It's Time for Utilities to Plan for Disruptive Solar PV Impacts

Rapidly Growing PV Markets Threaten Status Quo Operations and Planning

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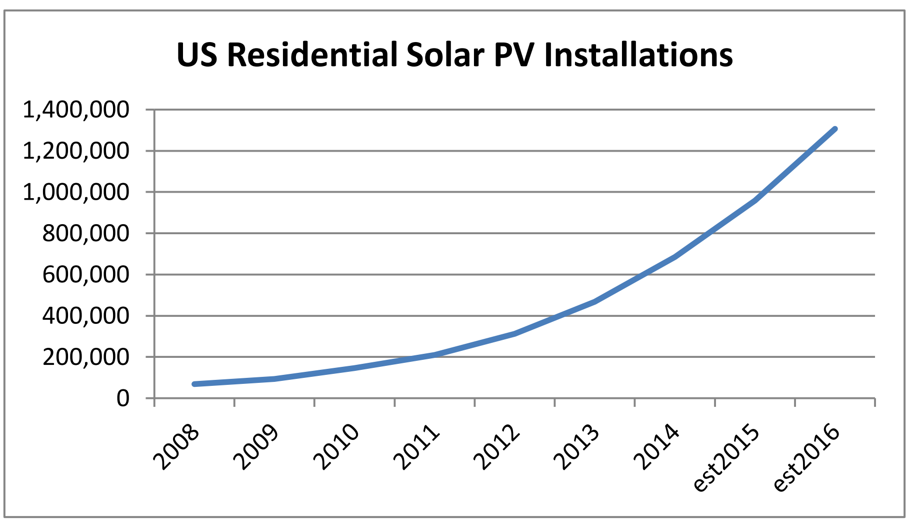
Introduction

Many utility executives consider PV-related power quality and other PV-related issues as something of a "back-burner" item given the number of current PV installations on their systems. However, new Smart Grid Research Consortium forecasting models and analysis indicate that these planning issues should be considered with some urgency to inform utility PV policies and programs and to prepare for dealing with concentrations of PV systems on certain portions of distribution systems.

While PV installations are still a relatively small percentage of the total utility customer base at most utilities, they tend to be geographically highly concentrated with potentially large impacts in certain ZIP areas, substations and along individual feeders. Heavy saturations of PV along feeders create power quality issues, asset life degradation due to excessive regulator and capacitor bank switching, and other problems. Utilities in Hawaii, California, New Jersey, and Arizona are already facing these challenges.

Dramatic PV cost reductions, popularity of third-party ownership arrangements, tax incentives and other factors are responsible for year-over-year doubling, or more, of PV installations in many states. The chart below shows the explosive growth in US residential solar PV installations. Residential solar PV installations are expected to grow to 1.3 million by the end of 2016, a 60 percent increase in the next year -and-a- half.



2014 data reflect an average of about 1.8 percent penetration for owner-occupied single family homes with incomes greater than $75,000/year and credit scores of 680 or above. The 2016 end-of-year estimate reflects an average penetration in this customer segment of about 3.4 percent. Since high-concentration PV installations tend to be clustered in areas with saturations as much as 5 to 8 times the average, 2014 clusters of 9-15 percent saturations could grow to as much as 17-27 percent in the next several years, edging into a saturation zone that creates power quality and voltage control problems. Increasing penetrations beyond that will require even more aggressive control strategies. Of course every feeder/circuit situation is different; however, these trends indicate that circuits that have a heavy potential "PV-receptive" concentration will soon become areas of power quality concern.

(Data Source: Jackson Associates based on state program reporting, federal reporting data, association data, and proprietary Smart Grid Research Consortium and Jackson Associates (SGRC/JA) data collection and analysis. 2015 and 2016 data reflect Smart Grid Research Consortium (SGRC) Solar PV Forecasting Models results.)

A growing PV market also raises a number of utility business model issues related to rate restructuring cross-subsidization, integration of PV assets as resources, utility participation in PV markets, and competition in providing electric service. These business model issues are a particular concern in financial markets. In May 2014 Barclays downgraded the entire electric sector corporate bond market to "underweight" because of challenges to electric utilities from solar energy. Barclays' preemptive bond reassessment indicates the need for a more proactive assessment and accommodation of solar PV within utility business models.

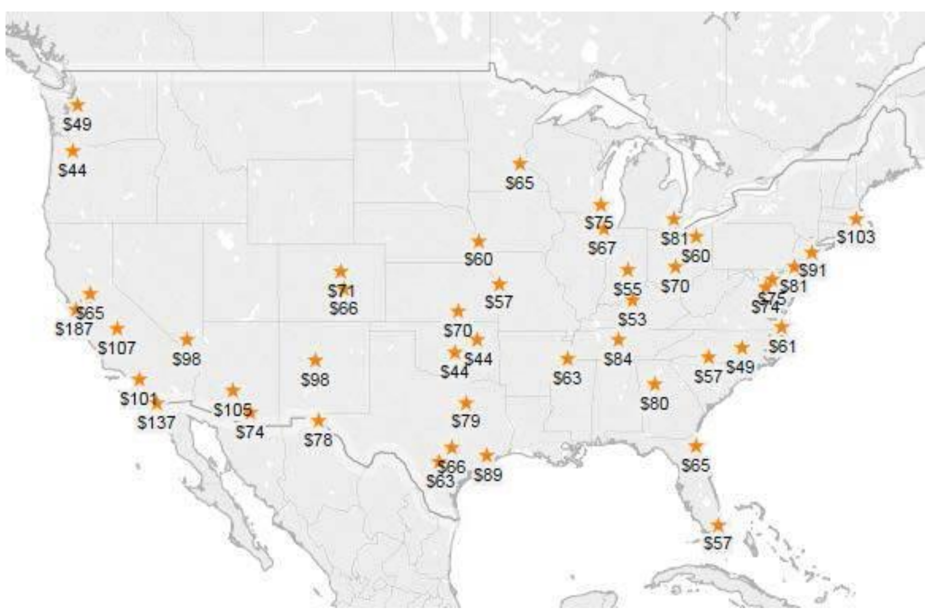
Over the last year, the Smart Grid Research Consortium (SGRC) developed, in collaboration with Jackson Associate (JA), an agent-based Utility Solar PV Forecasting model that is applied to individual utility service areas as a planning and analysis tool to forecast PV installations, load impacts and financial impact analysis. This model was developed as an evaluation and planning tool to assist utilities in making the transition to accommodate the rapidly growing utility PV presence both with respect to planning for operational changes and revenue/rate restructuring challenges.

As part of this modeling project, the research team identified PV market information that is both intuitive and detailed enough to allow readers to draw their own conclusions regarding potential growth and timing of solar PV-related issues in their service areas. This information is presented in the following sections.

Residential Solar PV Market Growth Determinants

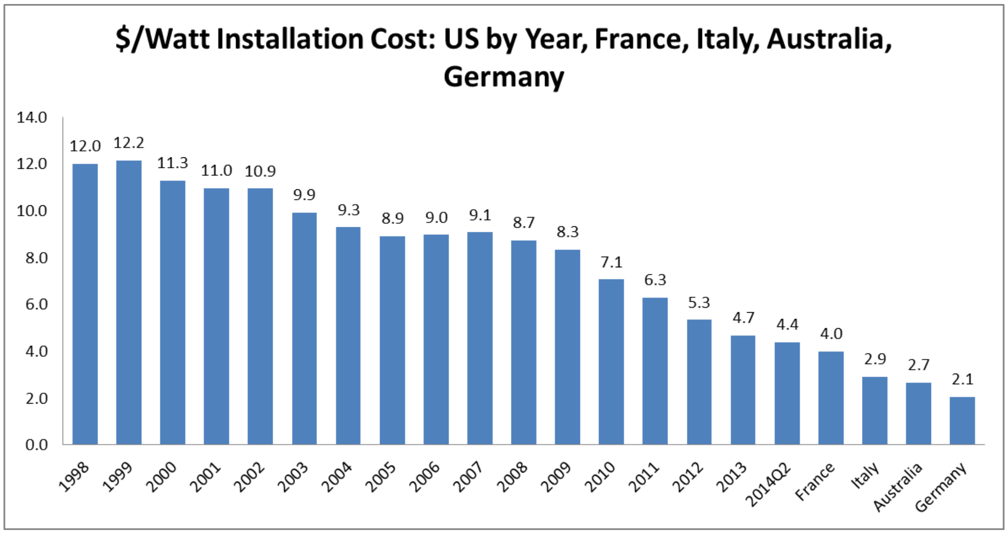
Solar PV market penetration depends in large part on the extent to which a PV system reduces electric bills. The graphic to the right shows monthly savings for a variety of cities based on kWh savings of a 5kW PV rooftop system and the local utility residential electric rate.

Source: "Going Solar in American", NC Clean Energy Technology Center

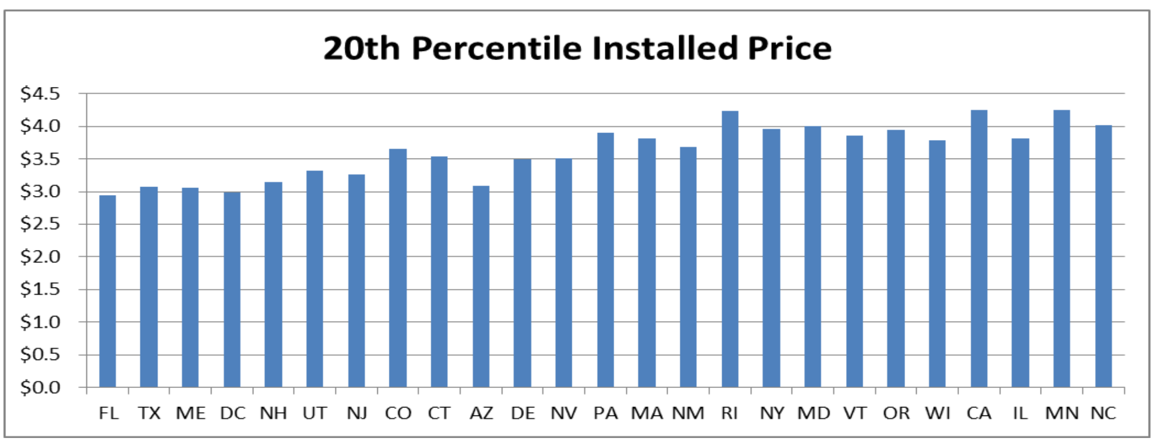


The combination of solar radiation and utility rates provides variations in monthly electric bill savings that range from $44 to $187 per month or $528 to $2,144 per year.

The figure on the right shows the dramatic decline in small (<10kW) solar rooftop installation costs over the last 15 years along with average system costs for similar systems in 4 other countries. The $/Watt installation cost has fallen by 63 percent over the last 15 years and could fall by an additional 50 percent from 2014Q2 cost of $4.4/Watt if system costs fall enough to meet German PV costs of $2.1/Watt. (Source: Tracking the Sun VII: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2013", Lawrence Berkeley National Laboratory, Berkeley, CA.)



While a variety of factors in the German market explain the difference between US and German installation costs, the variation in the 20th percentile installation costs across states shown in the figure below indicates that US costs have significant potential for continued reductions. The 2013 20th percentile costs can be considered "best-practice" and likely close to a median cost today, given the 10 percent or so annual cost reduction experienced in the last several years.



Source: Tracking the Sun VII: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2013", Lawrence Berkeley National Laboratory, Berkeley, CA.

Tables of paybacks for savings and installation costs with and without the current 30 percent investment tax credits are presented in Table 1. The 30 percent federal tax credit for residential applications will continue through 2016.

A fifteen year payback is consistent with a 2.5 percent return on the investment which is comparable to a long-term treasury bill. As indicated in the tables, even without the current 30 percent tax credit, 33 of the 48 combinations of bill savings/cost meet a 15 year payback criterion while 39 of the 48 meet a 20 year break-even payback.

Table 1 is a conservative presentation of solar PV economics because it does not include net metering benefits that can be captured in many areas nor does it consider benefits associated with combined solar/battery storage that exists in areas with time-of-use rates and high on-peak charges.

Table 1. Payback Years for a 5kW Rooftop Solar PV System

Monthly Bill Savings	$/Watt with no incentives 4.5	4	3.5	3	2.5	2
$42	45.0	40.0	35.0	30.0	25.0	20.0
$63	30.0	26.7	23.3	20.0	16.7	13.3
$83	22.5	20.0	17.5	15.0	12.5	10.0
$104	18.0	16.0	14.0	12.0	10.0	8.0
$125	15.0	13.3	11.7	10.0	8.3	6.7
$146	12.9	11.4	10.0	8.6	7.1	5.7
$167	11.3	10.0	8.8	7.5	6.3	5.0
$188	10.0	8.9	7.8	6.7	5.6	4.4

Monthly Bill Savings	$/Watt with 30% Investment Tax Credit 4.5	4	3.5	3	2.5	2
$42	31.5	28.0	24.5	21.0	17.5	14.0
$63	21.0	18.7	16.3	14.0	11.7	9.3
$83	15.8	14.0	12.3	10.5	8.8	7.0
$104	12.6	11.2	9.8	8.4	7.0	5.6
$125	10.5	9.3	8.2	7.0	5.8	4.7
$146	9.0	8.0	7.0	6.0	5.0	4.0
$167	7.9	7.0	6.1	5.3	4.4	3.5
$188	7.0	6.2	5.4	4.7	3.9	3.1

20 Year payback or better (yellow)
15 Year payback or better (green)

Table 1 also does not include incentives provided by states or utilities or the impact of the investment on the value of the home. For example, in Baltimore, monthly savings are $47 (annual savings $563) providing a payback of 36 years. However, the state installation incentive of $1,000 and the Solar Renewable Energy Credits (SRECs) payments at current market values reduce the payback to 17 years. With the 30 percent investment tax credit the payback drops to 9 years.

While the payback tables suggest a significant market expansion as installation costs continue to fall, they understate the existing and future market for residential solar PV. One financial benefit that is not included in the tables is the increase in value of a dwelling unit with a PV system associated with reduced future electric bills.

In addition, solar PV provides residential households with non-financial benefits including satisfaction associated with generating one's own electricity, reducing greenhouse gases and reducing other central electric plant environmental impacts. These non-financial benefits actually have a financial value which, along with the financial valuation of reduced electric bills is revealed in premiums paid for dwelling units with solar PV systems.

A 2011 National Bureau of Economic Research (NBER) study found that approximately 104 percent of the cost of residential solar PV systems in San Diego and Sacramento is returned to the owner at the time of the dwelling unit sale. This compares to a 60 percent return on a luxury kitchen remodeling (Source: Hanley Wood's 2010-2011 Cost v. Value report). A recent DOE/LBNL study (Selling Into The Sun: Price Premium Analysis Of A Multi-State Dataset Of Solar Homes, January 2015) analyzed data across eight states and found a premium of approximately $4/Watt which is consistent with the NBER study results.

Table 2 shows the total financial value provided to a PV homeowner assuming that the homeowner sells the dwelling unit in ten years. Financial value is calculated in the top part of table 2 as the total of annual savings while the homeowner is in the dwelling unit plus a 4 percent return on the initial investment when the house is sold.

Even with a lower capitalization of 80 percent of the initial cost, as shown in the lower part of Table 2, the PV investment pays off for all combinations of bill savings and cost.

Table 2. Total Financial Benefit With 10 Year Residencey

PV Investment Returns 104 Percent on Sale

Monthly Bill Savings	**$/Watt with no incentives** 4.5	4	3.5	3	2.5	2
$42	5,900	5,800	5,700	5,600	5,500	5,400
$63	8,400	8,300	8,200	8,100	8,000	7,900
$83	10,900	10,800	10,700	10,600	10,500	10,400
$104	13,400	13,300	13,200	13,100	13,000	12,900
$125	15,900	15,800	15,700	15,600	15,500	15,400
$146	18,400	18,300	18,200	18,100	18,000	17,900
$167	20,900	20,800	20,700	20,600	20,500	20,400
$188	23,400	23,300	23,200	23,100	23,000	22,900

PV Investment Returns 80 Percent on Sale

Monthly Bill Savings	**$/Watt with no incentives** 4.5	4	3.5	3	2.5	2
$42	$ 500	$ 1,000	$ 1,500	$ 2,000	$ 2,500	$ 3,000
$63	$ 3,000	$ 3,500	$ 4,000	$ 4,500	$ 5,000	$ 5,500
$83	$ 5,500	$ 6,000	$ 6,500	$ 7,000	$ 7,500	$ 8,000
$104	$ 8,000	$ 8,500	$ 9,000	$ 9,500	$ 10,000	$ 10,500
$125	$ 10,500	$ 11,000	$ 11,500	$ 12,000	$ 12,500	$ 13,000
$146	$ 13,000	$ 13,500	$ 14,000	$ 14,500	$ 15,000	$ 15,500
$167	$ 15,500	$ 16,000	$ 16,500	$ 17,000	$ 17,500	$ 18,000
$188	$ 18,000	$ 18,500	$ 19,000	$ 19,500	$ 20,000	$ 20,500

Considering capitalization of the PV investment returned on sale of the house makes the investment comparable to purchasing a bond where the bond purchase provides monthly dividends and can be sold in the future for some fraction (perhaps more than 100 percent as indicated in the NBER study) of its initial cost depending on the market value of the bond at the time of the sale.

More financially sophisticated evaluations than payback and total financial returns discount future savings and apply financial criteria such as internal rate of return and net present value. However, payback and total financial savings presented in the tables above reflect a more typical consumer evaluation and, as such, are more useful in evaluating likely future solar PV market penetration.

Utility Business Model Impacts

A variety of solar PV incentives and rate issues can impact the utility business model as PV penetrations increase. Net metering typically reimburses PV customers at a retail rate while utility avoided power purchase costs is typically much less than the reimbursement raising cross-subsidy issues. PV installations on certain circuits can provide a positive benefit to utilities and PV installations in general provide an avoided capacity cost and reduced system losses. Utility control of PV systems and or PV/storage systems can be integrated in utility resource management. Many utilities encourage PV installations either as part of meeting a renewable portfolio standard and/or to promote sustainable resources. However, additional voltage control and associated equipment and software costs can significantly reduce net benefits, especially as PV saturations increase.

Utilities can reduce costs associated with increased behind-the-meter PV systems by (1) identifying geographic areas where PV installations are most likely and fashioning programs and monitoring to address these issues, and (2) evaluating business case impacts of current PV incentives, rates and other policies to revise rate structures and potentially integrate behind-the-meter PV into the utility generation/distribution system.

Conclusions

Expected declines in solar PV installation costs will continue to expand PV solar markets. The positive economics for solar at its current cost level when capitalized value is recognized suggest that future growth of the solar market may be more substantial than even its most ardent proponents anticipate.

The Consortium's Residential Solar PV Models shows that the saturation of PV systems in a neighborhood are important determinants of new PV installations. This typical new technology market penetration relationship supports the view that PV exponential growth will continue for some time.

Clustering of PV-receptive customers will require extra utility effort to address power quality challenges. Revenue impacts, rate cross-subsidies, third-party electricity sales and other utility business model issues will accompany increasing PV penetration.

The rapidly developing PV market transformation provides urgency to utility planning for the increased penetration of residential solar PV installations.

Smart Grid Research Consortium PV Models and Forecasting Service.

A growing number of utilities are finding it necessary to develop a planning process to anticipate and address new issues that accompany growing utility PV saturations.   The "clustering" of installations creates power quality and control issues along certain feeders while business model issues including cross-subsidies, rate structure and revenue issues must be addressed.

The Smart Grid Research Consortium (SGRC) Solar PV Forecasting Models and Forecasting Services are designed to address these issues with utility-specific agent-based statistical models that are estimated and applied separately for each utility service area.   Data on more 7 million utility customers and nearly 500,000 solar PV installations have been compiled to support this modeling process. The SGRC Solar Models and Service provide the first commercially available annual forecasts of residential solar PV system installations, energy and hourly load impacts, costs and benefits over a 10-year forecast horizon. Forecasts are provided for distribution feeders, substations, ZIP areas, and the entire utility service areas.   Low, medium and high forecasts are provided to reflect the range of likely PV installation and load impacts.

The SGRC Models have been developed by merging the Consortium's Smart Grid Investment Model (SGIM) and Jackson Associates (JA) MAISY Utility Customer Databases and Agent-Based Energy and Hourly Load Forecasting Models.   The SGIM has been applied for 20 electric utilities since its development in 2010 while MAISY data, modeling and forecasting analysis have been applied at more than 100 energy-related organizations including utilities, equipment manufacturers, state and federal regulatory agencies and other energy-related organizations.

PV models and forecasts are designed both to assist utility distribution planners and to provide a program evaluation tool for utility solar program development. Additional information on the Solar PV Forecasting Service and the Consortium's Solar PV Forecasting Model is available at the SGRC web site: www.smartgridresearchconsortium.org/solarforecasts.htm   See the MAISY Web site (www.maisy.com) for example applications including agent-based analyses of CHP units for emergency power in natural disasters, electric utility rate impacts on CHP distributed generation system adoption, Duke Energy Smart Grid cost/benefit analysis and energy forecasts for the Indiana Public Service Commission.

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