



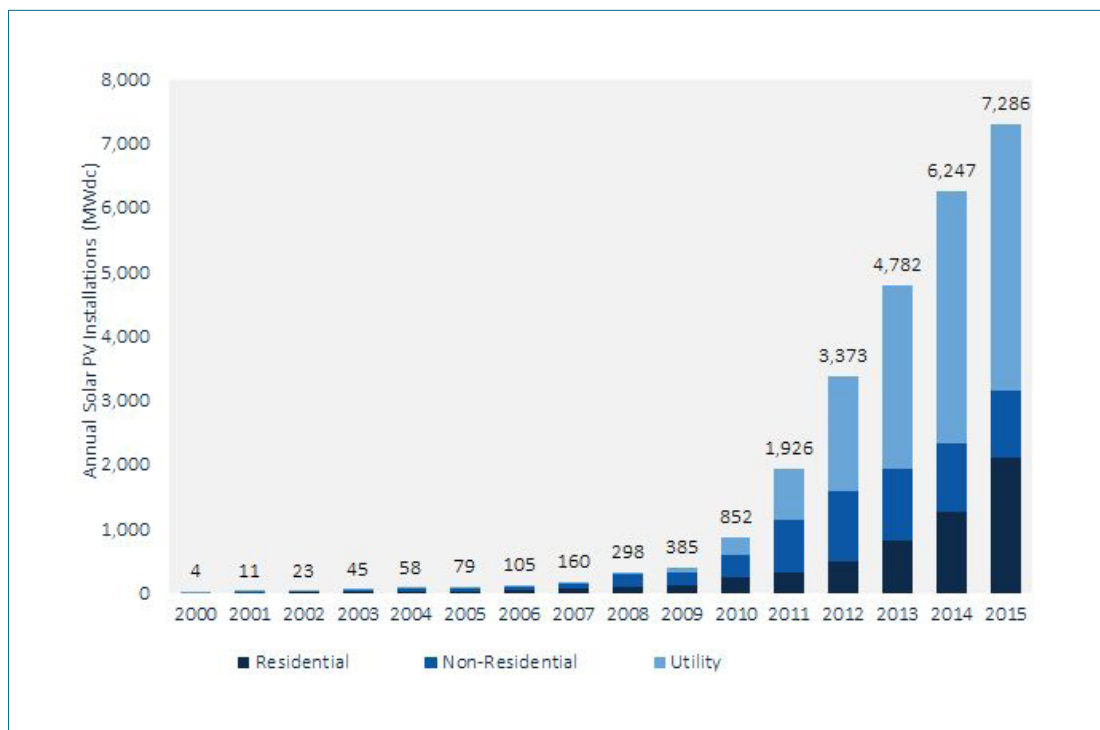
Assessing the Value of Distributed Solar

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INTRODUCTION

In 2015, the United States installed a record 2 gigawatts (GW) of residential solar photovoltaics (PV).¹ Solar PV has seen increasing investment over the last several years due to improvements in technology and steady declines in prices. This exponential growth has benefited Americans in numerous ways, including improvements in air quality and additions to the workforce. However, there is little consensus on what impact residential solar deployment will have on electricity grid systems and on economic equity among electricity customers. While solar advocates tout the many benefits of increased distributed solar PV development, many electric utilities have cited concerns over how new, intermittent, distributed resources will be incorporated into existing grid infrastructure and planning, and how to appropriately charge solar and non-solar customers for electricity service.



Source: GTM Research / SEIA U.S. Solar Market Insight Report

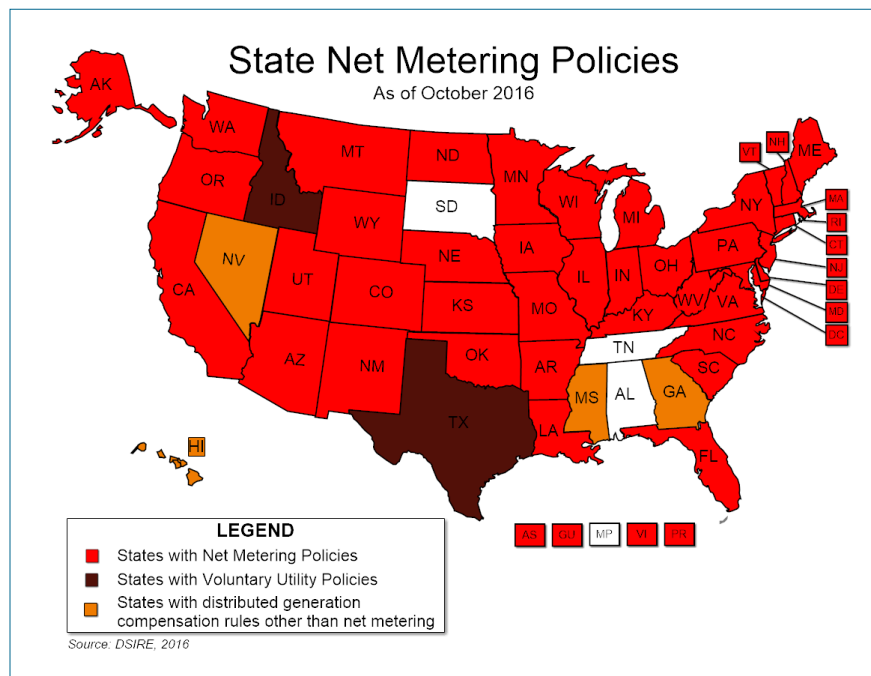
This paper provides an overview of how experts view solar PV's impact on electric grid systems and the value that increased solar PV can offer, as well as the potential challenges of continued solar growth and the questions that remain.

1 SEIA. *U.S. Solar Market Sets New Record, Installing 7.3 GW of Solar PV in 2015*. February 22, 2016. <http://www.seia.org/news/us-solar-market-sets-new-record-installing-73-gw-solar-pv-2015>

BACKGROUND

In recent years, many US electric utilities have raised concerns about the growth of distributed PV systems and the impact that such systems have not only on the grid but on equity in utility rate structures. This debate has been most prominent in states with net energy metering (NEM) where utilities have argued that customers with solar PV are not paying their fair share of electric grid infrastructure, operations, and maintenance costs.

Despite generating a portion of their own electricity, homes with solar PV are still connected to the electric grid and draw power when their demand is in excess of what their PV systems are generating. With net metering laws on the books in most states, customers with their own PV generators are able to sell excess electricity back to the utility at either the utility's avoided cost, or in some cases, the current fuel charge value (Rábago 2013).

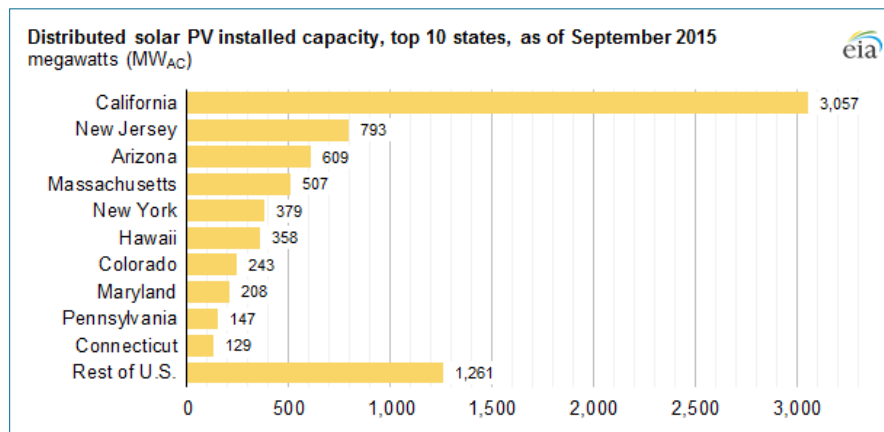


DSIRE, 2016

While NEM policies have allowed the solar industry to flourish by providing a straightforward way for customers to earn money from the energy they produce, many utilities and other stakeholders have recently begun to call for the revision or replacement of NEM policies. They cite that net metering programs do not reflect the true value of solar, instead pricing distributed solar energy at the same rate as retail electricity from the grid. Indeed, existing NEM programs have a number of key limitations (Rábago 2013):

1. NEM at the full retail rate does not ensure that utilities recover the full cost of serving solar customers. A large solar installation, for instance, could eliminate utility charges while the customer continues to receive power from the grid at night and on a standby basis.
2. Because the “avoided cost” rate of electricity is usually too small to justify investing in higher-capacity installations, customers are incentivized to size their PV systems according to their baseline energy demand. They are thus discouraged from being equipped to deliver excess power during periods of peak demand. Meanwhile, the utility has to deliver peak energy to other customers at higher-than-average costs.
3. In increasing tiered rate structures, NEM disproportionately benefits high energy consumers over lower energy consumers because the value of solar energy effectively increases as a customer enters each progressively more expensive consumption tier.
4. NEM can perversely incentivize customers to use more energy at peak times, and possibly even use more energy in general, if production in excess of consumption is credited at a much lower price.

There is broad stakeholder agreement that net metering is not a permanent solution to properly valuing distributed solar. Many states have capped the amount of installed megawatts of PV that can enjoy net metering rates, effectively postponing the value of solar discussion. Indeed, the relative costs and benefits of distributed solar are inextricably linked to rates of solar penetration in a given service territory. While Hawaii is currently the only state where utilities see solar penetration rates above 10 percent, in the next decade solar is expected to reach and exceed similar levels elsewhere in the US. At such high penetrations, distributed solar can have a disproportionate impact on electric rate structures (LBNL 2017).



Source: U.S. Energy Information Administration, *Electric Power Monthly*

In anticipation of these future impacts, utilities, solar advocates, regulators, and other stakeholders have begun to reassess NEM programs and consider new approaches to properly value solar. Even in some states where extant solar policies have never been strong enough to encourage large-scale growth, many utilities and regulatory commissions are pushing to overhaul net metering. When to replace NEM, and with what approach, has been hotly contested among stakeholders in various states.

VALUE OF SOLAR STUDIES

Regulators, utilities, and advocates in states throughout the country continue to debate the merits and demerits of net metering for PV customers. This report reviews a number of studies that each seek to formally establish the true value of distributed solar.

VALUE OF SOLAR COMPONENTS

The studies reviewed for this report are divided over how distributed PV provides value to the electricity grid, and whether that value is a net benefit. While in some cases the authors or sponsors of these studies have motives for their work beyond a strictly objective analysis of value, the studies provide a useful basis for how solar's value has been considered to date, the key value components of distributed solar, and remaining points of controversy.

Exact methodologies vary from study to study, but some components of solar value are recognized across most or all of them. These include distributed solar's impacts on the following:

TABLE 1. WIDELY RECOGNIZED VOS COMPONENTS

COMPONENT	DESCRIPTION	SUPPORTING STUDIES CITED
Avoided Energy Costs	Avoidance of energy produced by other sources	<ul style="list-style-type: none"> • RW Beck 2009 • RMI 2013 • NREL 2015 • Swisher 2015
Avoided capital and capacity investment in generation infrastructure	Deferment of upgrades to or construction of generation resources	<ul style="list-style-type: none"> • Farrell 2014 • Swisher 2015 • NREL 2015
Avoided capital and capacity investment in T&D infrastructure	Deferment of upgrades of transmission and distribution (T&D) lines	<ul style="list-style-type: none"> • RW Beck 2009 • NREL 2015 • Swisher 2015
Avoided O&M costs	Savings of operations and maintenance costs for generation, transmission, and distribution assets	<ul style="list-style-type: none"> • RW Beck 2009 • Farrell 2014 • NREL 2015

Other factors affected by distributed solar are included only in a subset of studies, either because their benefits are more contentious or they are less straightforward to calculate. These include:

TABLE 2. CONTENTIOUS VOS COMPONENTS

COMPONENT	DESCRIPTION	SUPPORTING STUDIES CITED
Increased grid resiliency and reliability	Alleviation of pressure and increased resiliency and reliability on the local grid	<ul style="list-style-type: none"> • Frontier 2016
Avoided losses and other locational benefits	Avoidance of electrical losses associated with delivery from centralized plants	<ul style="list-style-type: none"> • RMI 2013 • EPRI 2016c
Environmental benefits	Avoidance of greenhouse gas emissions, reduction in air pollution, and avoidance of environmental compliance costs	<ul style="list-style-type: none"> • RW Beck 2009 • Frontier 2015 • EEI 2014
Job Creation	Benefits from local economic development and job security	<ul style="list-style-type: none"> • Swisher 2015

Each of these categories can be calculated individually and then aggregated to approximate the monetary value delivered to the grid from distributed solar.

AVOIDED ENERGY COSTS

The bulk of potential annual savings to utilities from distributed solar results from the avoidance of the need to produce energy from other sources (RW Beck 2009). This reduced need for centralized generation capacity reduces fuel and purchased power requirements and consequently reduces line losses and annual fixed O&M costs.

As highlighted in the Rocky Mountain Institute's meta-analysis of VOS studies, there is broad agreement in the general approach to determining energy costs by calculating the avoided cost of the marginal resource (usually natural gas), though methodologies differ among studies (RMI 2013). In their study, the National Renewable Energy Laboratory recommended calculations based on natural gas price forecasts from the Energy Information Administration to project annual fuel costs per kWh. These data were then converted to offset costs using the displaced natural gas heat rate for a combined-cycle natural gas plant compared to calculated solar output (NREL 2015). This methodology would need to be adjusted based on the local fuel mix.

Utilities commonly engage in strategies to hedge against fossil fuel price volatility. Some studies (RW Beck 2009, Swisher 2015) also include the value associated with using power from a non-volatile energy source, called *fuel price hedge*. Although RW Beck values this based on natural gas pipeline reservation fees, the details of this calculation's methodology are not clear.

AVOIDED CAPITAL AND CAPACITY INVESTMENT IN GENERATION INFRASTRUCTURE

Distributed PV can help defer the need to upgrade or construct additional generation resources. However, because it is not dispatchable, there is some debate about how to properly quantify the generation savings. Most studies (Farrell 2014, Swisher 2015, NREL 2015) estimate the effective capacity of distributed energy resources (DER) using the effective load carrying capacity (ELCC) method. The ELCC is calculated based on probabilistic modeling and compared to a “perfect generator” (CPUC 2014). The resulting percentage indicates how often a resource can meet reliability requirements. This ELCC amount can then be compared to conventional generation — mostly natural gas power plants — that can be offset or deferred thanks to DER installations. A clear understanding of projected future capacity growth and existing financial commitments is essential to this calculation. All studies reviewed for this paper contained a value associated with avoided generation capacity.

It is worth noting that although new distributed PV capacity may offset the need to invest in other capacity upgrades, it is very challenging to forecast what kind of impact new, small-scale distributed generation will have on meeting load. Capacity upgrades have historically been undertaken in bulk to meet forecasted demand increases, whereas distributed generation is installed piecemeal and installation rates are difficult to predict. Moreover, increased PV capacity is not equal to increased capacity from non-intermittent sources, as its generation profile is variable and it is not a dispatchable resource.

AVOIDED CAPITAL AND CAPACITY INVESTMENT IN T&D INFRASTRUCTURE

By supplying power closer to points of demand, distributed PV can help defer or avoid the need to upgrade transmission and distribution (T&D) lines. However, because PV resources cannot be dispatched by utilities and thus may not necessarily alleviate peak demand — or congestion along T&D lines — there is debate about how to properly quantify the T&D savings. The potential for distributed generation to offset investment in T&D infrastructure is directly related to time of use for power. Without the ability to shift solar production or store electricity at scale, distributed PV may simply shift the load peak to later in the day (Swisher 2015). Avoided T&D upgrade costs can be calculated based on projected future upgrade capital expenditures. However, there is no short-term value to avoiding transmission infrastructure upgrades, as transmission lines are often built far ahead of realized demand (RW Beck 2009).

The National Renewable Energy Laboratory (NREL) calculation for avoided T&D infrastructure is based on average T&D costs nationally, as published by the American Society of Civil Engineers, divided by the average national retail sales for the same period (NREL 2015). Other calculations rely on the local wholesale price contribution (Austin Energy 2014). All studies reviewed for this paper contained a value of solar component associated with long-term avoided transmission capacity.

While distributed PV does not have any net positive effect on distribution systems, there may be benefits for specific feeders that could defer distribution upgrade investments (RW Beck 2009). Both EPRI and ICF provide engineering services to model specific feeders and assess the impact that distributed energy resources will have on the electric system.

AVOIDED O&M COSTS

With less demand placed on generation resources and T&D infrastructure, distributed PV often results in savings in operations and maintenance (O&M) costs across the grid (RW Beck 2009, Farrell 2014, NREL 2015). A study for APS energy found that O&M savings are directly tied to penetration rates. Higher penetration rates lead to greater reductions in fixed O&M costs (RW Beck 2009). For each piece of equipment that saw reduced run time, this study calculated the avoided annual maintenance costs, labor costs, rent, and utilities for facility operation that APS would incur for a generating unit whether the unit operates or not.

Some studies include avoided O&M costs with the capacity and T&D value, while others calculate it as a stand-alone value. All studies reviewed for this paper include a value associated with avoided O&M expenses.

INCREASED GRID RESILIENCY AND RELIABILITY

Although strategic DER investment could help relieve stress to the T&D system, the studies reviewed for this paper are divided on whether DER has a net positive impact on grid resiliency or reliability. Intermittent power not only complicates long-term utility planning, but also negatively affects second-to-second grid stability (Borenstein 2008). Solar advocates cite that DER can further provide benefits to the grid by mitigating the impact of outages to certain distribution areas (Frontier 2016).

Some utilities and other stakeholders argue that distributed PV has a net negative impact on grid reliability (RW Beck 2009, Brown 2016). They point out that DER can increase congestion and increase dispatch complexity, while not consistently and reliably alleviating demand.

Value pertaining to resiliency and reliability is inherently difficult to quantify due to the heterogeneity of grid characteristics where DERs are located. Most studies do not attribute a value to reliability and resiliency, and some, such as RW Beck (2009), say that without a way to reliably dispatch intermittent solar resources — such as storage — distributed PV adds negative value to the grid.

AVOIDED LOSSES AND OTHER LOCATIONAL BENEFITS

On average, electricity line losses comprise about 5% of the electricity transmitted and distributed annually in the US.² Many of the studies examined in this review do not attempt to calculate a value

2 EIA, How much electricity is lost in transmission and distribution in the United States?
<https://www.eia.gov/tools/faqs/faq.php?id=105&t=3>

associated with the locational effects of DER, but it is clear that adding distributed generation to distribution networks has an effect on the local grid.

Because the benefits or costs of distributed solar in the distribution system are inherently local, an accurate assessment of locational value requires a level of granularity that makes analysis complex and difficult, and cannot be generalized beyond the location in question (RMI). The question of whether distributed PV adds value to the electric grid cannot be answered uniformly, but rather depends on a number of factors.

According to a 2016 EPRI study, the potential costs or benefits of DER within a given distribution network are predicated on the DER portfolio composition, the area's load growth, and the timing of capital investments. Similarly, the ability for DER to provide deferral benefits is highly dependent on the location of the resource relative to a system constraint, and these considerations vary by the topology of the power system (EPRI 2016c). Additionally, DER is much less valuable — and potentially more problematic — in radial distribution systems, as opposed to network distribution systems.

The further electricity travels, the greater the percentage of power lost to inherent system inefficiencies. With more distributed generation situated closer to load points, these losses are mitigated — a positive benefit of DER. As included in the RMI meta-analysis, reductions in line losses have typically been included in studies, though calculation methodologies differ widely among studies. Additionally, some studies' loss calculations include energy and T&D savings, while others calculate it as a stand-alone value (RMI 2013).

ENVIRONMENTAL BENEFITS

Solar power provides numerous environmental benefits, including avoided greenhouse gas emissions and reduced air pollution. Most of the studies reviewed for this paper mention the environmental benefits associated with distributed solar, but calculating a quantified value for environmental benefits remains one of the more controversial elements of the Value of Solar discussion. Solar advocates assign significant value to the environmental benefits of distributed solar (Frontier 2015). However, studies differ in how they quantify such benefits, with some attributing value based on the avoided marginal damages of emissions, and others looking strictly at avoided environmental compliance costs based on existing legislation and regulations.

The Value of Solar study commissioned by the Maine Public Utilities Commission, for example, attributes values based on the calculated social costs of carbon, SO₂, and NO_x, as does the Value of Solar Tariff (VOST) methodology used by Minnesota. Other studies take a more pragmatic approach, and argue that such values should only be quantified in jurisdictions where there is already a regulated price on emissions and avoided incremental emissions will avoid regulatory penalties (RW Beck 2009).

In some jurisdictions, distributed PV can empirically reduce environmental costs to utilities; that is, they can reduce or avoid penalties associated with failures to meet regulatory requirements such as renewable portfolio standards (RPS), or solar carve-outs therein. Twenty-nine states and the District of Columbia have mandatory RPSs, and in more than half of those states, there are specific carve-outs for solar (LBNL 2016). Utilities involved in VOS studies are generally receptive to the concept of environmental benefit calculations associated with regulatory compliance, but discount the notion of societal environmental benefits as part of the VOS. This is both because no direct financial costs are being reduced or avoided and because many utilities view addressing societal environmental benefits as the purview of policymakers — through climate or air pollution policy, for example — rather than utilities (EEI 2014).

JOB CREATION

Some studies reviewed for this paper include an analysis of the economic development benefits of DER, primarily benefits from job creation (Swisher 2015, Brown 2016). While a thriving solar industry would certainly induce economic growth, it is difficult to quantify the net impact of DER in terms of cost-benefit analysis. Some argue that because benefits from local economic development and job security are meaningful to stakeholders, potential valuation methods should be explored (Swisher 2015). Others disagree that solar job creation is a net benefit, and compare the labor intensity and domestic presence of the coal industry to that of the less labor-intensive and more globalized solar industry (Brown 2016).

VALUE OF SOLAR AS A FUNCTION OF PENETRATION LEVEL

The components detailed above are all estimated or calculated for the current electrical grid. However, at higher solar penetration rates, the value of each impact may see a diminishing rate of return.

For instance, in low-penetration models, utility generation O&M costs may decrease with the reduction in power demand that results from distributed solar being added to the grid. However, at higher penetration rates, infrastructure upgrades that may have been deferred initially may require investment to support additional DER investment. Indeed, as laid out by Edison Electric Institute, increased DER penetration may in fact have the opposite effect, adding additional pressure to the T&D systems (EEI 2014).

VALUE OF SOLAR TARIFFS

Some states and municipalities faced with significant customer-driven growth of distributed PV systems have recognized the need to phase out net metering, and in its place develop rate structures that attribute monetary value to the electricity these systems contribute to the grid. These VOST calculations can provide value to multiple stakeholders (NREL 2015):

- Utilities benefit from straightforward, uniform regulation. VOST programs allow utilities to recover the cost of fixed-cost services like transmission and distribution.

- Residential solar customers benefit from long-term agreements that are not subject to frequent regulatory changes. Payment for solar generation helps customers recoup the cost of investment.
- The solar industry benefits from a long-term commitment by utilities to honor VOST. VOST programs provide predictability and risk reduction.
- VOST programs allow policymakers to address increasing demand for solar from constituents.

VOS TARIFF IMPLEMENTATION

Despite a growing rejection of NEM policies, few utilities have adopted VOST programs. Currently, only one utility (Austin Energy) and one state (Minnesota) have enacted VOST policies, though others have expressed interest.

AUSTIN ENERGY

In 2012, Austin Energy (AE) was one of the largest publicly owned utilities, with 2,922 megawatts (MW) of installed generation capacity serving over 370,000 residential customers (AE 2011). In the process of developing their first rate case in 18 years, AE proposed separating fixed costs from usage. As part of this rate case, AE proposed a Value of Solar Tariff (VOST) as an innovative method to meter and attribute value to residential solar installations. The primary goal of the VOST was to allow customers to benefit from solar installations in a manner that was economically fair to both AE and other customers. Unlike net metering, which disproportionately benefits customers who consume more energy, VOST decouples energy consumption from the solar rate, paying customers back based on revenue (Harvey 2017).

According to a 2014 study by AE, under net metering, customers could expect a payback of between 7 and 11 years on their solar panels, with higher electricity consumers benefitting from a quicker payback. At the 2014 \$0.107-per-kWh VOST rate, the average customer had a longer payback period than net metering, at more than 10 years.

Austin Energy's VOST consists of the following calculations:³

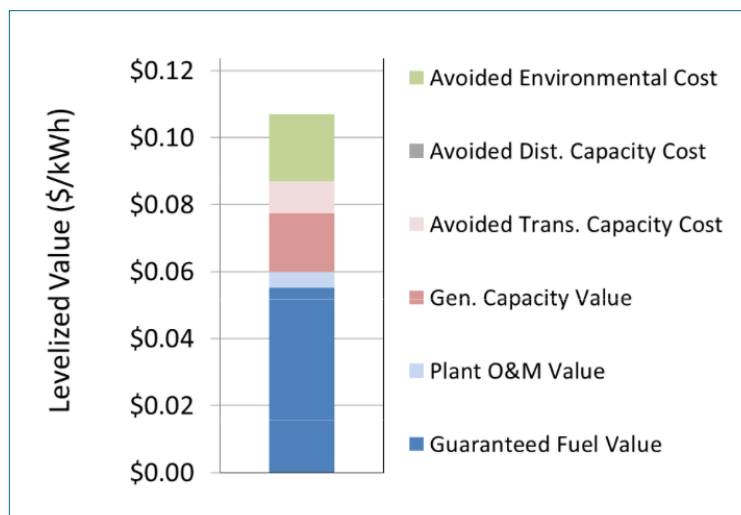
- **Guaranteed Fuel Value**, valued as the cost of fuel to meet electric loads and T&D losses inferred from nodal price data and guaranteed future natural gas prices
*Calculated as:
$$\frac{\sum (Implied\ Heat\ Rate * Gas\ Price * PV\ Production * Risk\ Free\ Discount\ Factor)}{\sum (PV\ Production * Risk\ Free\ Discount\ Factor)} * (1 + Loss\ Factor)$$*

3 City of Austin Electric Tariff, Value-of-Solar Rider.

<http://my.austinenergy.com/wps/wcm/connect/c6c8ad20-ee8f-4d89-be36-2d6f7433edbd/ResidentialSolar.pdf?MOD=AJPERES>

- Plant O&M Value**, including costs associated with operations and maintenance.
Calculated as: $(\sum (O \& M \text{ Cost} * (1 + \text{Inflation})^{\text{year}} * PV \text{ Capacity} * Risk \text{ Free Discount Factor})) * (1 + Loss \text{ Factor}) / \sum (PV \text{ Production} * Risk \text{ Free Discount Factor})$
- Generation Capacity Value**, including the capital cost of generation to meet peak load as inferred from nodal price data
Calculated as: $(\sum (Annual \text{ Capital Carrying Cost} * PV \text{ Capacity} * Risk \text{ Free Discount Factor})) * Load \text{ Match} * (1 + Loss \text{ Factor}) / \sum (PV \text{ Production} * Risk \text{ Free Discount Factor})$
- Avoided transmission and distribution capacity costs**, both operations and maintenance (O&M) and new investments
Calculated as: $(\sum (Transmission \text{ Cost} * PV \text{ Capacity} * Risk \text{ Free Discount Factor})) * Load \text{ Match} * (1 + Loss \text{ Factor}) / \sum (PV \text{ Production} * Risk \text{ Free Discount Factor})$
Where transmission cost is Austin Energy's contribution to ERCOT T-Cost. Distribution value is not currently calculated but will be included as solar penetration increases.
- Avoided Environmental Compliance Cost**, defined by the cost to comply with environmental regulations and policy objectives.
Set at the time of the original study at 2 cents per kilowatt-hour, loosely based on the Renewable Energy Certificate market.

SAMPLE AUSTIN ENERGY VOST CALCULATION (CPR 2013)



2014 Value of Solar at Austin Energy

AUSTIN VOST PROGRAM DETAILS AND OUTLOOK

Austin Energy adjusts the VOST annually based on updated inputs to the rate components above. After a dramatic decline in natural gas prices — and a corresponding decrease in VOS rates — in the first few years of the program, AE opted to convert the rate to a five-year rolling average, tempering the impact that short-term fluctuations can have on rates. While the VOS rate changes annually, the rate customers receive is actually an average of the current year plus the four years previous.

Austin Energy's VOST rate is widely viewed as a successful initiative from Austin Energy and the solar industry's perspective, and the utility saw more PV systems installed in December 2016 than in the combined first five years of the VOST program. In 2005, there were only five solar installers in Austin. Today, Austin's solar industry has burgeoned to over 45 installers. AE hosts monthly installer meetings which, along with providing regulatory guidance, also promote best practices among installers (Harvey 2017). In addition, AE officials view the VOST as beneficial for their business, as they maintain it transparently and fairly charges and compensates PV customers for their use of and contributions to the grid. Because the VOST was devised to credit PV customers at the "cost-neutral" rate at which AE has no preference as to whether they buy the electricity from distributed generators or generate it themselves, the utility is roughly kept financially whole (with the exception of the avoided environmental cost component), and any cross-subsidization between PV and non-PV customers is considered small or negligible.

The success of the VOST program is due in part to infrastructure investments that AE has made. The Austin grid is particularly robust, with a higher density of electrical nodes and redundant systems. Additionally, Austin requires that all homes with PV — currently there are about 5,000 residences with solar installations — use two separate meters provided by AE, a PV meter and a revenue meter. This arrangement allows AE to quantify solar production separately from energy consumption (Harvey 2017).

The VOST rate appears on residential customers' monthly electric bills as a credit on electricity costs. If customers produce more electricity than they consume, credits roll over to the following month. To encourage properly sized PV installations, Austin's program originally dissolved VOST credits at the end of each fiscal year. After receiving customer feedback, Austin has adjusted the credit system to roll over indefinitely; however, the credits are both nonrefundable and nontransferable. Because PV customers cannot be paid directly by the utility for their excess production, outside of bill credits, they are free from any potential tax implications associated with earning revenue (Harvey 2017).

As a result of the success of its residential VOST program, AE is currently in the process of establishing a commercial VOST program. AE commercial customers are billed based on peak demand, rather than consumption. A time-of-production VOST rate would allow AE to track and target peaks in demand, and thereby attribute more value to solar energy produced during peak periods (Harvey 2017).

It remains to be seen if the VOST is a cost-effective measure for AE in the longer run. Although the VOST was initially designed to be a “make whole” value, the burgeoning success of the program has shifted the economics. In discussions with AE staff, it appears that the utility has not attempted to quantify the cost differential between the VOST and the previous, net metering arrangement. So far, from the utility’s perspective, Austin’s VOST is a more favorable, financially sustainable solution to the ostensible challenges posed by net metering.

POTENTIAL REPLICABILITY

As other utilities across the country have pursued alternatives to net metering, it is worth considering why Austin may have been uniquely positioned to pioneer a Value of Solar methodology, and whether their program could be effectively replicated elsewhere.

UNIQUE AUSTIN CHARACTERISTICS

Because Austin Energy is a municipal utility, their financial decisions must be approved by the Austin City Council, in contrast to other US utilities, which are largely regulated by state public utility commissions (PUCs). PUCs tend to make decisions based on what will keep utility rates low for customers. While this is certainly a concern of the Austin City Council, the Council has a wider mission, making decisions based on a variety of objectives. The City Council is directly elected by Austin residents and as such represents the relatively progressive-minded population. It is unlikely that a state PUC would be as supportive of the type of pioneering VOST program that was implemented in Austin.

DEBATED VALUE COMPONENT CALCULATIONS

In addition to — and perhaps because of — the features unique to Austin Energy, some of the particulars of the VOST’s component calculations may not be as palatable in other states and regulatory jurisdictions. For example, AE’s *Value of Energy* calculation is based on highly transparent ERCOT power prices, but wholesale energy costs are much more opaque in other parts of the country and thus difficult to identify. AE’s 2-cent-per-kWh *Environmental Benefits* component is intended to capture the societal environmental benefits associated with incremental PV deployment. However, these benefits are not financially measurable from a utility’s perspective, as few regulations currently exist to reduce the environmental externalities imposed by the electricity sector.

For utilities that implement VOST programs in the future, rather than comprehensively replacing net metering, a more cautious strategy would be to pilot the VOST program to start. If done in a manner that allows for an analysis of causal treatment effects, the efficacy of the program may be assessed. This can be done before net metering is fully discontinued, to ensure that the VOST is not overly detrimental to solar development, presuming that this is a policy goal. Minnesota did not quite do this, but it did make VOST optional to start, a strategy that helps test the program, even if it does not provide causal estimates of the program’s effect.

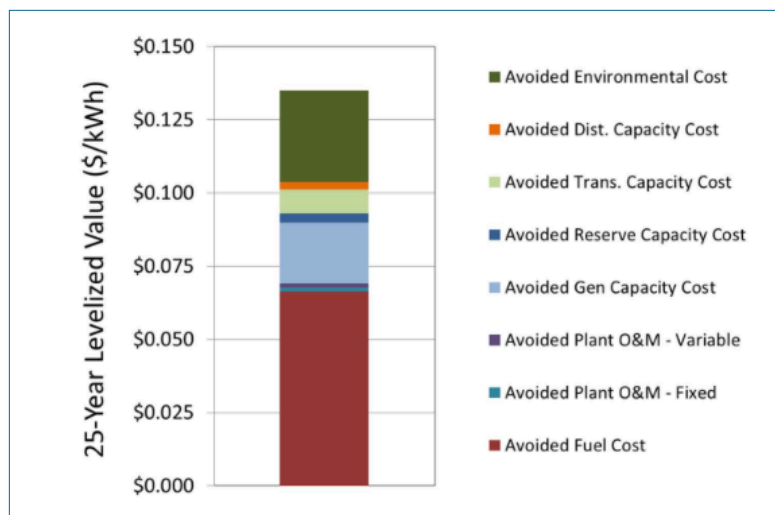
MINNESOTA

In 2013, the state of Minnesota passed legislation to establish a VOST program, which includes many of the same components as the AE VOST. Minnesota has established a methodology that can be deployed by individual utilities, with many of the components calculated based on utility projected costs. For each of these components, PV is considered to have a 25-year lifetime and the PV output degrades over time. The components vary accordingly over 25 years. The components are as follows (CPR 2014):

- **Avoided fuel cost:** Calculated based on the portion of energy market costs attributed to fuel, assuming a 25-year panel lifetime. This component includes three alternative methodologies utilities may use, based on futures markets, long term price quotations, or a utility-guaranteed price.
- **Avoided plant O&M cost:** Calculated based on the portion of energy market costs attributed to O&M.
- **Avoided generation capacity cost:** Calculated based on the capital cost of generation to meet peak load.
- **Avoided reserve capacity cost:** Calculated based on the capital cost of generation to meet planning margins and ensure reliability.
- **Avoided transmission capacity cost:** Calculated based on capital costs of transmission.
- **Avoided distribution capacity cost:** Calculated based on capital costs of distribution.
- **Avoided environmental cost:** Calculated based on the federal social cost of CO₂ emissions plus the Minnesota PUC-established externality costs of non-CO₂ emissions.

The components detailed above were selected by the Minnesota Department of Commerce based on requirements and guidance in the enabling statute. The Department of Commerce also solicited feedback from a wide variety of stakeholders, including Minnesota utilities, local and national solar and environmental organizations, local solar manufacturers and installers, and private parties. (CPR 2014).

SAMPLE MINNESOTA VOST CALCULATION (CPR 2014)



Unlike the annually adjusted AE VOST, the Minnesota VOST program allows customers to lock in a 25-year contract. Investor-owned utilities can voluntarily choose to file a VOST rate with the Minnesota Public Utilities Commission (MNPUCC) as a replacement for NEM. To date, no Minnesota IOUs have established or offered a VOST rate (NREL 2015). Although independent studies suggest that such policies would be less expensive for utilities in the long run (ILSR 2014), Minnesota utilities have determined that, in the short term, VOST policies will be less favorable than net metering.

The largest local utility, Xcel Energy, has disputed elements of the VOST. In particular, Xcel takes issue with the avoided fuel cost calculation methodology, the largest portion of the VOST (ILSR 2014). The methodology relied on a quote from September 2013, resulting in a 4.77% escalation rate. Given the volatility of the natural gas market, Xcel argued that this methodology was unreasonable. Xcel recalculated the escalation rate using a quote from February 2014, resulting in a -0.26% escalation rate. The Department of Commerce addressed this variability by recommending a revised escalation factor using 30-day averages (Minnesota PUC 2014).

Xcel also questioned whether within the avoided fuel cost a hedge value was worth including. The hedge value can be difficult to quantify; in fact, in their comments, Xcel noted that it has decided against financial fuel hedging in Minnesota, and therefore has no hedge value for solar to offset. The Department of Commerce argued that while Xcel may not have a hedge value, it adjusts for fuel price volatility through its Fuel Cost Adjustment rider, so Xcel's customers currently bear the risk of fuel price volatility and the stability of solar does constitute an avoided cost (Minnesota PUC 2014).

While this VOST continues to be debated, the MNPUCC recently voted to implement the VOST structure to any developments under 1MW (called solar gardens) applications filed after December 31, 2016.⁴ The results of this remain to be seen.

CONCLUSIONS

Across the many studies surveyed for the development of this paper, one point of irrefutable consensus was that the solar industry is growing at a remarkable rate. As more distributed solar resources are installed, and solar penetration rates continue to increase, utilities will face increased financial pressure to establish pricing mechanisms that fairly value the costs and benefits of these resources on the grid. While the reduction in total electricity demand that results from increased distributed PV is quantifiable, there are also impacts associated with the intermittent nature of solar generation, as well as with the upgrades required to support high penetrations of distributed generation.

4 *Minnesota Star Tribune*. Hughlett, Mike. 2016. "Minnesota Public Utilities Commission approves size caps, rate structure for solar projects."

<http://www.startribune.com/minnesota-utilities-commission-approves-size-caps-rate-structure-for-solar-projects/387872592/>

As the value of solar continues to be assessed, it is worth considering the implications to other fuel sources and the accuracy of calculations. Some stakeholders argue that VOS components should be calculated based on delivered benefits of specific projects rather than projected savings. For instance, many VOS calculations include a value associated with voltage regulation, within the T&D O&M savings component. In practice, all solar installations would be credited with this value, whether or not the solar installation actually included inverters that would provide such voltage regulation (Brown 2016). It is important to give further consideration to this and other stakeholder concerns in developing future VOS models and determining the role that VOS can play in an ever-changing electricity grid.

It is our hope that this study has provided some insight into the complex interplay between the many stakeholders involved in the evaluation of solar's true value to the grid, and offered some insights into where future opportunities lie and where further analysis can bolster VOS assessments.

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