markets are not open and free, but highly influenced by national and international policies, including climate policies. The second is that governments play an important role in creating the enabling conditions for new technologies to emerge… and to diffuse (through creating markets for new technologies).

As Etcheverry (2012) and Hoke and Komor (2012) suggest, policy makers should consciously attempt to craft incentives to match the most cost-effective and efficient uses of technologies. Hoke and Komor (2012) observe, "The costs and benefits of a PV system depend on a variety of factors, many of which utilities and regulators can control or influence." Thus, they recommend that policy makers should apply "regulatory and system design principles that encourage the most beneficial PV systems and discourage the most costly ones." Such strategies will help achieve maximum system benefits when using limited funds from taxpayers and non-participating ratepayers. Examples reported by Hoke and Komor (2012, pp. 63-65) include: (a) providing financial credits for solar installations where production will best match utility system peaks; (b) targeting incentives to a diversity of locations and to those locations that will produce the most system benefits; and (c) encouraging manufacturers and system designers to produce and implement advanced inverter functionalities. Barbose, Darghouth, and Wiser (2012) also recommend that policymakers consider differentiating levels of financial support for different sizes and types of projects.

As Hoke and Komor Hoke and Komor (2012, p. 65) point out:

> Fortunately, it is not necessary to answer the difficult question of whether distributed PV presents a net cost or a net benefit in order to implement policies that encourage the most beneficial PV systems and discourage the most costly. Regardless of the answer to the question of total PV cost/benefit, a policy environment that targets the most beneficial PV systems will improve grid reliability and decrease utility costs relative to a policy environment that ignores this issue.

Bradford and Hoskins (2013, pp. 17-18) discuss the challenges inherent in the task of working toward consensus on the issues raised. They observe:

> Many attempts have been made to construct comprehensive cost and benefits metrics… but all of these [studies] suffer from some real or perceived bias… . Clearly more work must be done, and it must be done collaboratively among all of the stakeholder groups. … By coming together and agreeing on a framework for regulatory and policy discourse, stakeholders can mitigate the costs (and maximize the value) of integrating distributive resources. By planning proactively, facilitating fair compensation and providing effective incentives for investing in and maintaining the distribution network, there is opportunity to create real economic value that can be shared by consumers, [distributed energy resources] providers, and distribution utilities.

Solutions to any impending dilemmas associated with growing markets for solar PV and other distributed energy resources could necessitate action by several actors and policymakers. At least some decisions about proposed changes will fall directly on state public utility commissions, but there will be others that seldom if ever fall under direct commission jurisdiction. A vitally important role for policymakers, as a group, is establishing and maintaining appropriate relationships and functions among the wide variety of existing solar incentive policies. In this context, commissioners might consider providing information to and possibly opening a dialog with the other policymakers, to try to achieve coordination amongst the various policies. As Sovacool (2008, p. 1539) concludes:

> [T]he barriers facing renewable energy and energy efficiency are diffuse, [so] a multitude of policies must be comprehensively implemented to eliminate them. … An effective and synergistic approach would need to treat each of these policy mechanisms as complementary, rather than as competitors that must constantly win approval from policymakers. No single-policy mechanism is a panacea, and until comprehensive policy changes are implemented, renewable energy… will never realize [its] full potential.

Solar policies interact somewhat like the individual faces on a Rubik's Cube puzzle: Trying to align all the details of one policy to meet one set of goals sometimes complicates or even subverts solutions for another, related policy and its set of goals. Thus, this report encourages commissions to proceed with caution and on the basis of thorough analysis and modeling when considering changes to the existing sets of policies that are supporting solar energy. One important objective of commission deliberations should be to understand, as best as current understanding will allow, both how existing solar policies are interacting to affect solar business and utility business models and what the likely effects will be of proposed changes. Another objective should be to prevent the premature dismantling of solar policy supports that might prove necessary to the fledgling solar industry.

## Bibliography


Abbey, Ross. (18 Sep 2012). "Making Rooftop Solar 'Business as Usual'" [Electronic article], *Fresh Energy*. http://fresh-energy.org/2012/09/making-rooftop-solar-business-as-usual/

Asmus, Peter. (25 Jan 2013a). *In California, Net Metering Hits the Wall* [electronic article]. Pike Research. http://www.pikeresearch.com/author/peter-asmuspikeresearch-com

_______. (3 Jan 2013b). *Community-based solar models take root* [electronic article]. Pike Research. http://www.pikeresearch.com/author/peter-asmuspikeresearch-com?page=2

_______. (23 Jan 2013c). *The case for net metering* [electronic article]. Pike Research. http://www.pikeresearch.com/blog/the-case-for-net-metering

Barbose, Galen L., Naïm R. Darghouth, and Ryan Wiser. (2012). *Tracking the Sun V: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2011*. Lawrence Berkeley National Laboratory, LBNL-5919E. http://emp.lbl.gov/publications/tracking-sun-v-historical-summary-installed-price-photovoltaics-united-states-1998-2011

Barnham, Keith, Kaspar Knorr, and Massimo Mazzer. (2013). "Benefits of Photovoltaic Power in Supplying National Electricity Demand," *Energy Policy 54*(2013), 385–390. http://dx.doi.org/10.1016/j.enpol.2012.10.077

Beach, Tom. (2013). "Data Not Drama: Evaluating the Benefits and Costs of Net Energy Metering" [PowerPoint Presentation] at *The Cost, Benefits and Equity Issues of Net Energy Metering*, NARUC Winter Committee Meetings, Washington DC, February 5, 2013. http://www.naruc.org/meetingpresentations.cfm?94

Beach, R. Thomas and Patrick G. McGuire, Crossborder Energy. (2012). *Evaluating the Benefits and Costs of Net Energy Metering for Residential Customers in California.* The Vote Solar Initiative. http://votesolar.org/wp-content/uploads/2012/10/Evaluating-the-Benefits-and-Costs-of-Residential-Net-Energy-Metering-in-California-final-with-appendices.pdf

Beach, R. Thomas and Patrick G. McGuire, Crossborder Energy. (2013). *The Benefits and Costs of Solar Distributed Generation for Arizona Public Service.* Solar Energy Industries Association. http://www.seia.org/sites/default/files/resources/AZ-Distributed-Generation.pdf

_______. (Jan. 2009). *Distributed Renewable Energy Operating Impacts and Valuation Study.* R.W. Beck, Inc. http://www.aps.com/library/solar%20renewables/DistRenEnOpImpactsStudy.pdf

Berkhout, Frans, Peter Marcotullio, and Tatsuya Hanaoka. (2012). "Understanding Energy Transitions." *Sustainability Science 7*(2), pp 109-111. doi:/10.1007/s11625-012-0173-5

Berst, Jesse. (17 Apr 2013).*Utilities: What Walmart's Power Plans Say About Your Future (It's Scary!)* [Electronic Article]. SmartGridNews.com. http://www.smartgridnews.com/artman/publish/News_Commentary/Utilities-What-Walmart-s-power-plans-say-about-your-future-it-s-scary-

Bird, Lori, Jenny Heeter, and Claire Kreycik. (2011). *Solar Renewable Energy Certificate (SREC) Markets: Status and Trends*. National Renewable Energy Laboratory, NREL/TP-6A20-52868. http://apps3.eere.energy.gov/greenpower/pdfs/52868.pdf

Bird, Lori, Ed Holt, Jenny Sumner, and Claire Kreycik. (2010). *Voluntary Green Power Market Forecast through 2015*. National Renewable Energy Laboratory, NREL/TP-6A2-48158. http://apps3.eere.energy.gov/greenpower/pdfs/48158.pdf

Bird, Lori, Andrew Reger, and Jenny Heeter. (2012). *Distributed Solar Incentive Programs: Recent Experience and Best Practices for Design and Implementation*. National Renewable Energy Laboratory, NREL- TP-6A20-56308. http://www.nrel.gov/docs/fy13osti/56308.pdf

Bird, Lori, Blair Swezey, and Karlynn Cory. (2008). *Renewable Energy Price-Stability Benefits in Utility Green Power Programs*. National Renewable Energy Laboratory, NREL/TP-670-43532. http://apps3.eere.energy.gov/greenpower/resources/pdfs/43532.pdf

Bloom, David, Paul Forrester and Nadav Klugman. (2011). "State Feed-In Tariffs: Recent FERC Guidance for How to Make Them FIT under Federal Law." *Electricity Journal 24*(4), pp. 26-33. doi:/10.1016/j.tej.2011.04.004

Bradford, Travis, and Anne Hoskins. (2013) *Valuing Distributed Energy: Economic and Regulatory Challenges*. Working paper for Princeton Roundtable. http://travisbradford.files.wordpress.com/2012/01/de-whitepaper-final-0426.pdf

Bronin, Sara C., and Paul R. McCary. (2013). "Peaceful Coexistence: Independent Microgrids Are Coming. Will Franchised Utilities Fight Them or Foster Them?" *Public Utilities Fortnightly* (Mar 2013). http://www.fortnightly.com/fortnightly/2013/03/peaceful-coexistence

Burgos-Payán, Manuel, Juan Manuel Roldán-Fernández, et al. (2013). "Costs and Benefits of the Renewable Production of Electricity in Spain." *Energy Policy 56*(2013), 259–270. http://dx.doi.org/10.1016/j.enpol.2012.12.047

Burns, John Edward, and Jin-Su Kang. "Comparative Economic Analysis of Supporting Policies for Residential Solar PV in the United States: Solar Renewable Energy Credit (SREC) potential." *Energy Policy 44* (2012), 217–225. doi:/10.1016/j.enpol.2012.01.045

Burr, Chrystie. (2012). *Subsidies, Tariffs and Investments in Solar Power Market* [working paper]. University of Arizona. https://econ.arizona.edu/docs/JobMarket/burr_jobmarket12.pdf

Burr, Michael T. (Mar 2013). "Turning Energy Inside Out: Amory Lovins on Negawatts, Renewables, and Neoclassical Markets." *Public Utilities Fortnightly* [1994] Mar. 2013: 28+. *Business Insights: Essentials*. Web. 5 Apr. 2013.

California Energy Commission. (2001). *California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects*. http://www.energy.ca.gov/greenbuilding/documents/background/07-J_CPUC_STANDARD_PRACTICE_MANUAL.PDF

California Public Utilities Commission. (2013). *Summary of Feed-In Tariffs* [web page]. http://www.cpuc.ca.gov/PUC/energy/Renewables/feedintariffssum.htm

California Public Utilities Commission. (2009). *Adopting Cost-Benefit Methodology for Distributed Generation.* Final decision in proceeding R0803008, D0908026, 21 Aug 2009. http://docs.cpuc.ca.gov/advancedsearchform.aspx

Campbell, Carolyn. (2013a). "Distributed PV in an ITC-Only World: Analyzing Arizona's Solar Market." *PV News 32*(1), 1, 12-13. http://www.greentechmedia.com/research/pv-news

Campbell, Carolyn. (2013b). Rate Design Matters: The Impact of Tariff Structure on Solar Project Economics in the U.S. GTM Research. http://www.greentechmedia.com/articles/read/Rate-Design-Matters-Utility-Tariffs-and-Solar-Project-Economics

Cardwell, Diane. (2012). "A Solar Fairness Debate." *New York Times*, 5 Jun 2012, p. B1. http://www.nytimes.com/2012/06/05/business/solar-payments-set-off-a-fairness-debate.html

Carl, Jeremy, and James E. Goodby (Eds.). (2010). *Conversations about Energy: How the Experts See America's Energy Choices*. Palo Alto, CA: Hoover Institution Press, Stanford University. http://books.google.com/books?id=meFvtxqSjXcC

Carley, Sanya. (2011). "The era of state energy policy innovation: A review of policy instruments." *Review of Policy Research 28*(3), 265-294. doi:/10.1111/j.1541-1338.2011.00495.x

Casten, Thomas R., and Robert U. Ayers. (2007). "Energy Myth Eight: Worldwide Power Systems Are Economically and Environmentally Optimal." In B.K. Sovacool and M.A. Brown (eds.), *Energy and American Society: Thirteen Myths*, pp. 201-207.

Chernova, Yuliya. (25 Mar 2013). "Utilities Facing a 'Mortal Threat' from Solar" [electronic article]. *Wall Street Journal*. http://online.wsj.com/article/SB10001424127887324789504578381820753301976.html, and (22 Mar 2013), http://blogs.wsj.com/corporate-intelligence/2013/03/22/utility-boss-faces-mortal-threat-from-solar/

Coddington, M., K. Fox, et al. (2012). *Updating Small Generator Interconnection Procedures for New Market Conditions*. National Renewable Energy Laboratory, NREL/TP-5500-56790. http://www.nrel.gov/docs/fy13osti/56790.pdf

Coffman, Makena, James P. Griffin, and Paul Bernstein. (2012). "An Assessment of Greenhouse Gas Emissions-Weighted Clean Energy Standards." *Energy Policy 45*(2012), 122-132. http://dx.doi.org/10.1016/j.enpol.2012.01.068

Colenmar-Santos, Antonio, Severo Campíñez-Romero, et al. (2012). "Profitability Analysis of Grid-Connected Photovoltaic Facilities for Household Electricity Self-Sufficiency." *Energy Policy 51*(2012), 749-764. http://dx.doi.org/10.1016/j.enpol.2012.09.023

Connor, Peter, Viet Bürger, et al. (In press, accepted 17 Sep 2012). "Devising Renewable Heat Policy: Overview of Support Options." *Energy Policy*. http://dx.doi.org/10.1016/j.enpol.2012.09.052

Contreras, J. L., Frantzis, L., Blazewicz, S., Pinault, D., & Sawyer, H. (2008). *Photovoltaics Value Analysis* (NREL/SR-581-42303). Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy08osti/42303.pdf

Curry, Robert E., Jr. (2013). "The Law of Unintended Consequences." *Public Utilities Fortnightly* [electronic article], March 2013. http://www.fortnightly.com/fortnightly/2013/03/law-unintended-consequences

Darghouth, Naïm R., Galen Barbose, and Ryan Wiser. (2013). *Electricity Bill Savings from Residential Photovoltaic Systems: Sensitivities to Changes in Future Electricity Market Conditions*. Lawrence Berkeley National Laboratory, LBNL-6017E. http://emp.lbl.gov/publications/electricity-bill-savings-residential-photovoltaic-systems-sensitivities-changes-future-

Darghouth, Naïm R., Galen Barbose, and Ryan Wiser. (2011). "The Impact of Rate Design and Net Metering on the Bill Savings from Distributed PV for Residential Customers in California." *Energy Policy 39*(2011), 5243–5253. doi:/10.1016/j.enpol.2011.05.040

Darghouth, Naïm, Galen L. Barbose, and Ryan H. Wiser. (2010). *The Impact of Rate Design and Net Metering on the Bill Savings from Distributed PV for Residential Customers in California*. Lawrence Berkeley National Laboratory, LBL-3276e. http://eetd.lbl.gov/ea/emp/reports/lbnl-3276e.pdf

De Martini, Paul, K. Mani Chandy, and Neil Fromer (Eds.). (2012). *GRID 2020: Towards a Policy of Renewable and Distributed Energy Resources*. CalTech: Resnick Institute. http://resnick.caltech.edu/learn/docs/GRID_2020_Resnick%20Report.pdf

Doris, E. and V. A. Krasko (2012). *Strategic Sequencing for State Distributed PV Policies: A Quantitative Analysis of Policy Impacts and Interactions*. National Renewable Energy Laboratory, NREL-TP-7A30-56248. http://www.nrel.gov/docs/fy13osti/56428.pdf

Duke, R., Williams, R., & Payne, A. (2005). "Accelerating Residential PV Expansion: Demand Analysis for Competitive Electricity Markets." *Energy Policy, 33*(15), 1912-1929.

Energy and Environmental Economics (E3). (2010). *Introduction to the Net Energy Metering Cost Effectiveness Evaluation.* California Public Utilities Commission, Energy Division. http://www.cpuc.ca.gov/PUC/energy/DistGen/nem_eval.htm

Energy and Environmental Economics (E3). (2012). "NEM Cost-Effectiveness Evaluation Workshop, stakeholder workshop, October 22, 2012" [Powerpoint Presentation], in *California Public Utilities Commission, Net Energy Metering (NEM) Cost-Benefit Study* [web page]. http://www.cpuc.ca.gov/PUC/energy/Solar/nem_cost_benefit_evaluation.htm

Etcheverry, José. (2012). "Sustainable Deployment of Photovoltaics: What's Wrong with the Current Policy and Technology Focus?" *Electricity Journal 25*(2), 24-31. doi:/10.1016/j.tej.2012.02.003

Fox, K. T., & Varnado, L. (2010). *Sustainable, Multi-Segment Market Design for Distributed Solar Photovoltaics*. Latham, NY: Interstate Renewable Energy Council. Prepared for the Solar America Board of Codes and Standards.

Fuchs, Gerhard, and Sandra Wasserman. (2012). *Organizing a Market: Photovoltaics in Germany*. SOI Discussion Paper 2012-01. University of Stuttgart, Institute for Social Sciences, Department of Organizational Sociology and Innovation Studies. http://www.unistuttgart.de/soz/oi/publikationen/soi_2012_1_fuchs_wassermann_photovoltaics_germany.pdf

Gainesville Regional Utilities. (2013). *Solar Programs* [web page]. https://www.gru.com/TabID/3823/

Galbraith, Kate. (12 Mar 2009). "Europe's Way of Encouraging Solar Power Arrives in the U.S." *New York Times, Energy & Environment* [electronic article]. http://www.nytimes.com/2009/03/13/business/energy-environment/13solar.html

Gauntlett, Dexter, and Mackinnon Lawrence. (2013). *Executive Summary: Distributed Solar Energy Generation – Market Drivers and Barriers, Technology Trends, and Global Market Forecasts*. Navigant Consulting. http://www.navigantresearch.com/research/distributed-solar-energy-generation

Gibson, Bob, and Mike Taylor. (22 May 2013). "Community Solar Programs are Challenged—and Sharpened—by Competition." [Electronic article]. Solar Electric Power Association. http://www.solarelectricpower.org/posts/2013/05/community-solar-programs-are-challenged-and-sharpened-by-competition.aspx

Gilliam, Rick. (2013). “Net Metering” [PowerPoint Presentation] at *The Cost, Benefits and Equity Issues of Net Energy Metering*, NARUC Winter Committee Meetings, Washington DC, February 5, 2013. http://www.naruc.org/meetingpresentations.cfm?94

Glassmire, John, Paul Komor, and Peter Lilienthal. (2012). “Electricity Demand Savings from Distributed Solar Photovoltaics.” *Energy Policy 51* (2012), 323–331. http://dx.doi.org/10.1016/j.enpol.2012.08.022

Glickstein, Jesse. (2012). “New York’s Proposed Solar Renewable Energy Market: Lessons Learned From Other States’ SREC Markets and Recommendations in Moving Forward.” *3 Pace Envtl. L. Rev. Online Companion 26*. http://digitalcommons.pace.edu/pelroc/vol3/iss1/2

Goldman, Charles A., Andy Satchwell, Peter Cappers, and Ian Hoffman. (2013). *Utility Business Models in a Low Load Growth/High DG Future: Gazing into the Crystal Ball?* [Presentation to Committee on Regional Electric Power Cooperation (CREPC)/State-Provincial Steering Committee (SPSC) Meeting, Boise, ID, April 10, 2013]. Lawrence Berkeley National Laboratory. http://emp.lbl.gov/publications/utility-business-models-low-load-growthhigh-dg-future-gazing-crystal-ball

Grace, R. C., Donovan, D. A., & Melnick, L. L. (Oct 2011). *When Renewable Energy Policy Objectives Conflict: A Guide for Policymakers*. National Regulatory Research Institute, No. 11-17, http://www.nrri2.org/index.php?option=com_content&task=view&id=359

Grinlinton, David, and LeRoy Paddock. (2010). “The Role of Feed-In Tariffs in Supporting the Expansion of Solar Energy Production.” *University of Toledo Law Review, 41*, pp. 943-973. http://heinonline.org/HOL/LandingPage?collection=journals&handle=hein.journals/utol41&div=44

Hall, Dana. (25 Oct 2012). “Connecticut’s LREC/ZREC Program, a Competitive Reverse Auction Model for 15-Year REC Contracts.” [Electronic Article]. *Energy Law Roundup*. http://energylawroundup.blogspot.com/2012/10/connecticuts-lreczrec-program_25.html

Heeter, Jenny and Joyce McLaren. (2012). *Innovations in Voluntary Renewable Energy Procurement: Methods for Expanding Access and Lowering Cost for Communities, Governments, and Businesses*. National Renewable Energy Laboratory, NREL/TP-6A20-54991. http://www.nrel.gov/docs/fy12osti/54991.pdf

Hempling, S., T. Stanton, and K. Porter. (2011). *A Guide for Ontario Energy Policy Makers: Multi-Criteria Decision Analysis to Develop Sound Energy Policy & Promote Green Energy*. National Regulatory Research Institute.

Hoff, Thomas. (2013). *Net Metering: Quantifying Benefits and Sharing Costs.* [PowerPoint Presentation]. Clean Power Research. http://www.cleanpower.com/resources/net-metering-quantifying-benefits-and-sharing-costs/

Hoke, Anderson, and Paul Komor. (2012). "Maximizing the Benefits of Distributed Photovoltaics." *Electricity Journal*, *25*(3), 1040-6190. doi:/10.1016/j.tej.2012.03.005

Huijben, J.C.C.M., and G.P.J. Verbong. (2013). "Breakthrough Without Subsidies? PV Business Model Experiments in the Netherlands." *Energy Policy 56*(2013), 362-370. http://dx.doi.org/10.1016/j.enpol.2012.12.073

Hull, Dana. (8 Apr 2013). "Mosaic Receives Approval to Offer $100 Million Worth of Solar Investments to California Residents." *Silicon Valley MercuryNews.com* [electronic article]. http://www.mercurynews.com/business/ci_22980791

IREC. (2013). *Blueprint for the Development of Distributed Generation in California*. Interstate Renewable Energy Council. http://www.irecusa.org/2013/02/irec-releases-blueprint-for-development-of-distributed-generation-in-ca/

Jacobs, David. (2012). *Renewable Energy Policy Convergence in the EU: The Evolution of Feed-In Tariffs in Germany, Spain and France*. London: Ashgate. http://www.ashgate.com/default.aspx?page=637&calcTitle=1&isbn=9781409439097

Kataoka, George K. (2013). *A Financial and Policy Analysis of Small Photovoltaic Ownership for Investor-Owned Utility Customers in North Carolina* [Master's Thesis]. Duke University, Environmental Management. http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/6778/Masters%20Project_George%20K.%20Kataoka.pdf

Keyes, Fox & Wiedman, LLP. (2013). *Unlocking DG Value: A PURPA-Based Approach to Promoting DG Growth*. Interstate Renewable Energy Council. http://www.irecusa.org/wp-content/uploads/2013/05/Unlocking-DG-Value.pdf

Keyes, Jason. (2013). "Net Metering—National Perspective" [PowerPoint Presentation] at *The Cost, Benefits and Equity Issues of Net Energy Metering*. NARUC Winter Committee Meetings, Washington DC, February 5, 2013. http://www.naruc.org/meetingpresentations.cfm?94

Keyes, Jason B., Kevin T. Fox, et al. (2009). "Net Metering and Interconnection Procedures Incorporating Best Practices," in *Proceedings, American Solar Energy Society Conference 2009*, Buffalo, NY. http://irecusa.org/wp-content/uploads/2011/01/ASES-2009-Paper-0131-net-metering-and-IC-best-practices-1.pdf

Keyes, J. B., & Wiedman, J. F. (2012). *A Generalized Approach to Assessing the Rate Impacts of Net Energy Metering*. Latham, NY: Interstate Renewable Energy Council. Prepared for the Solar America Board of Codes and Standards (Solar ABCs). http://www.solarabcs.org/rateimpact

Kind, Peter. (2013). *Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business*. Edison Electric Institute. http://www.eei.org/ourissues/finance/Documents/disruptivechallenges.pdf

Krasko, V.A. and E. Doris. (2012). *Strategic Sequencing for State Distributed PV Policies: A Quantitative Analysis of Policy Impacts and Interactions*. National Renewable Energy Laboratory, NREL/TP-7A30-56428. http://www.nrel.gov/docs/fy13osti/56428.pdf and http://www.nrel.gov/tech_deployment/state_local_activities/webinar_20121205.html

Lacy, Virginia. (2 May 2013). *The Calm before the Solar Storm* [electronic article]. Rocky Mountain Institute. http://blog.rmi.org/blog_2013_05_02_The_Calm_Before_the_Solar_Storm

Lappé, Annie. (8 Mar 2013). *Austin Energy's Value-of-Solar Tariff: Could It Work Anywhere Else?* [electronic article]. Greentech Media. http://www.greentechmedia.com/articles/read/austin-energys-value-of-solar-tariff-could-it-work-anywhere-else

Lappé, A. (2012). *Reply Comments of the Vote Solar Initiative* (In the Matter of the Application of Arizona Public Service Company for Approval of its 2013 renewable Energy Standard Implementation for Reset of its Renewable Energy Adjustor, Docket Nos. E-01345A-12-0290 and E-01345A-10-0394). Phoenix, AZ: Arizona Corporation Commission.

LaRue, Anna M., Noelle C. Cole, and Peter W. Turnbull. (2013). "What If This Actually Works?: Implementing California's Zero Net Energy Goals," in Sioshansi, Fereidoon P. [Ed.], *Energy Efficiency: Towards the End of Demand Growth*. Waltham, MA: Elsevier. http://www.sciencedirect.com/science/book/9780123978790

Lauderbaugh, Alex. (16 Jan 2013). *Seeking Funding, Solar Projects Look to the Crowd* [electronic article]. Pike Research. http://www.pikeresearch.com/blog/seeking-funding-solar-projects-look-to-the-crowd

Luxande, Amanda and GerritW. Clarke. (17 Jan 2013). *Review of Net Metering Practices*, v2. Report for Energy Control Board of Namibia. http://www.ecb.org.na/pdf/NetMetering/Review_of_Net_Metering_Practices_v2.pdf

Mahrer, Eran. (2013). "Net Energy Metering – Fare Deal?" [PowerPoint Presentation] at *The Cost, Benefits and Equity Issues of Net Energy Metering*, NARUC Winter Committee Meetings, Washington DC, February 5, 2013. http://www.naruc.org/meetingpresentations.cfm?94

Manyika, James, Michael Chui, et al. (2013). *Disruptive Technologies: Advances that will Transform Life, Business, and the Global Economy*. McKinsey Global Institute. http://www.mckinsey.com/insights/business_technology/disruptive_technologies

Martin, Christopher. (2013). "Goldman Sachs to Finance $500 Million for SolarCity Roofs" [electronic article], *Bloomberg*. *http://www.bloomberg.com/news/2013-05-16/goldman-sachs-to-finance-500-million-in-solarcity-roofs.html*

Matz, M. D. (2012, September). "In Search of Net Metering 2.0: Everyone Agrees that Net Metering Must Change—The Question Is, How?" *PHOTON*, 34-42.

Mehta, Shyam. (2013). *PV Technology and Cost Outlook, 2013-2017*. GTM Research. http://www.greentechmedia.com/research/report/pv-technology-and-cost-outlook-2013-2017

Mendelsohn, Michael. (2012). *How Do We Lower Solar Installation Costs and Open the Market to Securitized Portfolios: Standardize and Harmonize* [electronic article]. National Renewable Energy Laboratory, Renewable Energy Project Finance. https://financere.nrel.gov/finance/content/how-do-we-lower-solar-installation-costs-and-open-market-securitized-portfolios-standardize-

Mendonca, Miguel, David Jacobs, and Benjamin Sovacool. (2010). *Powering the Green Economy: The Feed-In Tariff Handbook*. London: Earthscan. http://www.routledge.com/books/details/9781844078585/

Millar, David R. (2013). "Quantitative Analysis of Decoupling, Distributed Generation, and Net Energy Metering" [Master's Thesis]. Duke University, Environmental Management. http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/6858/Masters%20Project%20D%20Millar.pdf

Miller, Emily, Erin Nobler, Christopher Wolf, and Elizabeth Doris. (2012). *Market Barriers to Solar in Michigan.* National Renewable Energy Laboratory, NREL/TP-7A30-54574. http://www.nrel.gov/docs/fy12osti/54574.pdf

Mills, Andrew, and Ryan Wiser. (Dec 2012). *An Evaluation of Solar Valuation Methods Used in Utility Planning and Procurement Processes*. Lawrence Berkeley National Laboratory, LBNL-5933E. http://emp.lbl.gov/publications/evaluation-solar-valuation-methods-used-utility-planning-and-procurement-processes

Mills, Andrew, and Wiser, Ryan. (2010). *Implications of Wide-Area Geographic Diversity for Short-Term Variability of Solar Power*. Berkeley, CA: Lawrence Berkeley National Laboratory, LBNL-3884E. http://eetd.lbl.gov/EA/EMP

Monies, Paul. (12 Apr 2013). "Oklahoma Utility Rules to Keep Some Solar Users in the Dark." *The Oklahoman* [Newspaper article]. http://www.energycentral.com/generationstorage/solar/news/en/28221393/

Morris, Jesse. (6 Mar 2013). *Other People's Money: How Crowdfunding Lowers the Cost of Solar Energy* [electronic article]. Rocky Mountain Institute. http://blog.rmi.org/blog_2013_03_6_Other_Peoples_Money

Morton, Teresa E., and Jeffrey M. Peabody. (2010). "Feed-In Tariffs: Misfits in the Federal and State Regulatory Regime?" *Electricity Journal 23*(8). doi:/10.1016/j.tej.2010.09.003

Mosey, G., & Vimmerstedt, L. (2009). *Renewable Electricity Benefits Quantification Methodology: A Request for Technical Assistance from the California Public Utilities Commission*. Golden, CO: National Renewable Energy Laboratory.

Naroditsky, Joe. (2012). "Response to New York's Proposed Solar Renewable Energy Market: Lessons Learned From Other States' SREC Markets and Recommendations In Moving Forward," *3 Pace Envtl. L. Rev. Online Companion 53*. http://digitalcommons.pace.edu/pelroc/vol3/iss1/3

Navigant Consulting, Inc. (2010). *Distributed Generation Study*. Burlington, MA: Navigant Consulting. Prepared for NV Energy. http://www.leg.state.nv.us/Session/76th2011/Exhibits/Senate/CL/SCL291F.pdf

Navigant Consulting. (2012). *Net Metering Bill Impacts and Distributed Energy Subsidies*. Phoenix, AZ: Prepared for Arizona Public Service. http://www.aps.com/library/renewables/NavigantNetMeteringImpactReport.pdf

Nelder, Chris. (15 Apr 2013). "Adapt or Die? Private Utilities and the Distributed Energy Juggernaut" [Electronic Article]. *Greentech Media, greentechgrid.* http://www.greentechmedia.com/articles/read/Adapt-or-Die-Private-Utilities-and-the-Distributed-Energy-Juggernaut

NYSERDA. (Jan. 2012). *New York Solar Study: An Analysis of the Benefits and Costs of Increasing Generation from Photovoltaic Devices in New York.* New York State Energy Research and Development Authority. http://www.nyserda.ny.gov/Publications/Program-Planning-Status-and-Evaluation-Reports/Solar-Study.aspx

Olmos, Luis, Sophia Ruester, and Siok-Jen Liong. (2012). "On the Selection of Financing Instruments to Push the Development of New Technologies: Application to Clean Energy Technologies." *Energy Policy 43*(2012), 252–266. doi:/10.1016/j.enpol.2012.01.001

Olson, Arne, and Ryan Jones. (Apr 2012). "Chasing Grid Parity: Understanding the Dynamic Value of Renewable Energy," *Electricity Journal* 25(3), 1040-6190. doi:/10.1016/j.tej.2012.03.001

Ong, Sean, Clinton Campbell, and Nathan Clark. (2012). *Impacts of Regional Electricity Prices and Building Type on the Economics of Commercial Photovoltaic Systems*. National Renewable Energy Laboratory, NREL/TP-6A20-56461. http://www.nrel.gov/docs/fy13osti/56461.pdf

Ong, Sean, Nathan Clark, Paul Denholm, and Robert Margolis. (2013). *Breakeven Prices for Photovoltaics on Supermarkets in the United States*. National Renewable Energy Laboratory, NREL/TP-6A20-57276. http://www.nrel.gov/docs/fy13osti/57276.pdf.

Ong, Sean, Paul Denholm, and Nathan Clark. (2012). *Grid Parity for Residential Photovoltaics in the United States: Key Drivers and Sensitivities*. Presented at the 2012 World Renewable Energy Forum, Denver, Colorado, May 13-17, 2012. National Renewable Energy Laboratory, NREL/CP-6A20-54527. http://www.nrel.gov/docs/fy12osti/54527.pdf

Ong, Sean, Paul Denholm, and Elizabeth Doris. (2010). "Impacts of Commercial Electric Utility Rate Structure Elements on the Economics of Photovoltaic Systems." National Renewable Energy Laboratory, NREL/TP-6A2-46782. http://www.nrel.gov/docs/fy10osti/46782.pdf

Payne, A., Duke, R., & Williams, R. (2001). "Accelerating Residential PV Expansion: Supply Analysis for Competitive Electricity Markets." *Energy Policy, 29*(2001), 787-800.

Perez, R. (2007, May 14). "Is There Really Enough Sun in the Empire State?" *Proceedings of the Solar New York 2007 Conference*, Albany, NY.

Perez, Richard, Benjamin L. Norris, and Thomas E. Hoff. (Nov 2012). *The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania*. Report for Mid-Atlantic Solar Energy Industries Association and Pennsylvania Solar Energy Industries Association, prepared by Clean Power Research. http://mseia.net/site/wp-content/uploads/2012/05/MSEIA-Final-Benefits-of-Solar-Report-2012-11-01.pdf

Perez, Richard, Ken Zweibel, and Thomas E. Hoff. (2011). "Solar Power Generation in the US: Too Expensive, or Bargain?" *Energy Policy*, *39*(2011), 7290-7297. doi:/10.1016/j.enpol.2011.08.052

Perkins, John. (2010). "Overcoming Jurisdictional Obstacles to Feed-In Tariffs in the United States," *Golden Gate University Law Review, 40*(1), Article 5. http://digitalcommons.law.ggu.edu/ggulrev/vol40/iss1/5

Power Pundits, LLC. (2013). *Distributed Energy and Net Metering Technical Conference, Workshop I Presentation* [Powerpoint]. Solar Future Arizona. http://www.solarfuturearizona.com/meeting.html

Rábago, Karl R., Leslie Libby, Tim Harvey, Benjamin L. Norris, and Thomas E. Hoff. (2011). *Designing Austin Energy's Solar Tariff Using a Distributed PV Value Calculator*. Austin Energy and Clean Power Research. http://www.cleanpower.com/research/economic-valuation-research/

Rai, Varun, and Benjamin Sigrin. (2013). "Diffusion of Environmentally-Friendly Energy Technologies: Buy versus Lease Differences in Residential PV Markets." *Environmental Research Letters 8*(2013), No. 014022. http://iopscience.iop.org/1748-9326/8/1/014022

Raugei, Marco, Pere Fullana-i-Palmer, and Vasilis Fthenakis. (2012). "The Energy Return on Energy Investment (EROI) of Photovoltaics: Methodology and comparisons with fossil fuel lifecycles," *Energy Policy 45*(2012), 576–582. doi:/10.1016/j.enpol.2012.03.008

Rocky Mountain Institute. (2013). *Net Energy Metering, Zero Net Energy, and the Distributed Energy Resource Future: Adapting Electric Utility Business Models for the 21st Century*. http://www.rmi.org/Content/Files/RMI_PGE_NEM_ZNE_DER_Adapting_Utility_Business_Models_for_the_21st__Century.pdf.pdf

Rocky Mountain Institute. (2013). *New Business Models for the Distribution Edge: The Transition from Value Chain to Value Constellation*. http://www.rmi.org/new_business_models

Roen, Harris. (10 Mar 2013). *New Financing Models for Solar Energy* [electronic article]. AltEnergyStocks.com. http://www.altenergystocks.com/archives/2013/03/new_financing_models_for_solar_energy_1.html

Rogers, Everett M. (2003). *Diffusion of Innovations* (5th Edition). New York: Simon & Schuster.

SAIC. (2013). *2013 Updated Solar PV Value Report: Arizona Public Service*. McLean, Virginia: SAIC. http://www.solarfuturearizona.com/2013SolarValueStudy.pdf

Schell, L. (2010). *Small-Scale Solar Photovoltaics in California: Incremental Value Not Captured in the 2009 Market Price Referent—Description of Methodology*. California Solar Energy Industries Association (CalSEIA).

Schwabe, P., M. Mendelsohn, D. Arent, and F. Mormann. (Jun 2012). *Mobilizing Public Markets to Finance Renewable Energy Projects: Insight from Expert Stakeholders*. National Renewable Energy Laboratory, NREL-TP-6A20-55021. https://financere.nrel.gov/finance/publications.

SEIA. (2012). *Solar means business: Top commercial solar customers in the U.S.* Solar Energy Industries Association. http://www.seia.org/research-resources/solar-means-business-top-commercial-solar-customers-us

Sherwood, Larry. (2012). *U.S. Solar Market Trends 2011*. Interstate Renewable Energy Council. http://www.irecusa.org/wp-content/uploads/IRECSolarMarketTrends-2012-Web-8-28-12.pdf

Siegrist, Carl R., Bianca Barth, Becky Campbell, and Mike Taylor. (2013). *Utility Community Solar Design Handbook: A Development Guide for Utility-Managed Community Solar Programs*. Solar Electric Power Association, Report No. 01-13. http://www.solarelectricpower.org/resources/publications.aspx#Utility_Community_Solar_Handbook

Smeloff, E. (2005). *Quantifying the Benefits of Solar Power for California*. San Francisco, CA: The Vote Solar Initiative.

Solar Future Arizona. (2013). *Solar Future Arizona: Arizona Public Service* [web site]. http://www.solarfuturearizona.com/

SolarPowerRocks.com. (2013). *2013 State Solar Power Rankings* [web page]. http://solarpowerrocks.com/2013-state-solar-power-rankings/

Sovacool, Benjamin K. (2009). "The Importance of Comprehensiveness in Renewable Electricity and Energy-Efficiency Policy." *Energy Policy 37*(2009), 1529–1541. doi:/10.1016/j.enpol.2008.12.016

Sovacool, Benjamin K. (2008). *The Dirty Energy Dilemma: What's Blocking Clean Power in the United States*. Westport, CT: Praeger.

Speer, Bethany. (Oct 2012). "Residential Solar Photovoltaics: Comparison of Financing Benefits, Innovations, and Options." National Renewable Energy Laboratory, NREL/TP-6A20-51644. http://www.nrel.gov/docs/fy13osti/51644.pdf

Stanton, Tom. (2012). *Electric Utility Standby Rates: Updates for Today and Tomorrow*. National Regulatory Research Institute, Report No. 20-12. http://www.nrri.org/documents/317330/94c186ab-4f16-4a69-8e8c-ece658e752b1

Tang, Amy, Nicola Chiara, and John E. Taylor. (2012). "Financing Renewable Energy Infrastructure: Formulation, Pricing and Impact of a Carbon Revenue Bond." *Energy Policy 45*(2012), 691-703. http://dx.doi.org/10.1016/j.enpol.2012.03.022

Tempchin, Rick. (2013). "Time to Rethink Metering Rules: Cost and Fairness" [electronic article]. *IntelligentUtility*. http://www.intelligentutility.com/article/13/06/time-rethink-metering-rules-public-policy

Trabish, Herman K. (1 Apr 2013). *What's Wrong with Pennsylvania Solar?* [electronic article]. Greentech Solar. http://www.greentechmedia.com/articles/read/whats-wrong-with-pennsylvania-solar

Tweed, Katherine. (24 Apr 2013). *The End of Paying for Electricity by the Kilowatt-Hour: Changes to Utility Rate Designs Are Afoot in the U.S. and Europe* [electronic article]. Greentech Grid. http://www.greentechmedia.com/articles/read/The-End-of-Paying-For-Electricity-By-The-Kilowatt-Hour

USDOE. (2013a). *DSIRE Glossary of Policy Terms* [web page]. Database of State Incentives for Renewables & Efficiency. http://www.dsireusa.org/glossary/

USDOE. (2013b). *Greenpower Network* [web site]. http://apps3.eere.energy.gov/greenpower/

USDOE. (2013c). *Green Pricing Utility Programs by State* [web page]. http://apps3.eere.energy.gov/greenpower/markets/pricing.shtml?page=1

USDOE. (2013d). *Sunshot Initiative: Project Highlights* [web page]. http://www1.eere.energy.gov/solar/sunshot/project_highlights.html

USDOE. (2013e). *3rd Party Solar PV Power Purchase Agreements* [map]. Database of State Incentives for Renewables & Efficiency. http://www.dsireusa.org/summarymaps/

USDOE. (2011). *Solar Powering Your Community: A Guide for Local Governments*. http://www1.eere.energy.gov/solar/pdfs/47692.pdf

USDOE. (2007). *The Potential Benefits of Distributed Generation and the Rate-related issues that May Impede Its Expansion*. Report Pursuant to §1817 of the Energy Policy Act of 2005. http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/1817_Study_Sep_07.pdf and http://www.doe.gov/sites/prod/files/oeprod/DocumentsandMedia/1817_Report_-final.pdf

USDOE. (No date). *The History of Solar* [electronic article]. U.S. Department of Energy. http://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf

USEIA. (2012a). *Annual Electric Power Industry Report (EIA-861 data file)*. U.S. Energy Information Administration. http://www.eia.gov/electricity/data/eia861/

USEIA. (2012b). *Green Pricing and Net Metering Programs*. U.S. Energy Information Administration. http://www.eia.gov/renewable/annual/greenpricing/

USEIA. (2012c). "New EIA Data Show Total Grid-Connected Photovoltaic Solar Capacity." *Today in Energy* [electronic article]. U.S. Energy Information Administration. http://www.eia.gov/todayinenergy/detail.cfm?id=8510

Verbruggen, Aviel, and Volkmar Lauber. (2012). "Assessing the Performance of Renewable Electricity Support Instruments." *Energy Policy 45*(2012), 635–644. http://dx.doi.org/10.1016/j.enpol.2012.03.014

Vermont Public Service Board. (1 Mar 2013). Order in Docket No. 7873, re: Establishment of Standard-Offer Prices and Programmatic Changes to the Standard-Offer Program. http://psb.vermont.gov/sites/psb/files/orders/2013/2013-03/7873%267874%20%20Order%20Re%20Prices%20and%20Program%20Changes.wpdpd_.pdf

Wiedman, Joseph F., and Erica M. Schroeder. (2012). *Community Renewables: Where Are We Now?* World Renewable Energy Forum, Denver, Colorado, May 13-17, 2012. http://ases.conference-services.net/resources/252/2859/pdf/SOLAR2012_0245_full%20paper.pdf

Yamamoto, Yoshihiro. (2012). "Pricing Electricity from Residential Photovoltaic Systems: A Comparison of Feed-In Tariffs, Net Metering, and Net Purchase and Sale." *Solar Energy 86*(9), 2678–2685. http://dx.doi.org/10.1016/j.solener.2012.06.001

Zahodiakin, Phil. (11 Dec 2012). "Connecticut Auction Cuts Clean Energy Costs" [electronic article]. *Greentech Media, greentechsolar*. http://www.greentechmedia.com/articles/read/Connecticut-Auction-Cuts-Clean-Energy-Costs

Zhai, Pei. (2013). "Analyzing Solar Energy Policies Using a Three-Tier Model: A Case Study of Photovoltaics Adoption in Arizona, United States," *Renewable Energy 57*(2013), 317-322. http://dx.doi.org/10.1016/j.renene.2013.01.058