# Value of Solar: Program Design and Implementation Considerations

Mike Taylor
*Solar Electric Power Association*

Joyce McLaren and Karlynn Cory
*National Renewable Energy Laboratory*

Ted Davidovich, John Sterling, and Miriam Makhyoun
*Solar Electric Power Association*

**NREL is a national laboratory of the U.S. Department of Energy**
**Office of Energy Efficiency & Renewable Energy**
**Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

**Technical Report**
NREL/TP-6A20-62361
March 2015

Contract No. DE-AC36-08GO28308

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

# Value of Solar: Program Design and Implementation Considerations


Mike Taylor
*Solar Electric Power Association*

Joyce McLaren and Karlynn Cory
*National Renewable Energy Laboratory*

Ted Davidovich, John Sterling, and Miriam Makhyoun
*Solar Electric Power Association*



Prepared under Task No. SM13.1570

**NREL is a national laboratory of the U.S. Department of Energy**
**Office of Energy Efficiency & Renewable Energy**
**Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.



National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov



**Technical Report**
NREL/TP-6A20-62361
March 2015

Contract No. DE-AC36-08GO28308

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Available electronically at http://www.osti.gov/scitech

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/ordermethods.aspx

*Cover Photos: (left to right) photo by Pat Corkery, NREL 16416, photo from SunEdison, NREL 17423, photo by Pat Corkery, NREL 16560, photo by Dennis Schroeder, NREL 17613, photo by Dean Armstrong, NREL 17436, photo by Pat Corkery, NREL 17721.*

# Acronyms

Distributed Generation (DG)

Distributed Generation Photovoltaics (DGPV)

Distributed solar generation (DSG)

Distributed Solar Photovoltaics (DPV)

Investment Tax Credit (ITC)

Kilowatt (kW)

Kilowatt-hour (kWh)

Levelized Cost of Energy (LCOE)

Megawatt-hour (MWh)

Modified Accelerated Cost Recovery System (MACRS)

Net Energy Metering (NEM)

Operations and Maintenance (O&M)

Photovoltaics (PV)

Public Utilities Commission (PUC)

Public Utilities Regulatory Policies Act (PURPA)

Qualifying facility (QF)

Renewable Energy Certificate (REC)

Value of Solar (VOS)

Watt (W)

# Acknowledgments

This paper was prepared by the National Renewable Energy Laboratory (NREL) and the Solar Electric Power Association (SEPA), who worked together closely to research and author this report. NREL managed the project, led analysis of the results, and co-authored the report. SEPA was key to engaging utility partners and to developing report content. NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency & Renewable Energy operated by the Alliance for Sustainable Energy, LLC. SEPA is a 501 (c)(3) educational non-profit research organization that delivers the latest actionable information to help members (utilities, developers, manufacturers, and installers) implement solar business plans, become more informed about the changing energy sector, meet peers, and exchange ideas.

The authors would like to thank our project sponsors, Christina Nichols and Elaine Ulrich of the U.S. Department of Energy (DOE) SunShot program, for valuable guidance and support throughout this project. We would also like to thank the following individuals and companies for providing valuable input, insights, and feedback throughout this project: Ben Norris (Clean Power Research), Christina Nichols (DOE), Tim Harvey and Danielle Murray (Austin Energy), Joseph Wiedman (Keyes, Fox & Wiedman LLP), Tom Starrs (SunPower), Lori Bird, Liz Doris, Paul Denholm, Jeff Logan, and David Hurlbut (NREL), and Eran Mahrer (First Solar).

Finally, we offer our appreciation to Jim Leyshon for providing support on some of the graphics and to NREL Communications for providing editorial support.

# Executive Summary

Distributed generation solar photovoltaic (DGPV) technology is being rapidly adopted in many areas of the United States, spurring jurisdictions to investigate the costs and benefits of grid-connected DGPV to the electricity system. The value of solar (VOS) is a relatively new mechanism for the purchase of distributed solar generation that is being considered in some locations. A VOS tariff is intended to be compensation for real value provided by the solar installations to the electric system.[1] This report is designed for utilities, regulators, and stakeholders who are interested in issues related to VOS program design and implementation. It discusses and addresses VOS program design options and considers how a VOS rate may impact future development of DGPV projects. The work herein does not consider the calculation of a VOS rate and does not address the cost of solar in relation to utility retail rates.

The degree to which DGPV is deployed within a jurisdiction is largely determined by the economic proposition facing the electricity customer. Distributed solar technology can be an economically interesting alternative if the levelized cost of energy (LCOE) at which solar can be deployed is lower than (or equal to) the electricity costs avoided by the customer (e.g., the price of purchasing generation from the utility at the retail electricity rate). Given current solar costs, some form of incentive is still required to make solar deployment economical for the average electricity customer in many locations. Over time, if solar costs continue to decline, the need for incentives is expected to diminish as solar generation becomes more price-competitive with retail electricity rates.

As the costs of solar continue to decline, the VOS mechanism is likely to gain increasing attention. A VOS rate is determined through a bottom-up calculation of each of the benefits and costs that distributed solar provides to or imposes on the electricity system. The values generally represent avoided costs to the utility and the overall system (e.g., avoided transmission and distribution (T&D) services) and the costs of incorporating solar into the system.[2] These value streams are added together to arrive at a single VOS rate, expressed in cents per kilowatt-hour (kWh). This is the rate at which customers are compensated for electricity generated by their grid-connected DGPV systems.[3]

The VOS mechanism is in the early stages of development and has been adopted in only two locations: Austin Energy (where it is in active use) and in the state of Minnesota (where it is under development). In both of these locations, the VOS mechanism is a “buy-all sell-all” transaction wherein customers purchase all of their electricity needs at the applicable retail rate and sell all of the solar production to the utility at the VOS rate being offered (typically through a bill credit). Another design option, which has not yet been implemented, is to pay the VOS rate

---

[1] In this document, *VOS rate* and *VOS tariff* are used interchangeably to refer to the amount (number) that is being paid by the utility for solar generation by self-generating customers. The term *VOS mechanism* is used to refer to the policy or program in the broader sense.
[2] Few studies, to date, have included cost components in the calculation of the VOS rate. The analysis conducted for this report is based on the most commonly discussed value components and does not include the costs of solar to the electricity system.
[3] The goal of this report is not to estimate the VOS rate or “number” for any value component in any particular location. Research by NREL, Clean Power Research (CPR), Electric Power Research Institute (EPRI), Rocky Mountain Institute (RMI), and Interstate Renewable Energy Council (IREC) lays the foundation for performing VOS rate calculations; summaries of some existing VOS rate calculation research are presented in the Appendix A.

for only the net excess generation that is fed back to the utility (that is, to subtract out any generation that is consumed on-site).

The stakeholders in a VOS rate program have various interests and concerns, some shared and some individual. The utilities, regulators, and electricity customers all have an interest in the provision of reliable electric service that meets electricity demands into the future. Solar generation, being a local supply of power with no fuel cost, offers some future reliability benefit. Utilities will benefit from a VOS program that is straightforward to manage, a characteristic that can be considered during VOS program design. Utilities also may want to recover the costs of providing fixed-cost services (such as transmission and distribution) to their customers. A "buy-all, sell-all" VOS program design separates the utility's compensation for solar generation from the customer's purchase of retail electricity, which can allow for full recovery of utility fixed costs.

Policymakers have an interest in ensuring that the utility receives payment for the services that it provides and that cross-subsidies between solar and non-solar customers are minimized. They also may want to address increasing customer demand for distributed solar and to capture the associated environmental benefits. The DGPV owner is interested in having a long-term agreement to receive payment for solar generation that (at least) covers the cost of solar investment. The PV system generation purchaser/owner can benefit from the hedge that fixed-cost solar electricity can provide from future increases in retail rates. By being alert to the existing market for solar, and adding interim support mechanisms to the VOS rate, if necessary, policy makers can support continued solar develop and address customer interests.

The solar industry likely seeks an open, fair market for solar products and services, certainty in payments for solar generation, predictability in policy, and long-term assurance for its investors. All customers, and society at large, benefit from electricity generation that meets public policy goals for environmental protection and economic development at the lowest possible cost to the consumer. (Kind 2013; Keyes and Rábago 2013; Hansen, Lacy, and Glick 2013). By setting clear procedures and timelines for the application and update of VOS rates, program designers can ensure that the VOS program provides the predictability and risk reduction necessary to make solar projects attractive to investors, as well as financeable.

While there has been much discussion and debate across the country regarding the most effective or appropriate method to calculate the variety of benefits and costs associated with distributed solar, as well has how those could be monetized in a rate, very little broad-based analysis has been conducted on the design of a VOS program. This report describes the numerous program design options utilities face as they consider a VOS tariff offering.

When designing a VOS policy, several considerations can be evaluated. One of the first to consider is the market construct that impacts program design; three feasible market constructs include:

- **Price-support Market (LCOE-PV > VOS Tariff)**
    - VOS rate is not sufficient to recover the levelized-cost of DGPV installations
    - Additional incentives are likely needed to fill the difference between the VOS payments and the levelized cost of PV, in order to sustain the solar market

- **Transitional Market (LCOE-PV ≈ VOS Tariff)**
    - VOS rate is nearly equal to the levelized cost of PV installation
    - Few incentives are needed to sustain the solar market
    - VOS program design needs to reflect the shift toward equalization
- **Price-competitive Market (LCOE-PV ≤ VOS Tariff)**
    - VOS rate is higher than the levelized cost of PV installations
    - The solar market is self-sustaining and separate incentives are no longer needed.

Many factors drive the type of market that exists in a given region. For example, the strength of the solar resource, lower permitting or interconnection fees, and the presence of incentives can all drive down the LCOE-PV, while capacity needs, efficiency of the generation fleet, and environmental value may increase the value of solar generation to the electricity system. These factors change over time, so transitional markets can float between price-support and price-competitive, depending on circumstances.

Here, we present an analysis that assesses the potential market type that might form in the United States under a VOS rate, given current national average solar costs and various incentive scenarios, for the most populous city in each state. Three hypothetical VOS tariffs were developed, based on assumptions of avoided fuel costs, avoided capacity, environmental benefits, and line losses, to represent a of range of possible VOS rates. The levelized cost of solar in 50 locations is calculated using NREL's System Advisor Model (SAM) using input assumptions regarding system size, resource quality, avoided capacity (aka capacity factor) and a variety of incentives. Comparing the solar costs with the hypothetical VOS rates illustrates the various market types that may form under a VOS program, in different locations.

Based on the high-level analysis completed to support this report,[4] the implementation of a VOS rate in the ranges typically discussed today is unlikely to result in a price-competitive market in most locations. Even including the federal investment tax credit (ITC), a VOS rate at the generic levels assumed for the analysis do not appear to cover the levelized cost of solar deployment in most locations. The bars in Figure ES-1 indicate the range of solar markets that may manifest themselves in locations across the country, assuming different VOS rates and various combinations of incentives at the state and federal levels. The solar market is considered to be price-competitive only in locations and scenarios for which the results fall above the x-axis. Note that this chart does not include net energy metering (NEM) as it is assumed that the VOS tariff replaces NEM (this replacement of NEM with VOS is the dominant model under discussion in the market to date). Based on this generic, national analysis it appears that incentives, including the federal ITC, are likely to continue to play a critical role in deploying solar nationally in the near term, even where a VOS rate might be applied.

[4] This analysis did not include every possible solar value proposition. It relied on publicly available, published data sources. The analysis provides a general indication of a range of potential markets that could result based on the analysis assumptions. Each jurisdiction would need to do a more specific analysis for its situation to get a more exact understanding of that particular VOS tariff.

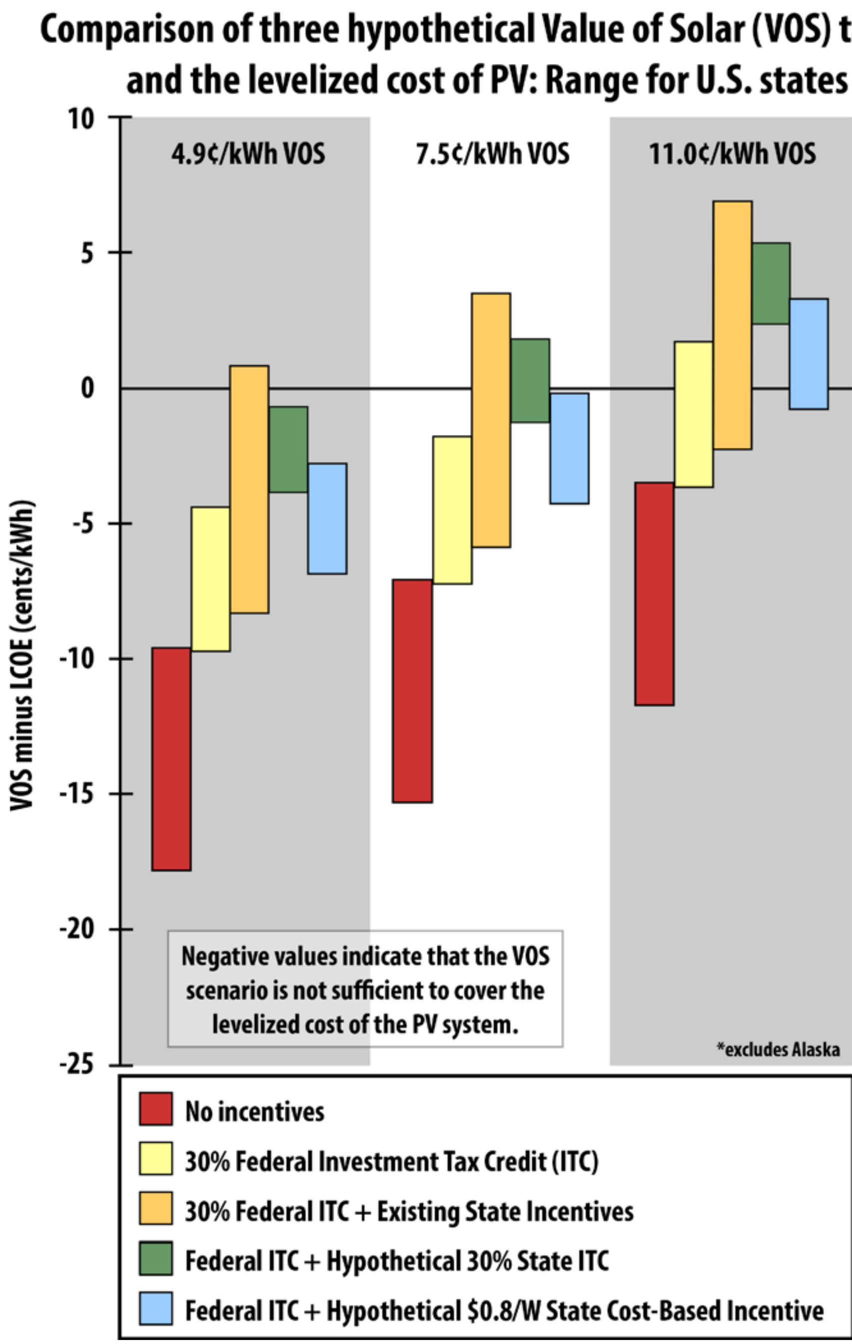



**Figure ES-1. Comparison of VOS and LCOE-PV**

Rate calculation methods and program design elements are important aspects for decision makers to evaluate when considering offering a VOS program. These two components are strongly linked and greatly influence the results of a VOS program. Within the realm of program design, the authors focus on four major program design areas, with a multitude of individual design considerations available under each:

1. Installation details
2. Rate options
3. Incentive options
4. Administrative issues.

VOS program design encompasses issues such as:

- The objectives and philosophy of the program design process
- Eligibility and installation rules and details for participation
- Rate and contract terms implemented for a long-term program
- Additional price supports needed to sustain continued PV development
- Stakeholder involvement in the VOS program development
- How program design components might change as the solar market changes.

Utilities can, to some extent, draw on experiences from managing other programs that support solar, including NEM and incentive programs, such as rebates. However, several areas are unique to the new market transaction structure that a VOS tariff represents. For these jurisdictions that have a combined goal of maintaining a robust solar market that is fair and equitable to all parties and that moves solar from a position of price-support to price-competitive, VOS programs will require sufficient design and implementation flexibility to ensure that market growth continues.

# Table of Contents


**Executive Summary ........ v**
**1 Introduction ........ 1**
1.1 Calculating the Value of Solar ........ 1
1.2 Program Design ........ 3
1.3 Analysis ........ 3
**2 Historical Distributed Solar Markets: VOS in Context ........ 5**
2.1 VOS Functionality in the Context of Existing Policies ........ 5
2.2 PV Penetration Market Stages ........ 7
**3 VOS in Context ........ 9**
3.1 VOS Definition and Features ........ 9
3.2 Overview of VOS Calculation Methodology ........ 10
3.3 VOS Policy Principles ........ 11
3.4 VOS Case Studies ........ 12
Austin Energy: Municipal Utility Case Study ........ 13
Minnesota VOS Policy – State Case Study ........ 15
**4 Solar Market Characterization: Comparing the VOS to the Cost of Solar ........ 19**
4.1 VOS Case Profiles ........ 19
Modeling Assumptions ........ 19
VOS Modeling Results ........ 21
4.2 Calculating the Levelized Cost of PV ........ 22
LCOE-PV results ........ 23
4.3 Comparing the VOS profiles with the LCOE-PV ........ 23
Results of Comparing the VOS level with the Cost of Solar ........ 26
**5 VOS Program Design Framework ........ 33**
5.1 Balancing Design Considerations ........ 35
5.2 Installation Details ........ 36
5.3 VOS Rate and Contract Treatment ........ 41
VOS Program Structure ........ 41
Number and Kind of VOS Rates ........ 43
Future Value (or Cost) Components ........ 44
Rate and Contract Adjustments over Time ........ 44
Rate Differentiation Options ........ 46
5.4 Potential Additional Price Support ........ 48
Incentive Benchmark ........ 49
Incentive Type ........ 50
Incentive Reductions ........ 50
5.5 Administrative Issues ........ 52
VOS Transition Plan ........ 52
Cost Accounting ........ 53
Stakeholder Interests ........ 54
**6 Analysis Synthesis ........ 57**
**Appendix A. Select VOS Calculation Analyses to Date ........ 61**
A Regulator's Guidebook: Calculating the Benefits and Costs of Distributed Solar Generation 61
Methods for Analyzing the Value of Distributed Photovoltaic Generation ........ 62
A Review of Solar PV Benefit and Cost Studies: Second Edition ........ 64
**Appendix B. VOS Scenario Calculation Assumptions ........ 66**
Generic Assumptions ........ 66
Sourced Assumptions ........ 66
**Appendix C. VOS Tariff by Incentive Scenario ........ 67**
**References ........ 70**

# List of Tables

Table 1. Distributed Solar Transaction Mechanisms........................................................................ 6
Table 2. Stakeholder Perspectives on VOS Program Design ............................................................ 12
Table 3. VOS Category Assumptions ................................................................................................ 21
Table 4. VOS Hypothetical Ranges (¢/kWh) ..................................................................................... 22
Table 5. Input Assumptions for LCOE Calculations in the System Advisor Model ........................... 22
Table 6. Range of Life-cycle Cost of PV for Different Incentive Levels (Excluding Alaska) ............ 23
Table 7. Summary of VOS Program Design Options ......................................................................... 40
Table 8. Summary of Installation Details Application by Hypothetical Utilities ................................ 41
Table 9. Summary of VOS Rate and Contract Options ...................................................................... 47
Table 10. Summary of Rate and Contract Application by Hypothetical Utilities ............................... 48
Table 11. Summary of VOS Incentive Options .................................................................................. 51
Table 12. Summary of Price-support Application by Hypothetical Utilities ...................................... 52
Table 13. Summary of VOS Administrative Issues ............................................................................ 55
Table 14. Summary of Administrative Issues Application by Hypothetical Utilities .......................... 56
Table 15. VOS Program Considerations ............................................................................................ 58

# List of Figures

Figure ES-1. Comparison of VOS and LCOE-PV ............................................................................ viii
Figure 1. Austin Energy customer-sited solar .................................................................................... 14
Figure 2. Minnesota VOS – sample calculations ................................................................................ 17
Figure 3. Solar market stages under VOS tariff .................................................................................. 25
Figure 4. Comparison of VOS and LCOE-PV (excluding Alaska) ..................................................... 27
Figure 5. Difference between three levels of VOS tariffs and the LCOE-PV in 50 U.S. locations: .... 28
scenarios with no incentives and existing incentives ........................................................................... 28
Figure 6. Difference between three levels of VOS tariff and the LCOE-PV in 50 U.S. locations:...... 29
scenarios with hypothetical state incentives ......................................................................................... 29
Figure 7.VOS program design balance considerations ....................................................................... 35
Figure 8. Example of annualized versus levelized VOS rate ............................................................... 45
Figure 9. Comparison of VOS and LCOE-PV (excluding Alaska) ..................................................... 59
Figure 10. Possible flow of an integrated DGPV study ....................................................................... 64
Figure 11. RMI meta-study: benefits and cost of distributed PV, by study ......................................... 65

# 1 Introduction

The distributed solar electricity market in the United States, most predominately represented by rooftop solar installations, has been growing rapidly for several years, with 7,853 MWdc of distributed solar installed by October 2014, representing nearly half of the total installed solar capacity in the U.S. (SEIA/GTM 2014). The amount and growth of distributed solar generation is spurring policy discussions across the United States around the costs and benefits of these systems.

Net energy metering (NEM) policies have been one important part of the foundation that has enabled the growth of distributed solar development in nearly all states. NEM allows a utility's solar customers to manage solar generation and electricity consumption mismatches over time, utilizing the electric grid as an accounting "bank" for excess solar kWh in one moment to be "withdrawn" for future consumption. However, rapid solar growth in some states has raised concerns about the sustainability of NEM at high DGPV penetrations to the utilities' long-term business health. Utilities may desire to recover the fixed costs of operating the electric grid by spreading the costs across all ratepayers. Even in states where solar is not yet an economical alternative and there are few installations, the future prospect of increased deployment is sparking discussion about alternative payment mechanisms. Key discussions have focused on several options, including keeping NEM as is, studying and reporting on the costs and benefits of solar, adding or increasing the fixed fee in solar customers' rates, adjusting recovery models within all customer rates, and (as is most germane to this paper) compensating solar generators at a rate commensurate with the value that solar provides to the electricity system. This latter alternative is known as the VOS tariff.

The VOS tariff is one of the most commonly discussed alternatives to NEM. Unlike NEM, the VOS tariff dissociates the customer payments for electricity consumed from the compensation they receive for solar electricity generated. Under a VOS tariff, the utility purchases some (i.e., the net excess) or all of the generation from a solar installation at a rate that is independent of retail electricity rates.[5, 6]

## 1.1 Calculating the Value of Solar

Calculating the VOS rate (the amount paid by the utility for distributed solar generation) involves identifying the tangible benefits and real costs that solar provides to the electric system. The value of each is calculated and those values are summed to form a bundled purchasing rate for solar generation. The electric system benefits (e.g. cost savings) attributable to solar can include energy, capacity, transmission and distribution (T&D) system deferral, and line loss reductions, as well as environmental and other benefits as assessed in each jurisdiction. The VOS rate can also be used as a means through which the utility receives compensation for the costs of integrating the solar generation into the electricity system or for providing transmission and distribution services in connection with the solar system. As a general principle, the categories

[5] This purchase can be compensated as a financial bill credit (at the purchasing rate) rather than a kWh credit under NEM to avoid causing a tax liability from income.

[6] There are hybrid transaction possibilities where kWh credits offset the customer's consumption and the solar purchase rate is given for the excess kWhs beyond the consumption.

and calculations are real-dollar costs and savings to the electric system that will be monetized in all ratepayers' rates over time.

In principal, the VOS tariff does not represent an incentive or subsidy, but rather compensation for real value provided by the solar installations to the electric system.[7] Some categories of value (such as energy and line losses) are not controversial, and there is general agreement among a variety of stakeholders on their inclusion in the VOS rate. Other categories, such as generation value, are location-specific. Other categories, such as environmental benefits, are not as simple, eliciting much debate among stakeholders. Although the VOS can also be used as a means to compensate utilities for the services provided to the solar customer (e.g., integration and T&D), few calculation methodologies to date have included the costs of solar to the electricity system.[8] There is an emerging body of research, both completed and in-process, addressing the VOS categories and their calculations (See Appendix A for high level summaries of a few analyses).[9]

This report specifically avoids analyzing whether it is appropriate to transition away from NEM, which payment mechanism is preferable (VOS is one of many), and, if the VOS mechanism is chosen, how the VOS rate could be calculated. These questions are specific to each state's and utility's jurisdictions. This analysis assumes the decisions have been made to support distributed solar deployment using a VOS program and that the VOS calculation methodology has been agreed upon or even completed. The questions that this analysis addresses are: What happens next? How do utilities, in conjunction with local stakeholders, build a VOS program that supports distributed solar markets over time, that is efficiently administered, and that maximizes the long-term goals and benefits to all stakeholders that were intended in deploying solar resources? This analysis presents the main design options of setting up a VOS program--beyond calculating a VOS rate number--and will help readers consider some of the key major decisions necessary to create an effective VOS program.

The report is structured in five main sections:

- Section 2: provides a historical perspective on distributed solar markets and how the rationale for the VOS mechanism, the research to date, and the program design elements fit within the ongoing market evolution;
- Section 3: covers lessons learned from two case studies and from early VOS programs, and creating a program for successful market transition
- Section 4: develops three conceptual market frameworks through an analysis of VOS rates relative to the current costs of solar
- Section 5: covers VOS program design elements
- Section 6: synthesizes the main points of the report.

[7] An additional incentive may be provided on top of a VOS rate as part of a program design decision.
[8] The costs of solar to the system were not included in the creation of the example VOS rates for the analysis presented in this report.
[9] In this paper, references to 'electric system cost reduction' or 'utility cost savings' and similar language refers to the diversity of possible categories of value (benefits and costs), their inclusion or exclusion, and their calculation.

## 1.2 Program Design

VOS program design includes the structure and rules for participation. It can include the basic parameters around eligible customer classes, technologies, and project size applicability, as well as payment frequency, rate recalculation frequency, stakeholder communication methods, contracting periods, aggregate participation limits, additional incentive support, and the program transition process away from NEM. Basically, program design includes the nuts and bolts of how a solar customer applies for and receives the VOS rate.

VOS program design is equally as important as the calculation of the VOS rate. In fact, how a VOS program is designed could impact whether specific policy objectives are reached, to a greater extent than the VOS rate. The design attributes of a VOS program with a low tariff rate could elicit greater participation over the long term than another program offering a higher rate. Solar incentive programs over the last two decades bear the lessons of such unintended consequences. Excessively favorable incentives have been known to create 'market exuberance' that can attract more system installers to the market, some with more experience and qualifications than others. Incentives designed flexibly can respond when solar market prices or conditions change rapidly. Incentive programs with performance requirements may help prevent underperforming systems. Examples from Spain, New Jersey, and Nevada, among others, demonstrate some of these lessons with long incentive program waitlists, rising installed prices, and poor installation practices (Voosen 2009). Programs with too many design or paperwork requirements add disproportionately to installation costs. Time and experience has already smoothed out many of these issues for existing, successful programs. VOS programs will have uniquely different issues than incentive programs because of their inextricable link to value calculations, but the general principle of increased success through thoughtful program design applies.

## 1.3 Analysis

This report creates a VOS program design framework for utilities (independently operated utilities, municipal utilities, and rural cooperatives),[10] regulators, and stakeholders to consider when implementing VOS programs. The report presents a "range of options" for jurisdictions to consider as they contemplate their VOS program goals and design options best suited to meet its policy goals and priorities. It does not suggest which solar value components could be included as part of the VOS rate, how the components are calculated, or a specific VOS rate for a particular utility or location (though hypothetical examples are included for instructive purposes). Appropriate options will vary across solar markets; what works in Hawaii will not necessarily work in Kansas. Accordingly, this report differentiates how program design varies across three solar market types.

The three market types are characterized by whether the levelized cost of deploying solar PV technology (LCOE), expressed on a kWh basis, is greater than, approximately equal to, or less than the VOS rate. Using the LCOE is, arguably, an imperfect measure of the price-competitiveness of solar. While the LCOE calculation attempts to account for the total costs of solar deployment, it is realistically unable to capture these costs perfectly. There may be

[10] This analysis focuses on the perspective of the traditional utility. Other perspectives, including that of the DG solar customer-owner or of the independent third-party owner, are also important. The authors decided to limit the scope of this analysis to the impact of a VOS program on a traditional utility.

interconnection or O&M costs that are unaccounted for, actual generation output of the system may vary, and financing terms may deviate from those assumed. Nevertheless, LCOE still provides a generally acceptable method to approximate system costs.

As such, the three solar market types discussed in this report are:

- **Price-support Market (LCOE-PV > VOS Tariff)**
  - VOS rate is not sufficient to economically recover the cost of DGPV installation
  - Additional incentives are likely needed to fill the difference between the VOS payments and the levelized cost of PV, in order to sustain the solar market
- **Transitional Market (LCOE-PV ≈ VOS Tariff)**
  - VOS rate is nearly equal to the levelized cost of PV installation
  - Few incentives are needed to sustain the solar market
  - VOS program design needs to reflect the shift toward equalization
- **Price-competitive Market (LCOE-PV ≤ VOS Tariff)**
  - VOS rate is higher than the cost of PV installation
  - The market is self-sustaining
  - VOS program focus turns away from providing economic support to other key factors (e.g., annual program installation caps).

Importantly, as market conditions change over time, an existing market could transition from one type to another type of market. This could result from an addition or reduction of state or federal incentives, shifts in fossil fuel prices, or a disruption in the market. The market is not expected to be static, and it will be important to be alert to changes over time and consider these in future policy structures. After a few years, pioneering VOS programs are likely to help inform policy changes, program design, and updates needed to address those transitions more effectively and completely.

# 2 Historical Distributed Solar Markets: VOS in Context

This section reviews analysis and experience to date that can inform future VOS program design and puts the scope and breadth of value-based electricity purchases in context. It provides an historical perspective on support structures for distributed solar installations over the past two or three decades, and contrasts the functionality of the VOS rate structure with NEM and other mechanisms.

## 2.1 VOS Functionality in the Context of Existing Policies

Utilities and policy makers might decide to support DGPV for a number of reasons. These could include meeting growing customer demand for solar and meeting broader environmental goals. But why pursue a VOS program specifically? Distributed solar generators have used a number of standard transaction mechanisms over the last 25-30 years. These standard transaction options differ from competitive solicitations (e.g. requests for proposals [RFPs]), in that they are open to any generator at any time (unless an overall program budget, capacity cap, or other programmatic limit was met). Table 1 provides a summary of the various mechanisms. Note that two are applied on the customer-side of the meter reducing on-site load (parallel generation and NEM), and three are applied on the utility-side of the meter as wholesale purchases.

One attraction of VOS programs is that utilities could count all of the purchased distributed solar generation produced in their territory toward meeting renewable mandates (e.g., renewable portfolio standards, or RPS). Nineteen states, plus the District of Columbia (DSIRE 2013), have solar or distributed generation set-asides in their policies. Utility purchases under a VOS program could count towards RPS compliance (if RECs are bundled) in these states.

NEM is one of the most commonly used policies in the United States today. It is defined by SEPA as

> "a billing mechanism for electric utility customers with grid-connected distributed generation (DG). NEM facilitates use of the electric utility system, allowing customers to virtually manage generation not used immediately, in exchange for kWh and/or financial credits. Those customers subsequently may draw on their credits at other times to offset consumption and/or charges when the DG system is not meeting their full energy needs, up to the total amount they have banked within the applicable period (often 12 months)" (Cliburn et al. 2013).

Although not part of a formal rate proceeding, NEM conceptually values solar generation at the retail price of electricity (though NEM credits provided to customers can be below retail rates in many cases). By reducing the kWh billed at the retail rate, some NEM programs set the value of the customer's on-site generation as equal to the retail rate.

Under the Public Utilities Regulatory Policies Act (PURPA), utilities are obligated to purchase independent power producers' electricity at the utilities' avoided energy cost. The avoided cost is usually determined in a contested proceeding before the utility's regulatory body, and the methodology is not consistent across states. Sometimes it is based on the wholesale electricity rate for a full generating portfolio, sometimes the power plant on the margin, sometimes in other ways. Avoided costs to the utility usually include energy generation but can also include avoided emissions, line losses, generator capacity value, T&D capacity, and ancillary services (values which may be part of VOS programs, among others).

**Table 1. Distributed Solar Transaction Mechanisms**

| Transaction Type | Enabling Mechanism | Benefit | Timing | Commentary |
|---|---|---|---|---|
| **Qualifying facility (QF)** | PURPA | Avoided energy costs | 1980s-present | Rates based on avoided energy costs, with methodologies that vary across states and utilities (e.g., avoided portfolio energy, marginal energy, new resource energy, renewable energy, etc.).<br>Not particularly economic for distributed solar; low historical participation rates (though has emerged in niche locations like North Carolina and Idaho as solar prices have declined and unique state circumstances allow). |
| **Parallel generation** | Utility policy | Retail rates + avoided energy costs | 1980s-present | Offset consumption as solar generation occurs, but excess is purchased at avoided costs; suitable for large loads that will absorb all generation at all times.<br>Not widely utilized since PV systems are sized much smaller than load to maximize benefits. |
| **NEM** | PURPA with state or utility policy details | Retail rates | 1990s-present | Offset retail rates directly; manage excess generation as kWh credit for future consumption.<br>Strong policy expansion over last two decades; core enabler of most state DGPV activity (along with federal, state, and utility incentives). |
| **Feed-in tariff (FIT)** | State or utility policy | Tariff based on profitable cost of solar | 2000s-present | Design calculations ensure a defined rate of return for solar projects and most often ignore utility rates (i.e., they are based on the cost of solar to produce power profitably).<br>Limited examples in U.S., though extensively used in Europe. |
| **VOS** | State or utility policy | Tariff based on the VOS to utility | 2011-present | Design calculations based on the value of the solar electricity to the utility and/or their system (not the cost of solar).<br>Limited active or proposed programs, though significant general interest. |

A feed-in-tariff (FIT) is "an energy supply policy focused on supporting the development of new renewable energy projects by offering long-term purchase agreements for the sale of [renewable] electricity" (Couture et al. 2010, p.6). The calculation methodology of a FIT differs compared to the VOS policy. While the VOS policy is focused on estimating the value of the solar generation to the utility and/or their system, most FIT policies are focused on estimating the cost of solar to the project owner while also providing the generator compensation for the costs plus a "reasonable" return (Couture et al. 2010; Couture 2014). Therefore, a FIT policy aims to pay the developer/owner for the actual cost of the project (including a profit) whereas the VOS policy aims to pay the estimated value the project provides to the utility system.

VOS is one of the transaction mechanisms used to compensate customers for the power their solar systems generate. State incentives are often used in addition to these transaction mechanisms to fill a remaining economic gap. The incentives are reviewed and periodically adjusted since the solar market, equipment costs, and soft costs change over time. More detail on VOS program design is included in later sections.

## 2.2 PV Penetration Market Stages

NEM has driven significant market activity over the last five years, in combination with incentives, solar technology cost reductions, and third-party contracting. The other three mechanisms covered in Table 1 (QFs, parallel generation, and FITs) have not gained widespread traction in the United States, especially for distributed solar. NEM-based solar policies and markets vary significantly across the United States, reflecting varying economic conditions across states and utilities, including different solar resources, installed costs, solar industry business models, policies, and incentives. These different solar markets can be characterized as non-economic, pre-economic, and grid-competitive (referring to the comparison of the cost of PV to the retail price of electricity).

A non-economic market exists when the LCOE-PV is significantly higher than the price of grid power. The payback period for a DGPV system is long and only early adopters may be willing to make the investment. A market has transitioned to pre-economic when the LCOE-PV is nearing the price of grid power. The payback period is shortened and more individuals are willing to make the investment in PV. Third-party leases may facilitate development and state or utility incentives may serve to fill the remaining gap between the cost of solar and the cost of utility-provided power. When the solar market has reached grid competitiveness, state and utility incentives may no longer be needed (although market conditions can change). A variety of financing options are likely to be available, and the payback periods for solar development are acceptable to investors.

The goal of characterizing general PV market stages is to lay a framework for identifying whether a separate incentive (in addition to the VOS tariff) could help DGPV projects to be a more economic option (or close enough to economic) after the transition to a VOS tariff. If a solar market remains pre-economic after the implementation of a VOS tariff, little distributed solar development can be expected.

It is only within the last two years that solar in portions of certain states (e.g., Hawaii, California, and Arizona) has moved from pre-economic to grid-competitive, allowing for the reduction or elimination of state and utility incentives while still maintaining high solar growth rates. Utilities in those three states account for 65% of the national distributed solar market capacity in MW (Makhyoun et al. 2014). The federal investment tax credit[11] (ITC), for which solar PV is eligible, remains in the calculation and is expected to remain a key driver until it changes in 2017.[12]

[11] Specifically known as the business energy investment tax credit and the residential renewable energy tax credit for the respective taxpayers.

[12] Beginning on January 1, 2017, the ITC changes from 30% to 10% of installed costs for business taxpayers and is eliminated for residential individual taxpayers (DSIRE 2014a). If DGPV is grid-competitive, residential customers may still choose to install systems, even with the lower ITC. If economics are still pre-economic, residential customers may choose third-party companies to install systems on residential homes (in states where they are

Again, this report takes no position on the public policy of comparing solar costs to current utility rates and state and federal incentives.

While the VOS concept is the latest distributed solar transaction mechanism to emerge, there is currently more discussion than there are tangible program examples. Only one active utility program exists (Austin Energy n.d.). Other activity includes the withdrawal of a proposal by CPS Energy in San Antonio, Texas (Hamilton 2013), and significant state policy and stakeholder action to set up program rules in Minnesota (Minnesota Dept. of Commerce 2014) as well as at the Tennessee Valley Authority (TVA) (TVA 2014). All other momentum around the VOS mechanism involves research and theoretical development by industry, utilities, and consultants. It remains to be seen how much traction VOS policy will ultimately gain, but the conceptual interest is strong.

allowed). As business taxpayers, they retain ownership of the solar system, secure the benefits of the tax credits, and sign a lease or performance contract with their customers (to whom they could pass some/all of the benefit.

# 3 VOS in Context

It is important to set the VOS policy in context before proceeding to discuss program design analysis. The focus of this report is on the way that a VOS program is designed, or the VOS policy framework, from the perspective of the traditional, conventional utility. While calculating the VOS rate value is a critical discussion, equally important is how the VOS policy is structured and implemented through the key program design elements. This section describes the VOS mechanism, considers some important features, and examines the functionality of the VOS mechanism in the context of existing policies. Importantly, there are two analyses that are not addressed in this report: 1) the efficacy and process of VOS rate calculation methodology (Appendix A summarizes existing literature) and 2) the comparison and contrast of the relative merits and challenges of the VOS mechanism to other policies.

## 3.1 VOS Definition and Features

As described earlier, a VOS program establishes a transaction between the utility and the self-generating customer. The VOS rate is determined by: 1) identifying the categories in which solar provides both benefit and cost to the utility and society, 2) calculating values of each of these categories (assigning positive and negative as appropriate), and 3) combining these components into a single rate. The VOS rate represents the real value of distributed solar to the utility, considering both costs and cost savings, which will be monetized in all ratepayers' electric bills over time.

There are several ways to design the transaction. Under the design used by Austin Energy, typically called a buy-all, sell-all transaction, self-generating customers buy all of the electricity they use at the applicable retail tariff and sell all of their PV generation to the utility at the VOS rate. The purchase of electricity for use on-site is completely decoupled from the sale of the solar generation to the utility. And as long as the costs to the utility of integrating the PV system and providing T&D services are included in the VOS rate,[13] this structure can keep the utility "whole" and significantly reduce or eliminate cross-subsidization. The utility receives payment for all of the services that solar customers use through the retail rate, just the same as it does with non-solar customers. In addition, if utilities purchase the solar generation bundle with the associated renewable energy credits (RECs), they can apply those credits toward DG or PV set-asides associated with RPS policy mandates.

An alternative VOS program design is the net excess transaction, where the customers offset their own electricity demand with self-generated solar power before selling excess generation to the utility at the VOS rate (Keyes and Rábago 2013; Starrs 2014). The self-generators may claim the environmental attributes of the power they use on-site or sell the rights in the form of unbundled RECs to the utility.

One disadvantage of the net excess method is that, since it does not decouple the solar customer's purchase of electricity from the sale of their solar generation, it does not address the cross-subsidy and cost-recovery issue that is presented by net metering. This point is notable

[13] The example VOS rates that were created for the analysis in this report do not include the estimated costs of solar PV to the electricity system. While including the costs, in addition to the benefits, of solar to the electricity system is in line with the general philosophy of a VOS calculation methodology, only the components that have been most commonly included in existing calculations were used for this analysis.

since, to some extent, the transition from net metering to an alternative mechanism, such as VOS, has been spurred by concerns about the potential for cross-subsidization within the residential sector and utilities' varying ability to recover fixed costs (Kind 2013).

In addition, the total incremental incentive (on top of the VOS rate) per system may be estimated as larger, depending on how the retail rate compares to the cost of PV in a particular market. This is because the incremental incentive would be applied to a smaller portion of the generation from each system (the net excess portion). As a result, program costs could be higher until solar price-competitiveness is achieved, particularly if a large number of systems are needed in order to comply with an RPS policy. It should be noted that the net excess transaction approach to VOS program design has not yet been applied or studied in the context of any particular market (see Section 5.4 below for more information).

## 3.2 Overview of VOS Calculation Methodology

Generally, the first step in calculating a VOS rate is for the utility, regulators, legislators, or other stakeholders to propose which value and cost components could be used to build the VOS rate. Once the components that will be included have been determined, a calculation methodology will be established for each component. The benefits are represented by a positive number, while any costs are represented as a negative number. Summing these components to get the net of all benefits and costs yields the VOS rate, which represents the value that solar provides to the electricity system.

The goal of this report is not to estimate the VOS rate number for any value or cost component in any particular location; this is necessarily specific to each utility, and for vertically integrated utilities, is determined through contested ratemaking proceedings. Other research by NREL, Rocky Mountain Institute (RMI), and Interstate Renewable Energy Council (IREC) lays the foundation for performing VOS rate calculations (Denholm et al. 2014; Hansen, Lacy, and Glick 2013; and Keyes and Rábago 2013). Summaries of some of this existing VOS rate calculation research are presented in Appendix A. NREL's 2014 report (Denholm et al 2014) examined these various solar valuation methodologies, concluding that the seven main components being used, include:

- Energy
- Emissions
- T&D loss savings
- Generator capacity
- T&D capacity
- Ancillary services
- Other costs and benefits, such as other environmental impacts, fuel price hedging, diversity, market price suppression, O&M costs, integration costs, grid support services, and resiliency.

Note that a VOS rate calculation for a particular location may consider the specific physical characteristics, market conditions, and policies that are applicable. If a utility has a large service territory, variations of VOS rates or program designs within that territory could be considered.

## 3.3 VOS Policy Principles

Before creating any new distributed solar policy, it is important for policy makers and regulators to articulate the main principles or objectives that the policy is expected to attain. In order to establish VOS program principles, it is important to understand the different stakeholder perspectives about the benefits and challenges of a VOS program. This section provides an overview of some of the main VOS policy goals and challenges that could be considered in the establishment of a VOS policy.

Table 2 shows, for the major stakeholders, a sampling of VOS policy objectives and concerns specific to VOS programs. While not comprehensive, the table shows that there are several themes common across all stakeholders. By identifying these themes, it may be possible to establish them as VOS policy design principles that can help set the stage for policy success through meeting the needs of key stakeholders.

Key themes that could be used as VOS policy design principles include:

1. Sufficient utility revenues for grid services provided to support solar growth
2. Recognize the VOS benefits and costs–not only to the utility system, but to society as well (to the extent the benefits are codified in utility financial structures)–and pay the project owner appropriately
3. Limit cost to customers, both those with solar and those without
4. Create a transparent VOS rate calculation methodology, including input assumptions and updates.

Specific stakeholders in any particular location will have their own motivations and concerns. A successful program will be informed by discussions with key stakeholders about their policy objectives and concerns. The common themes in the discussions should then be prioritized by the stakeholders and used to establish policy design principles. This achieves two main objectives: 1) the VOS policy design will be structured to consider key elements that are most important to most, if not all, stakeholders, and 2) the VOS program design has a better chance for success.

**Table 2. Stakeholder Perspectives on VOS Program Design**

| Stakeholder | VOS Policy Objective | VOS Policy Concerns |
|---|---|---|
| **Utility** | -Maintain reliability of the entire system<br>-Meet growing customer demand for DGPV<br>-Be "made whole," or paid for all electric grid services used by decoupling DGPV payments from retail rates<br>-Reduce/eliminate cross-subsidization, where non-solar customers pay to support services exclusively used by DGPV<br>-Create transparent payment<br>-Design an efficient, straightforward way to manage program<br>-Track actual customer load, not just net load<br>-Meet other environmental goals/mandates | -Realize cost savings of societal benefits/externalities<br>-Ratepayer VOS program transparency<br>-Which terms could be included as part of VOS rate calculation?<br>-What calculation method will be used for each term?<br>-What input assumptions will be used for all calculations?<br>-Limit cost to customers<br>-How can a program be structured to keep the utility whole?<br>-Who owns the renewable energy certificates (RECs)? |
| **PV Generating Customer** | -Support on-site generation (customer, utility, or third-party owned)<br>-Benefit from all kWh generated with a rate that will cover costs<br>-Be paid a rate over a long period of time to recover lifetime costs<br>-Meet individual/societal environmental goals | -Be properly compensated for all solar generation (which VOS terms, calculation method, input assumptions)<br>-Avoid overpaying for utility services<br>-What input assumptions will be used for all calculations? |
| **Non-solar customer** | -Benefit from low cost electricity<br>-Benefit from reliable electricity supply<br>-Support public renewables goals | -Non-solar customers paying for services that support solar systems<br>-Ratepayer VOS program transparency |
| **Policymaker** | -Support customer desire for DGPV<br>-Create transparent VOS tariff<br>-Fairly compensate utilities for their services to support DG on their systems<br>-Reduce/eliminate cross-subsidization<br>-Meet environmental goals for society<br>-Provide mechanism to meet renewable energy mandates | -Limit cost to customers<br>-Structure a program that keeps the utility whole while also limiting incremental costs to the utility (i.e., avoid straining existing infrastructure)<br>-Ratepayer VOS program transparency |
| **Solar Industry** | -Help all customers explore solar options with clear process for program changes<br>-Be paid for all kWh generated over a reasonable and predetermined time period, with a rate that will facilitate market transactions and cover costs<br>-Benefit from and pay for utility services<br>-Provide long-term investment certainty for investors | -Be properly compensated for all solar generation, including environmental goals<br>-Provide a smooth transition from current solar transaction method<br>-Minimize negative disruptions to customer prospects, hiring, cash flow, and other business issues<br>-Ratepayer VOS program transparency – which terms will be included? What calculation method will be used for each term? Input assumptions? |
| **Society** | -Improved economy<br>-Better air/water quality | -Limit cost to society |

Sources: Kind (2013); Keyes and Rábago (2013); Hansen, Lacy, and Glick (2013)

## 3.4 VOS Case Studies

This section illuminates lessons learned about the VOS mechanism to date through detailed case studies of the Austin Energy VOS program and the Minnesota statewide voluntary VOS program.

### Austin Energy: Municipal Utility Case Study

In 2012, Austin Energy (Austin, Texas) was the first U.S. utility to enact a VOS mechanism (CPR 2013). As of that year, it was the nation's eighth-largest publicly-owned electric utility, serving over one million residential customers, with nearly 13 billion kWh. The Austin Energy service territory is 437 square miles, half of which is outside of the city limits (CPR 2013).

Austin Energy has shown a strong commitment to clean energy, working toward city council-mandated solar and renewable energy goals and offering several renewable energy programs including residential solar rebates, a performance-based incentive for commercial solar, and the GreenChoice green power purchasing program. The utility has over 850 MW of wind power and 30 MW of utility scale solar, and obtains 20.7% of its total generation mix from renewables (CPR 2013).[14] Over 3,250 customer-sited PV systems are signed up for the utility's VOS rate (CPR 2013).

One of the goals of establishing a VOS tariff was to create a program that does not provide different benefits to customers based on their consumption. Under net metering, customers that used more energy received more benefit from installing solar since they were able to offset a greater amount of grid-supplied electricity. In designing the VOS program, the utility aimed to provide fair compensation for the solar generation, avoid impacts of solar programs on non-solar customers, and enable the utility to recover costs (Harvey 2014). In line with these goals, a buy-all sell-all program design was chosen such that payments for solar generation are decoupled from billing for customer electricity usage. Customers pay the retail rate for all electricity they consume, and are compensated for the full amount of generation from their on-site solar systems through electric bill credits at the VOS rate (CPR 2013).

Austin Energy and Clean Power Research performed the VOS rate calculation, which included the components of energy savings, generation, capacity value, T&D deferral, loss savings, and an environmental value (Rábago et al. 2012). The initial VOS rate was set at $0.128/kWh (levelized value), with all solar generation valued equally. Under the program rules, the VOS rate can be reassessed and adjusted annually, with adjusted rates applied to new solar customers (CPR 2013; Harvey 2014). Adjustments to the calculation were made in both 2011 and 2014, resulting in VOS rates of $0.128/kWh and $0.107/kWh, respectively.[15] These declines reflect lower natural gas price projections (as based on the futures market), an adjustment of the assumed project life from 30 years to 25 years, less assumed savings due to avoided losses, and a change in the calculation methodology to account for the market changes within the Electric Reliability Council of Texas (ERCOT) (Harvey 2014).[16]

[14] Austin Energy also has a number of sustainability programs including a green building rating program, a 35% renewable energy supply goal by 2020, an active energy efficiency program (that avoided construction of a 700-MW power plant), auto-cycling thermostats, internet-enabled thermostats, and 185 public electric vehicle charging stations (CPR 2013).

[15] The decline in the calculated VOS rate caused concern for some stakeholders, who had anticipated that increasing natural gas prices would result in a higher VOS since the energy value component of the VOS calculation is a main driver of the final VOS rate. However, while current prices were volatile, the futures market did not predict rapid natural gas price increases.

[16] The VOS rate was originally calculated assuming it would be implemented in a vertically integrated market environment. After Texas implemented a nodal electricity market, Clean Power Research recalculated the rate using nodal market data from one year. When additional data were available, CPR re-ran the analysis using two years of

Thus, in the current market, the combination of the VOS tariff and the federal tax credit does not cover the cost of distributed solar installations in the Austin Energy territory. Accordingly, the utility provides a solar rebate on top of the VOS rate. This creates an acceptable return on investment and drives distributed solar adoption. Like the VOS rate, the solar rebate has also declined in several stages over time, going from \$2/W to a current \$1.10/W (Harvey 2014). Installed solar costs, however, have not declined to the same extent, going from an average of \$3.50/W down to \$3.25/W. Even given these economics, customer uptake of solar has been steady, as shown in Figure 1. Continued investment may be encouraged by the maturation of the solar industry, increased public acceptance, and positive utility support for solar.

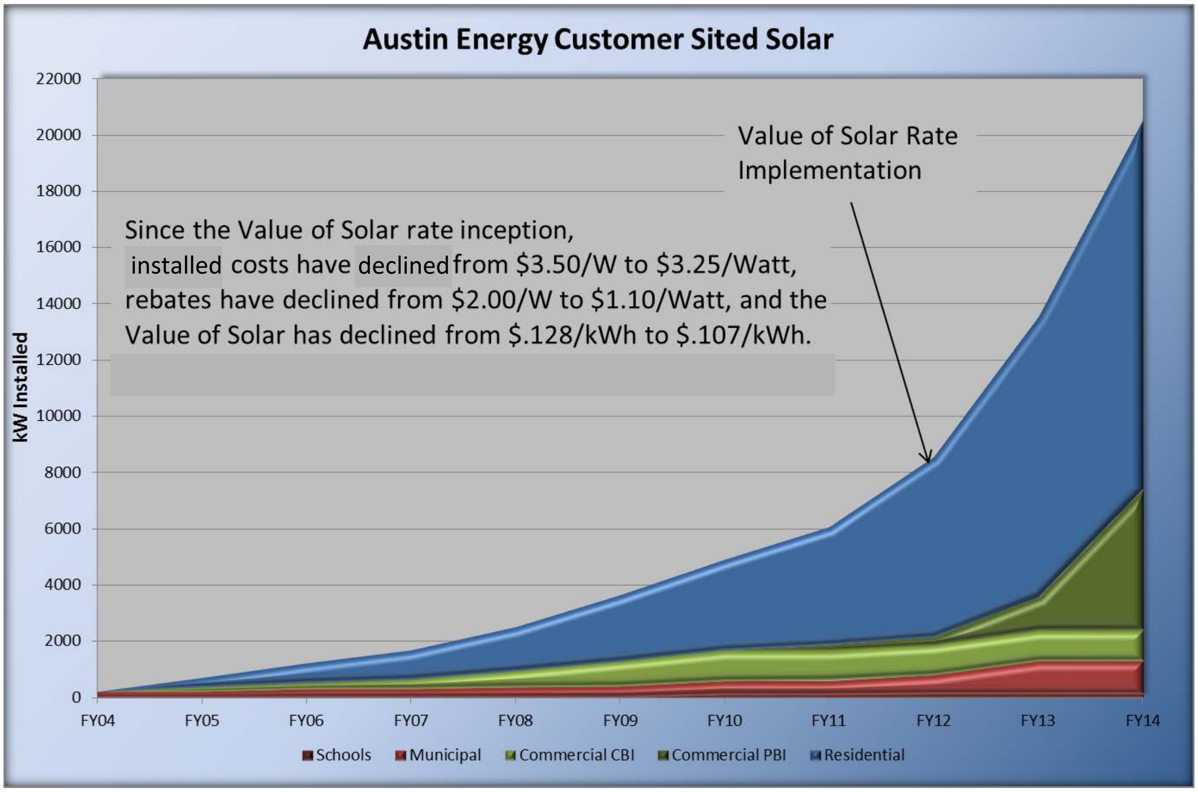



**Figure 1. Austin Energy customer-sited solar**

Re-printed with permission from Tim Harvey's Utility Solar Conference presentation
Source: Harvey (2014)

nodal data with the intent of extrapolating future nodal pricing. It was found that market prices had lowered from \$0.073/kWh to \$0.038/kWh, which would have resulted in a drop in the VOS rate. In addition, it was decided that adjusting the VOS rate in line with historical nodal prices was not in alignment with the agreed-upon use of long-term avoided costs, so the VOS calculation method was refined. The implied heat rate (mmBtu/MWh) of the market was adjusted to recognize the on-peak production of solar, and was validated through modeling and comparisons with known outputs for base-load plants. This was multiplied by forecasted natural gas prices and the result multiplied by modeled PV fleet production, using relevant discount factors. The sum of the results were converted into an energy value expressed in \$/kWh (Harvey 2014).

In a 2014 presentation at the SEPA Utility Solar Conference, Austin Energy's senior program specialist, Tim Harvey, provided some observations and recommended improvements to the Austin Energy VOS program (Harvey 2014):

1. **Rollover credits.** As the program was originally designed, any unused VOS bill credit was zeroed out at the end of the year (CPR 2013). This was done to avoid any negative tax implications that could complicate the program. Customers, however, were displeased with losing "their solar energy." After further consideration, it was determined that the compensation for the solar generation is not considered income since the credit is nonrefundable and nontransferable. This relieved any potential tax implications to the carry over of credits. As such, Austin Energy is proposing to the city council that the solar credits roll over indefinitely, as long as they are applied toward the electricity bill and remain nonrefundable and nontransferable.
2. **Updated, transparent calculation methodology.** As originally designed, Austin Energy could update the VOS calculation on an annual basis to reflect changing market circumstances (CPR 2013). However, customers were upset to learn that they were not included in the methodology development process. Wanting to be responsive to these concerns, Austin Energy is proposing (and intends) to have the VOS calculation methodology reviewed as part of the annual budget planning process, which includes commission and city council approval.
3. **Variability of the rate.** Because the rate can vary from year to year, both the utility and its customers are concerned about the possibility that the VOS tariff could fluctuate significantly. Austin Energy is proposing that the current year's VOS rate be averaged with previous years' rates to create a rolling average VOS rate factor, thus decreasing volatility from year to year.
4. **Third-party solar leases.** The current VOS program only allows for participation of customers who own their solar systems. The utility is considering allowing the participation of customers who lease their systems through third-party providers.

Overall, Austin Energy posits that it is successfully supporting customer-sited solar while ensuring utility revenue recovery and the avoidance of rate impacts on non-solar customers.

### *Minnesota VOS Policy – State Case Study*

The State of Minnesota passed legislation in 2013 that required the Minnesota Department of Commerce (MN DOC) to establish a calculation methodology to quantify the value of DGPV. The legislation required specific components to be included: energy and its delivery, avoided capacity, transmission capacity, T&D line losses, and environmental value. The methodology was then to be passed to the Minnesota Public Utilities Commission (PUC) for approval. Investor-owned utilities could voluntarily choose to file a VOS rate as a replacement to NEM. To date, no Minnesota utilities have established or offered a VOS rate to replace NEM.[17]

The objectives in establishing the Minnesota VOS program, with respect to the methodology, were to (Grant 2014):

[17] Xcel did file a VOS rate on May 1, 2014 (Revised June 19), but it has not been adopted into a program.

- **Accurately account for all relevant value streams** (benefits net of costs) from a societal perspective
- **Simplify** the methodology and input data sets (where possible and warranted)
- **Provide transparency**
- **Facilitate modification**, if necessary, in future years.

In order to operationalize the Minnesota VOS legislation, the Minnesota DOC conducted an extensive stakeholder process in the fall of 2013 (MN DOC n.d.). They engaged Clean Power Research to conduct the technical and analytical support. RMI and Karl Rábago of Rábago Energy (who led the Austin Energy program design while working at that utility) provided context and background. Four workshops were held to provide background to engaged stakeholders on key issues, and more than 50 sets of comments were received, which helped shape subsequent workshops and inform the final draft VOS methodology. According to Bill Grant, the Deputy Commissioner at the Minnesota DOC, Division of Energy Resources (Grant 2014), Minnesota utilities were concerned that the valuation was not based on least-cost or avoided cost, while environmental groups were concerned that VOS tariff payment level would not be high enough to support solar development without the use of additional incentives.

The Minnesota DOC submitted the draft methodology to the Minnesota PUC in January 2014. The Minnesota PUC approved the method in March and issued an approval order on April 1, 2014 (MN DOC n.d.). At the 2014 SEPA Utility Solar Conference, Deputy Commissioner Grant explained some key characteristics included in the Minnesota VOS policy:

- **Voluntary -** Investor-owned utilities may voluntarily apply to the Minnesota PUC to enact a program in lieu of net energy metering
- **Project size limitations -** PV systems must be under 1 MW in size
- **Decouple use and generation -** Customer electricity usage is separated from production
    - Customers are billed for their total electricity consumption at the retail rate
    - Compensation for the solar system is through a bill credit at the VOS tariff
- **Value**
    - **Production-based -** VOS rate is expressed in ¢/kWh, levelized over 25 years, and adjusted for inflation on an annual basis
    - **Includes key elements** – VOS rate represents the value of distributed solar to the combination of the utility, its customers, and society
    - **Rigorous, transparent calculation**
        - Once the VOS rate is established in any one year, that rate schedule is applicable over the full contract period to all customers who enter during that year
        - The valuation will be updated annually for new annual VOS program participants to incorporate utility inputs for the value of PV in the year of installation

– A VOS utility-specific input assumption table is part of the utility's application and will be made publicly available

– A VOS utility-specific calculation table will break out the value of individual components and the computation of total levelized value, and it will be made public

- **A tariff is not an incentive -** A VOS tariff is not intended as an incentive for DGPV, and it is not intended to replace existing incentives or prevent future incentives.

The Minnesota DOC calculated sample results for the Minnesota VOS rate shown in Figure 2. As shown, the biggest drivers of the rate are avoided fuel cost, avoided environmental cost, and avoided capacity cost. The calculation used the federal government's avoided cost of carbon.

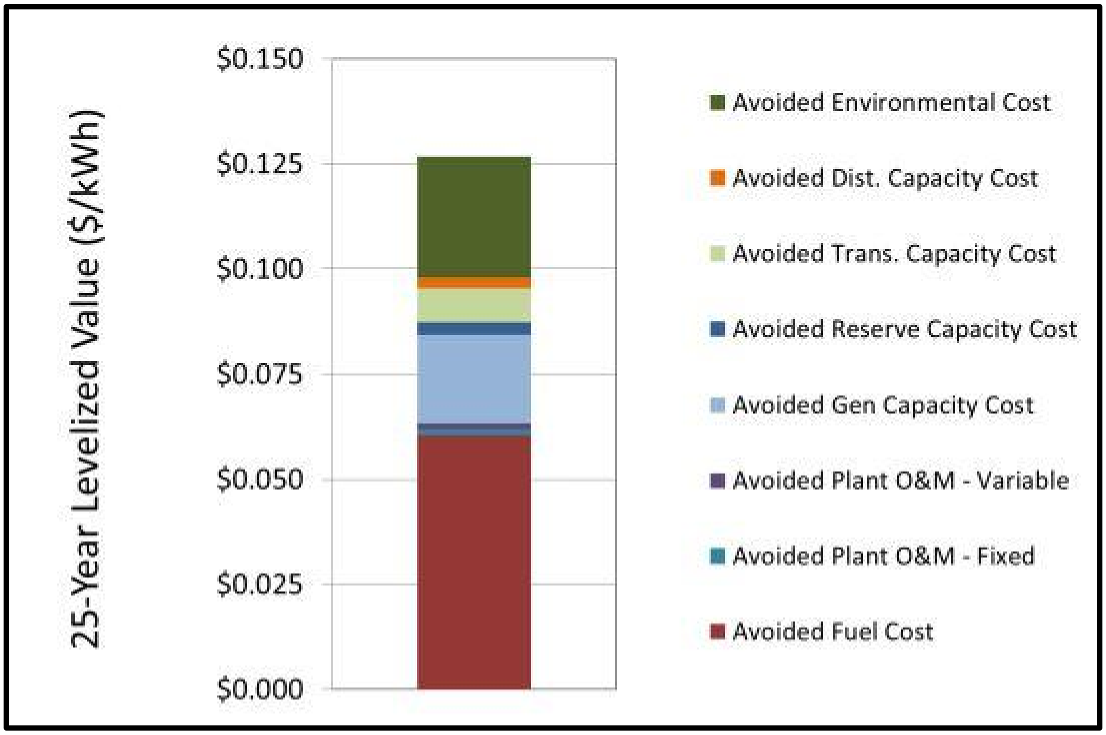



**Figure 2. Minnesota VOS – sample calculations**

Source: MN DOC (2014)

At the SEPA Utility Solar Conference, Bill Grant provided some reflections from the Minnesota process (Grant 2014):

1. **NEM alternative.** Input from some stakeholders during the public process appears to indicate that the VOS tariff mechanism may be a good alternative to NEM. The program sets a new solar standard that appears to meet many of the objectives set out at the beginning. Even so, the MN DOC raised the NEM cap so that DGPV could still go forward if voluntary adoption of the VOS program is slow by utilities.

2. **Cross-subsidies addressed.** Customers pay for their entire electric energy usage at the standard rate; this is one way of addressing cross-subsidy concerns.
3. **Stakeholder involvement critical.** The state government DOC was generally satisfied with the public stakeholder process and felt it was a good choice to involve all stakeholders in the methodology development of the resulting tariff.
4. **Third-party business models.** It is unclear if VOS programs are compatible with third-party business models where solar companies own the equipment on a utility customer's site; the consumer then signs a lease or performance sales contract with the equipment owner. This was not examined closely in Minnesota because these business models are not currently available to customers and cannot be tested in the state. View Section 5.2 on program eligibility.

# 4 Solar Market Characterization: Comparing the VOS to the Cost of Solar

This section presents the methodology by which three market frameworks were developed to characterize the solar market under various VOS tariffs, resource qualities, and incentive levels. As mentioned previously, the three market types that can occur under a VOS tariff are a price-support market, a transitional market, and a price-competitive market. This characterization is accomplished by comparing the levelized cost of solar (LCOE-PV) and the VOS tariffs in order to determine the difference. Similarly, these frameworks can be used to characterize markets under any of the transaction types used to support DGPV deployment.

The goal of this effort is *not* to conduct a state-by-state analysis of solar market under a VOS for specific locations, but rather to characterize the market for a variety of representative situations. Understanding the range of possibilities, and how the variables interact to influence the market, provides a foundation from which to discuss VOS program design elements. Additionally, NEM was not included in this analysis as the VOS was considered as a replacement for NEM programs.

## 4.1 VOS Case Profiles

The goal of defining VOS case profiles is to recreate, using publicly available data, a range of outcomes that could span various geographic, policy, and market scenarios. It is not meant to show any bounding limits of the VOS, but only a reasonable potential range of low, medium, and high values that could represent a variety of state or utility characteristics. The components included in this VOS study are easily estimated using published information and includes energy, avoided capacity, T&D capacity, line losses, and environmental costs. It does not include items such as O&M, fuel hedging, integration costs, and non-traditional items such as grid support services, resiliency, etc. as these are not currently easily calculated using publicly available data at a nationwide level (presumably they could be easier at a particular location). Each jurisdiction will have differing conditions, and will need to explore which value categories the relevant stakeholders want to include and how those values can be formulated into a VOS rate that best represents the conditions in their specific location. Methodology and assumptions used for generating the generic VOS rates used in this analysis are discussed below.

### *Modeling Assumptions*

The modeling assumptions and sources of cost information that were used in the development of the three VOS profiles are described below (more details are described in Appendix B). The differences between the three VOS case profiles are detailed in Table 3. The U.S. Energy Information Administration (EIA) 2013 Annual Energy Outlook is the source for avoided capacity and avoided fuel calculations, as well as the T&D deferral calculation and escalation rate.[18] Other basic, generic input assumptions that were needed to complete the cost calculations (e.g., discount rates, tax rates, solar system life, reserve margin, etc.) were set at mid-range values. Using published data for generation construction costs—in this study a combustion turbine[19]—and average T&D expenses, and then varying the resource timing need or avoided

[18] This analysis was performed before EIA released the Annual Energy Outlook for 2014, in May 2014.
[19] A combined cycle turbine was used because it is typically the next resource to be added to the generation fleet in a utility integrated resource plan.

investment, allows for a range of outcomes while bypassing any jurisdictional intricacies such as forecast T&D costs and the marginal generation unit type. Readers interested in understanding the range of data and modeling options for conducting VOS rate calculations are invited to consult an NREL report that details a range of simplified and more complex methodologies for calculating a VOS rate (Denholm et al. 2014). The assumptions included herein, by term, are:

**Avoided capacity**. The EIA overnight build cost (EIA 2013a) for a new, combined-cycle natural gas combustion turbine (shown in Appendix B of this report) is used as the basis for avoided capacity. It is assumed the plant is constructed over a two-year period. An economic carrying charge was applied to annualize the investment in the generation facility. Depending on the VOS case profile considered, the avoided capacity investment was either deferred for 5 or 10 years, assuming no immediate capacity need in the middle or low VOS cases, or there was an assumed immediate capacity need in the high VOS case. Limiting the marginal unit to a combined-cycle natural gas turbine with variable fuel prices simplifies the calculations.

**Avoided fuel**. Three natural gas forecasts from the EIA 2013 Annual Energy Outlook were used to generate avoided fuel mixes for the three profiles. These were converted to costs using the displaced natural gas heat rate for a combined-cycle natural gas plant and the solar output (accounting for degradation).

**T&D deferral.** Average national T&D costs from the American Society of Civil Engineers from 2001-2010 are used for T&D deferral costs. These are divided by the average national retail sales from EIA for the same period (EIA 2013a).

**Environmental.** Environmental values for the three profiles are sourced from the National Academies of Science for natural gas-fired generation (National Research Council [NRC] 2010). This provides a breakout of values for non-greenhouse emissions, which includes sulfur dioxide ($SO_2$), nitrous oxide ($NO_X$), and particulate matter. Greenhouse gases are listed separately, which allowed for their inclusion in only the high VOS case profile.

**Losses.** An average loss of 7% is applied to the sum of the avoided capacity, avoided fuel, T&D deferral, and environmental for each of the three cases (EIA 2013).

Using the sources of cost information above, low, medium, and high VOS case profiles were created. The three cases attempt to capture a realistic range of VOS rate outcomes that might occur—again, only based on publicly available data. Individual utilities or jurisdictions can include additional terms if they have access to additional data. The low VOS case assumes no immediate capacity needs, and that T&D deferral and environmental benefits are not included in the VOS calculation. The medium VOS case assumes slightly different inputs, including T&D deferral after 5 years and environmental benefits not related to greenhouse gas emissions. The high VOS case assumes immediate capacity needs, T&D deferral, and all environmental benefits. The details of these inputs into the VOS case profiles are given in Table 3.

**Table 3. VOS Category Assumptions**

| Category | Low | Middle | High |
|---|---|---|---|
| Avoided fuel[20] | Natural gas prices from EIA Annual Energy Outlook 2013 "High Oil and Gas Resource" case | Natural gas prices from EIA Annual Energy Outlook 2013 "Reference" case | Natural gas prices from EIA Annual Energy Outlook 2013 "Low Oil and Gas Resource" case |
| Avoided capacity | No generation needed for 10 years | No generation needed for 5 years | Immediate capacity need |
| T&D Deferral | No T&D benefit is assumed | 5 year T&D deferral based on ASCE average T&D expenditures from 2001-2010 and the retail sales from the same period (EIA 2013a) | Immediate T&D avoided investment based of ASCE average T&D spend from 2001-2010 and the retail sales from the same period (EIA 2013a) |
| Environmental | No environmental benefit is assumed | Non-greenhouse benefit of natural gas electric generation (NRC 2010) | Non-greenhouse and greenhouse (CO2) benefit of natural gas electric generation (NRC 2010) |

Note: several candidate VOS terms were not included in this national-level analysis because publicly available sources of data are not readily available. These include T&D loss savings, O&M, ancillary services, fuel hedging value, diversity, integration costs, grid support services, resiliency, and market price suppression.

Sources: EIA (2013a); NRC (2010)

### *VOS Modeling Results*

The VOS component calculation results are outlined in Table 5. The largest VOS component is the avoided fuel cost. It ranged from about 3.5 ¢/kWh to a little over 6 ¢/kWh, with changing natural gas prices driving the difference. Avoided capacity is the second-largest component, ranging from a little over 1 ¢/kWh to a little over 2 ¢/kWh. The high VOS case incorporates the assumption that there is an immediate need for generation capacity. Avoided environmental cost adds up to nearly 2 ¢/kWh, which is almost as much as the generating capacity component for the high VOS case. This is because of the societal impact of carbon included in the high VOS case. Avoided costs associated with T&D deferral are relatively small, with the highest case having a value of just under 0.2 ¢/kWh. Losses are a function of the sum of all the other components. Adding the value components together gave a range of nearly 5 ¢/kWh to 11 ¢/kWh, with the medium case at 7.5 ¢/kWh.

[20] The "High Oil and Gas Resource" case indicates that substantial supplies are available in the future, which has a dampening effect on pricing.

**Table 4. VOS Hypothetical Ranges (¢/kWh)**

| Category | Low | Middle | High |
|---|---|---|---|
| Avoided fuel | 3.6 | 5.2 | 6.1 |
| Avoided capacity | 1.0 | 1.5 | 2.1 |
| T&D deferral | 0 | 0.14 | 0.19 |
| Environmental | 0 | 0.18 | 1.9 |
| Losses | 0.3 | 0.49 | 0.72 |
| **Total** | **4.9** | **7.5** | **11.0** |

## 4.2 Calculating the Levelized Cost of PV

The next step in the characterization of the possible markets under a VOS tariff is to calculate the LCOE-PV for a variety of representative locations. This was done using the System Advisor Model (SAM)[21], a solar cost model developed by NREL (NREL 2014a). In order to capture the costs of solar development across the entire United States, the LCOE-PV was calculated for the most populous city of each state. This method was chosen over using the cities with the best resources, since doing so could bias the output toward a lower LCOE-PV. Since the VOS mechanism is widely discussed as a tariff to compensate customer generators in the residential sector, calculations were based on a residential-sized PV system of 4 $kW_{DC}$. These and other input assumptions are summarized in Table 5, below.

**Table 5. Input Assumptions for LCOE Calculations in the System Advisor Model**

| Variable | Value |
|---|---|
| PV array | 4 $kW_{DC}$; 7 modules per string, 2 strings in parallel<br>30 degree fixed-tilt; south facing, 77% derate factor |
| Panels | Produced an output of 284.7 $W_{DC}$ each |
| Inverter | Rating: 3,800 W, 240V |
| Degradation | 0.5% per year decline (default) |
| System cost | \$3.77/$W_{DC}$ (default) |
| Financing | 20 years |
| System life | 25 years |
| Real discount rate | 7.5% |
| State Income Tax | Weighted population rate |
| State Sales Tax | Median of highest and lowest |
| Inflation rate | 1.8% |
| Weather Data | TM3 for most populous city in each state<br>(Class 1 preferred) |

[21] Version 2014.1.14 of the System Advisor Model was used for this analysis. Since this analysis was completed a new version of SAM has been released, which includes updated LCOE data.

A separate set of LCOE-PV calculations were made for five different levels of incentives, holding all else constant:

1. No federal or state incentives
2. A 30% federal investment tax credit (ITC) only
3. The federal ITC, plus existing state incentives (as of Jan 2014)
4. The federal ITC, plus a hypothetical state investment tax credit of 30% applied to all states
5. The federal ITC, plus a hypothetical state upfront cash incentive of $0.80/W applied to all states.

The last two calculations, which assume a hypothetical level state incentive in each location, were intended to investigate the result of implementing either an ITC or a cash incentive in each state, regardless of whether one is currently offered. Currently, eleven states offer investment tax credits, the value of which fall in the range of 10% - 50%. A hypothetical investment tax credit of 30% represents the median of these actual tax credits. The hypothetical cash incentive was set at $0.80/W because this is the median of the currently offered incentives.

### *LCOE-PV results*

SAM outputs provided the LCOE-PV for the largest city in 49 states and the District of Columbia assuming different levels of incentives. The range of LCOE-PV values at each incentive level are given in Table 6. The range excludes the values for the state of Alaska. Due to the low solar resource quality, Alaska has the highest LCOE-PV of all locations studied for every scenario. In addition, several of the scenarios for Alaska yield the same LCOE-PV result because no state incentives are offered. Thus, a summary of the LCOE ranges is more informative without this outlier. Complete data for all 50 states are available in the Appendix C.

**Table 6. Range of Life-cycle Cost of PV for Different Incentive Levels (Excluding Alaska)**

| Incentive Level | Low End of LCOE-PV (¢/kWh) | High End of LCOE-PV (¢/kWh) |
|---|---|---|
| No incentives | 14.5 | 22.8 |
| 30% federal ITC only | 9.3 | 14.6 |
| 30% federal ITC + existing state incentives | 4.0 | 13.1 |
| 30% federal ITC + 30% state ITC | 5.6 | 8.6 |
| 30% federal ITC + $0.80 state capacity-based incentive (e.g., grant, rebate) | 7.6 | 11.8 |

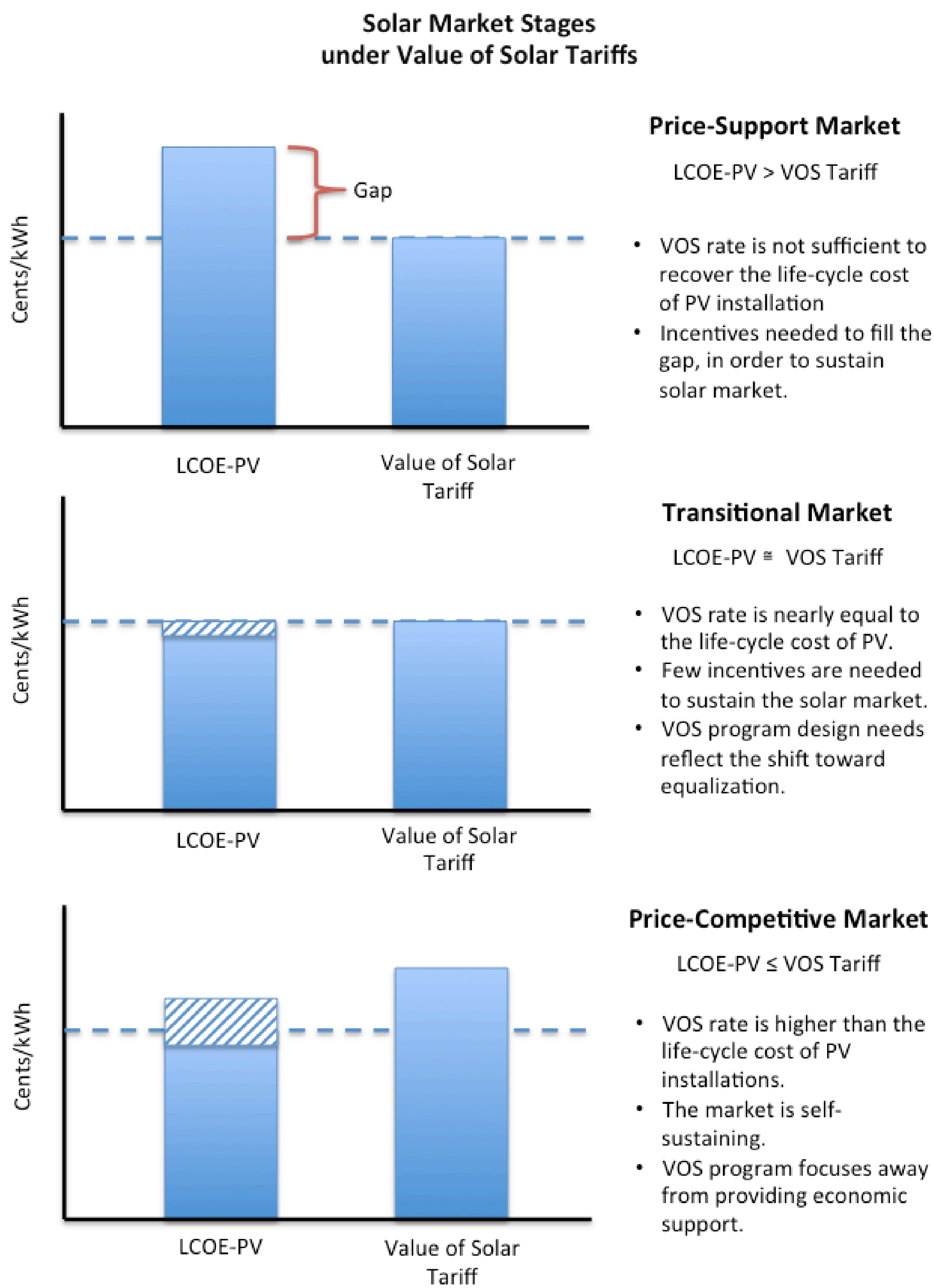
## 4.3 Comparing the VOS profiles with the LCOE-PV

Next, the difference between the VOS profiles and the LCOE-PV was determined by subtracting the LCOE-PV from the VOS level for each permutation. It is important to note that this methodology of calculating the difference assumes that the payment structure being employed in the VOS program is ‘buy-all/sell-all.’ In other words, all of the solar generation produced by the system is purchased by the utility for the VOS rate. An alternative program payment structure is one where the utility only pays the solar system owner the VOS rate for the excess generation that is fed onto the grid (i.e., the generation that is not immediately consumed on-site is not purchased by the utility). These different payment structures have vastly different effects on the economics of solar.

Understanding that this analysis is assuming a 'buy-all/sell-all' payment structure, the difference between the VOS profiles and the LCOE-PV indicates the degree to which the VOS payment would cover the cost of a solar development. For each location and each scenario, the cost of solar is greater than, near to, or less than the VOS level. The factors that impact this result include the amount of solar resource available at the most populous location within each state, the sales and income tax rates of the state, the federal and state incentives assumed to be in place, and the VOS payment level.

Figure 3 illustrates various market types that are a possible result from the calculation (LCOE-PV minus the VOS rate). The two bars in each chart show the cost of solar and the level of the VOS tariff in three market types.[22] The shaded areas indicate the range in which the LCOE-PV may fall for the particular market type. A price-support market occurs when the LCOE-PV is significantly greater than the VOS tariff. In this case, additional incentives are needed to fill the gap in order to sustain the solar market. A transitional market occurs where the VOS tariff level is approaching the LCOE-PV and limited incentives may be needed. And in a price-competitive market, the VOS rate is higher than the LCOE-PV. As we will see in following sections, VOS program design needs will differ for each of these market types.

[22] Figure 3 is for illustrative purposes of market types and is not based on analysis.




Notes: This figure illustrates solar market types that may occur under a VOS tariff. It does not present analysis results. The shaded areas indicate the range in which the cost of solar may fall under that market type.

**Figure 3. Solar market stages under VOS tariff**

### Results of Comparing the VOS level with the Cost of Solar

When the difference between the VOS rate and the LCOE-PV is calculated for all locations and all scenarios considered in this study, all three market stages are represented. The range of results of these calculations is shown in Figure 4. The figure shows that when no incentives are accounted for (the scenario depicted by the red bar), the difference between the VOS and LCOE-PV is below zero for all of the locations and levels of VOS. In other words, the assumed VOS tariff does not cover the LCOE-PV, creating a price-support market. As the difference between the VOS and LCOE-PV approaches zero, the market can be said to be transitioning from price-support to a transitional market. Scenarios that fall above the x-axis are in the price-competitive stage. For example, a price-competitive market occurs for all locations in the scenario where there is a high VOS, a 30% federal ITC, and a hypothetical 30% state ITC (represented by the green bar on the right-hand side of the figure).

Some locations and scenarios that were modeled for this study fall within the price-competitive market stage. These are indicated by the ranges where the bar rises above the zero line. When all existing incentives are considered (the orange bar), there are at least some price-competitive markets for each level of national, generic VOS tariff considered here. Note again that this analysis did not include net metering, as the VOS was considered a replacement for NEM. When a high VOS level was assumed, the largest number of price-competitive markets occurs. There are a few locations for which the solar market is shown to be price-competitive under a high VOS rate, with only the 30% federal ITC in place. Notably, under a high VOS rate and a 30% federal and 30% state ITC, every location was found to have a price-competitive solar market.

Figures 5 and 6 show the results in a different form. The points on these graphics show the result of each cost comparison for all locations and all scenarios. Figure 5 shows the results for the scenario without incentives and those with existing incentives. Figure 6 shows the results for the scenarios that include hypothetical state incentives. Similar to Figure 4, the data points that are above the x-axis indicate locations where price-competitive markets exist for the given scenario.

The location names are intentionally left out of the result displays because the purpose of this analysis is not to focus on specific locations, but to generally characterize the markets that might be expected to occur under various levels of VOS tariffs and various levels of incentives. These data are only general representations; they are not intended to be used to make conclusions regarding the potential economic viability of distributed solar in a particular location.

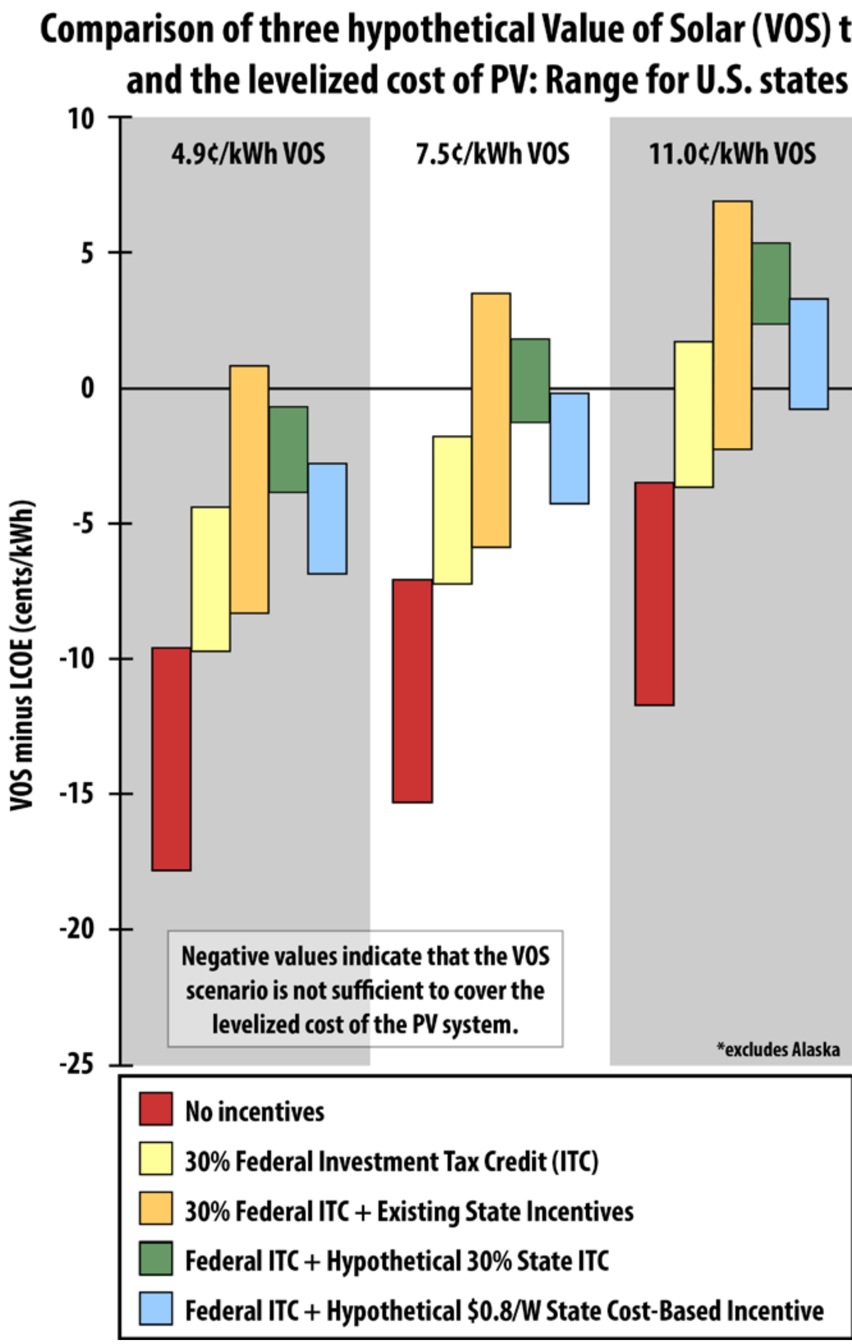



**Figure 4. Comparison of VOS and LCOE-PV**

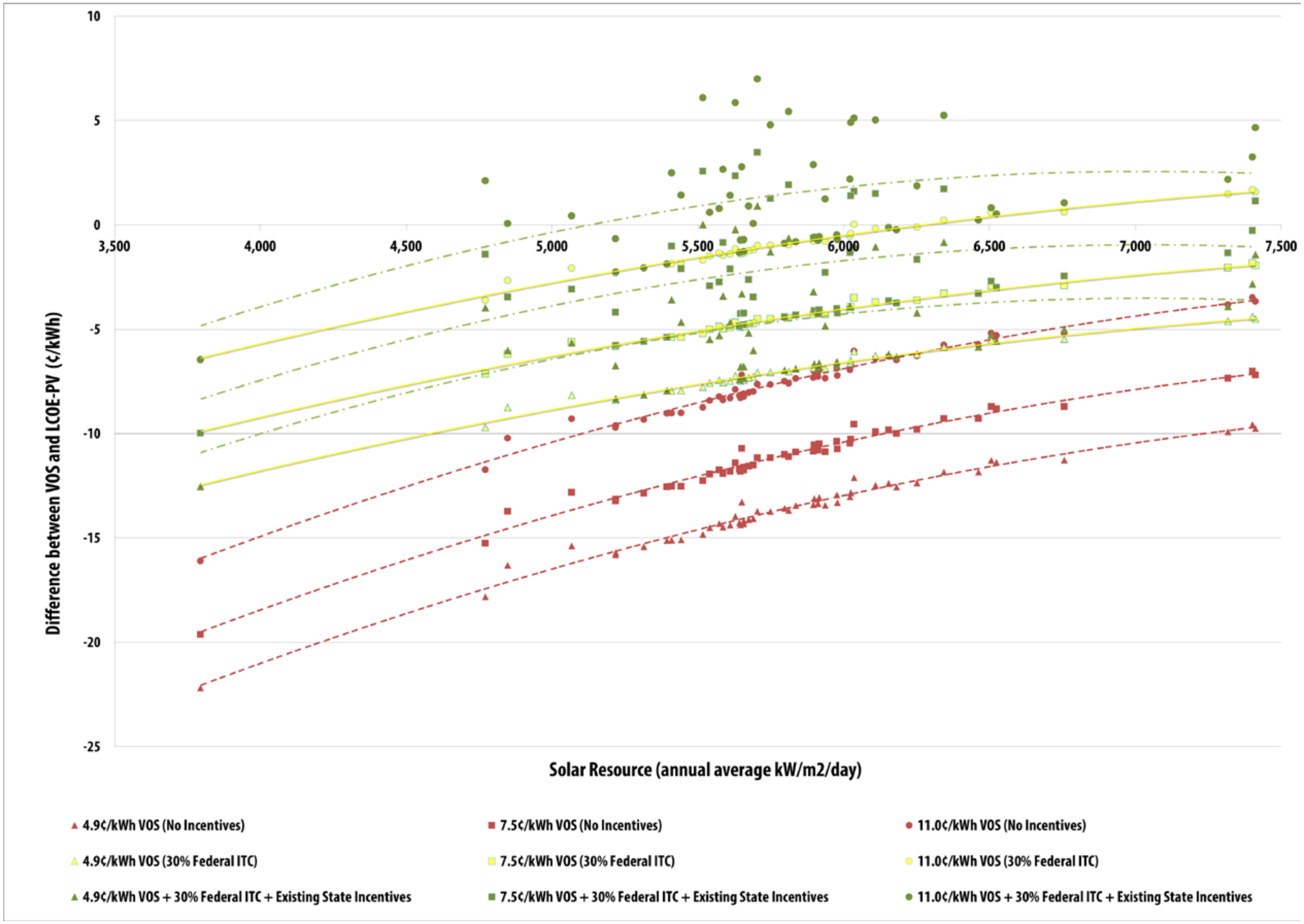



**Figure 5. Difference between three levels of VOS tariffs and the LCOE-PV in 50 U.S. locations: scenarios with no incentives and existing incentives**

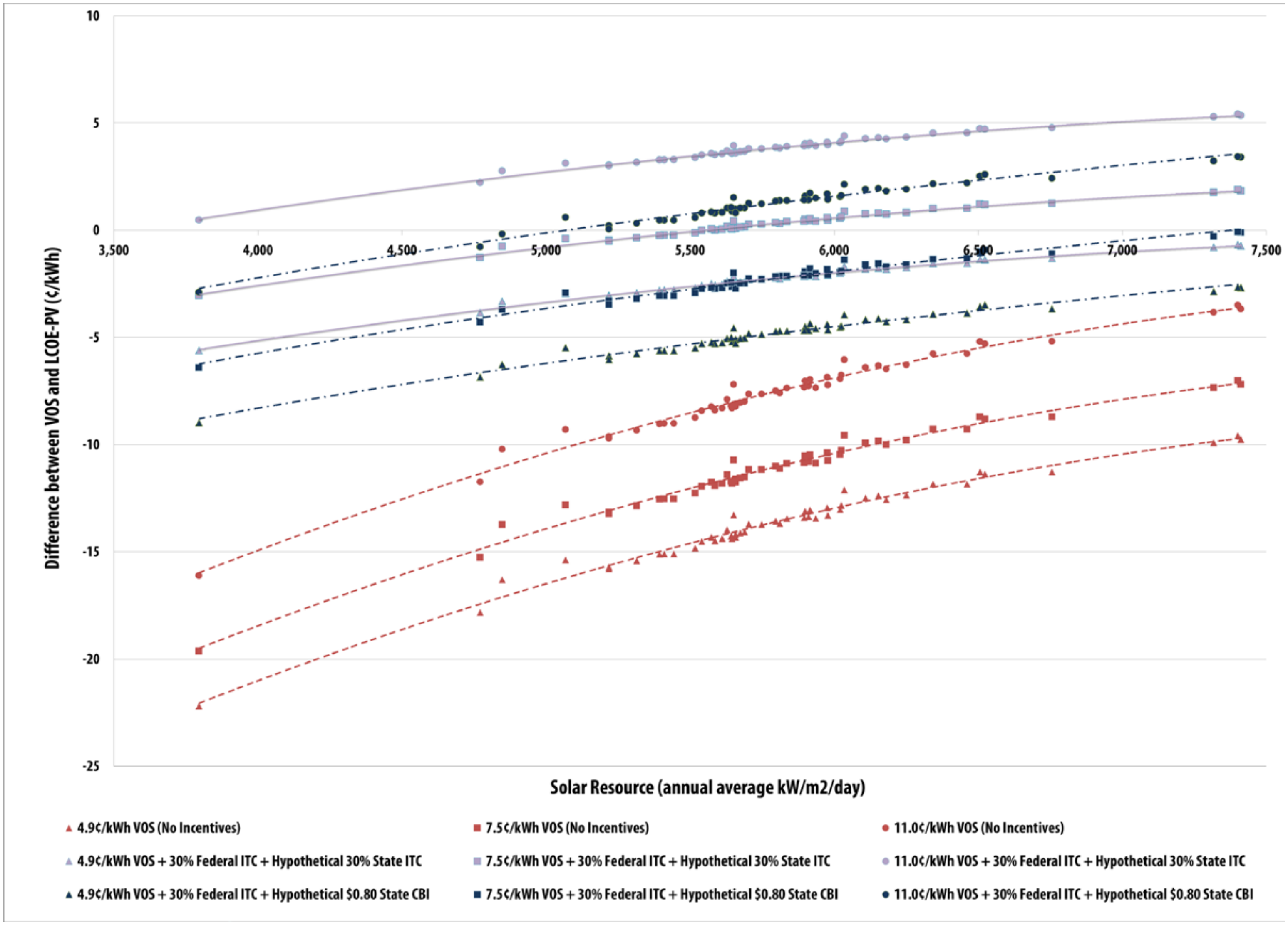



**Figure 6. Difference between three levels of VOS tariff and the LCOE-PV in 50 U.S. locations: scenarios with hypothetical state incentives**

## *Key Takeaways*

Some key takeaways from the modeling effort are summarized below. The points are categorized by the assumptions regarding the available incentives, as well as the assumption regarding the level of VOS tariff available. See the Appendices for more details on the results of the modeling.

**No Incentives**

- If no federal and state incentives are taken into account, the three hypothetical VOS tariff levels selected for this study are substantially lower than the LCOE-PV derived from the modeling assumptions, indicating price-support markets in all locations.

**Federal ITC only**

- When only the 30% federal ITC is taken into account (no state incentives), the economics of the modeled PV systems improves for the high VOS tariff case. Results indicate a transitional market in most locations and a price-competitive market in nine locations.
- Low and medium VOS tariff levels result largely in price-support markets.

**Federal ITC + Existing State Incentives**

- A high VOS tariff along with existing state incentives yields a competitive market in the majority of locations (32 out of 50). Only one location is pre-economic under this scenario.
- The medium VOS tariff results in 10 price-competitive markets and 17 transitional markets; the rest are pre-economic.
- Most locations studies under the low VOS tariff are pre-economic, although there are a handful of transitional (9 markets) and 2 price-competitive.

**Federal ITC + Hypothetical 30% State Tax Credit**

- Under a high VOS rate plus a 30% federal ITC and a 30% state investment tax credit, solar is price-competitive in all locations.
- With a medium VOS rate, more than half of the locations are price-competitive and only one location is price-support.
- The majority of locations are transitional with a low VOS tariff.

**Federal ITC + Hypothetical $0.80/W State Capacity Based Incentive (CBI)**

- A high VOS tariff along with a federal ITC and a $0.80/W state CBI yields a competitive solar market in nearly every location (47 out of 50). The other three locations have transitional markets.
- The medium VOS tariff results in mostly transitional markets; only 9 are pre-economic.
- Only 3 markets are transitional with a low VOS tariff; the rest are all pre-economic.

**Low VOS Level**

- Very few instances of price-competitive markets occurred under the low VOS tariff level modeled for this study.

- When the federal ITC + a hypothetical 30% state ITC is considered, 45 locations show transitional markets. The remaining five locations have price-support markets.
- For the federal ITC + existing state incentives, the low VOS tariff results in 2 price-competitive markets and 9 transitional, with the rest being pre-economic.
- All or most (at least 47/50) locations have price-support markets for 3 of the incentive scenarios modeled (no incentives; federal ITC only; federal ITC + hypothetical $0.80/W CBI).

**Medium VOS Level**

- A medium level VOS tariff yields mixed results for the various scenarios modeled. Economic markets are present in only two scenarios: federal ITC + existing state incentives (10 states) and the federal ITC + a hypothetical 30% state ITC (the majority of states).

**High VOS Level**

- Under the high VOS scenario, all but three locations have price-competitive markets under the hypothetical incentive scenarios (federal ITC + 30% state tax credit (all markets) or a $0.80/W CBI).
- More than half of the locations (32 of 50) have price-competitive markets when the federal ITC+ existing state incentives are included in the modeling. In this scenario, only one location results in a price-support market.
- The federal ITC only high VOS tariff resulted in 9 price-competitive markets, 2 pre-economic, and the majority transitional. Without the federal ITC, no markets were even transitional; they all were pre-economic.

One general takeaway is that, under the assumptions of this analysis, the presence of federal and state incentives has a greater impact on the solar market stage than the VOS level (see Figure 4 and Appendix C). When the level of VOS is held constant, the shift of the LCOE-PV is a direct result of the incentives being included. For example, note the difference between the LCOE-PV results for the “no incentive” case and the “30% Federal ITC + existing incentives” case. Not surprisingly, the LCOE-PV range bar shifts upwards (toward a more competitive market) with the addition of incentives. Now compare the LCOE-PV ranges when the VOS level is increased, while the level of incentives is held constant. In all cases, increasing the level of VOS also shifts the LCOE range upwards, but the shift is smaller than that induced by the addition of incentives. This indicates that incentives have a greater impact on market competitiveness than the level of VOS, under the analysis assumptions.

The other key takeaway is that a VOS program will most likely be dynamic. As market conditions change, the relative values and costs of the solar system, the market in which it is participating, and other key factors will change. Therefore, it may make sense to reevaluate the tariff structure and design as conditions change over time. The challenge is how to do that in such a way that keeps investors neutral to the changes; in other words, any adjustments cannot undermine the overall project economics that lead to investment, or investors may not be interested in supporting DGPV in those locations.

This section presented an analysis comparing the current LCOE-PV in 50 U.S. cities with 15 different scenarios for compensating and incentivizing customers for distributed solar generation. The difference between the cost of installing a solar system and the payments received by the owners is presented as an indication of the status of the market in each location. The results provide decision makers with a framework for considering the potential market impact of implementing a VOS rate and the importance of state-level incentives in supporting the transition from a pre-economic market to a competitive market over time.

# 5 VOS Program Design Framework

This section examines a VOS program design framework, outlining the principles that can be used in developing the administrative rules and functional decisions of a VOS program.

A VOS program is somewhat similar to other utility-managed customer solar programs, such as NEM, as well as incentive programs, both of which have a well-established history of design improvements and best practices in the United States. However, a VOS tariff is not an incentive– it is a utility rate program. Moreover, VOS programs often represent a market shift away from net metering, and as such, have potentially higher stakes among customers and the solar industry. No single program design may satisfy all interests perfectly, but a thorough approach to the design and implementation process can improve the end results. For example, a goal of a VOS program might be to support the solar industry and enable a successful transition from NEM. One method of doing so could be to layer a multi-year, declining incentive program on top of the VOS rate, gradually transitioning to an incentive-free market as solar costs decline. While this design construct could result in a higher VOS program cost in the early years, it would avoid a significant market disruption during the transition period, essentially narrowing the near-term difference between the chosen VOS tariff level and the current cost of solar.

Note that this report is not a complete VOS program design guide–the nascent and emerging nature of the VOS concept does not lend itself to a known checklist or best practices. In fact, the VOS design concepts introduced here are likely to raise more questions than answers, and further research will be required to design VOS programs to suit the regional context of any particular utility. At this point, investigating the lessons learned and design options of other policies can provide insights for developing new policies (for more information on policy design options and lessons learned, see Couture et al. 2010; Bird et al. 2012; Lantz and Doris 2009; and Cory and Swezey 2007). Proactively identifying and addressing potential issues during the design phase may be easier than retroactively addressing a forgotten issue. Similarly, this framework does not favor or promote one program design decision over another. The approach lays out the range of options with directional indicators of their net effects.

The LCOE-VOS comparative analysis in the previous section indicated that the “price-support market,” where the VOS rate is less than the LCOE-PV, is likely to be the most common solar market condition currently across the United States (individual situations may vary and likely will be calculated for each jurisdiction). While it may not be the case in every circumstance, it is a good starting point to assume that a VOS alone may not be enough to cover the LCOE-PV of development given today’s solar costs. Going forward, other market types and design needs will emerge over time, as VOS rates are adjusted and the LCOE-PV declines. Given this assumption, the design discussions below use the price-support market as the default market framework, noting adaptations for the “Transitional” (VOS = LCOE-PV) and “Price-competitive” (VOS > LCOE-PV) markets, where applicable. And while some programs may be designed as a buy-net sell-net (or net excess) transaction, we only investigated the buy-all sell-all transaction used in Austin and considered in Minnesota.

This analysis generally defaults to the most common scenario driving VOS program adoption to date–a roof-mounted, PV system on a residential customer using a single, bundled VOS rate. Variations of this scenario are discussed, but unless noted, this is the default arrangement.

The design categories by section include:

- 5.1 *Balancing Design Decisions*: Setting objectives, understanding the necessary design and stakeholder interest tradeoffs, and placing the program needs in the context of what can be rapidly changing market and business conditions
- 5.2 *Installation Details*: Covering the installation rules for participants
- 5.3 *Rate and Contract Treatment*: Establishing how the VOS rate is implemented within a long-term program
- 5.4 *Price Supports*: Considering an additional incentive on top of the VOS rate
- 5.5 *Administrative Issues*: Thinking through the internal utility program operations and accounting.

**Text Box 1. Design Application: Hypothetical Utilities**

Each section below discusses the range of program design options from which decision makers can choose in shaping and defining an overall program, akin to a program design menu. Category by category, the range of options is intended to be inclusive of a variety of options and to provide the context for specific decisions to make the report more tangible. Two hypothetical utilities were created with different characteristics to create example programs, and contrast the differences between different program designs. The text boxes within this chapter explore how the utilities might approach VOS program design.

*Utility A* is located in a cost-support market and is seeking to:

- Transition from NEM to VOS tariff for residential customers only
- Utilize solar installations to assist with future generation capacity needs
- Keep billing simple and utilize its existing billing system
- Plan for future VOS rate values that could be realized in the future.

*Utility B* is located in a price-competitive market and is seeking to:

- Transition from NEM to VOS tariff for all customers
- Leverage new technologies, creating a diverse fleet of distributed resources
- Seek out a utility return on investment where possible in the price-competitive market
- Develop a sophisticated customer information and billing system.

These two utility examples will follow each section below in similar textboxes, weaving the sometimes broad list of options into a specific program decisions and their related thought processes based on these goals.

## 5.1 Balancing Design Considerations

One theme throughout this section is how to balance competing design philosophies to create a useful program, as shown in Figure 7. The accuracy of a program's design needs to be balanced against the costs to attain that accuracy and the impacts on program participation. In other words, what level of complexity is a VOS program equipped to manage, and will added complexity actually lead to more satisfactory results or equivalent benefits?

For example, location-specific VOS rates could be designed to represent a greater or lesser VOS across an individual utility's service territory, which would manifest in utility cost savings at the distribution or transmission level. While it is more accurate to reflect each individual solar system's value to the utility system, the question remains whether this level of accuracy yields sufficient benefit or practicality. When put into practice, the VOS rate could vary across hundreds of individual distribution circuits or in several larger geographic areas. But this accuracy needs to be balanced against the simplicity of a single VOS rate across an entire utility's territory. Limiting the number of different VOS rates[23] will likely facilitate calculations, rate updates, customer marketing and communications with customers, the industry and other stakeholders. Just as utilities set electricity rates based on an average customer consumption profile per customer class, a single VOS rate, representing the average value that solar provides across the system may be easier to set and implement than multiple rates.

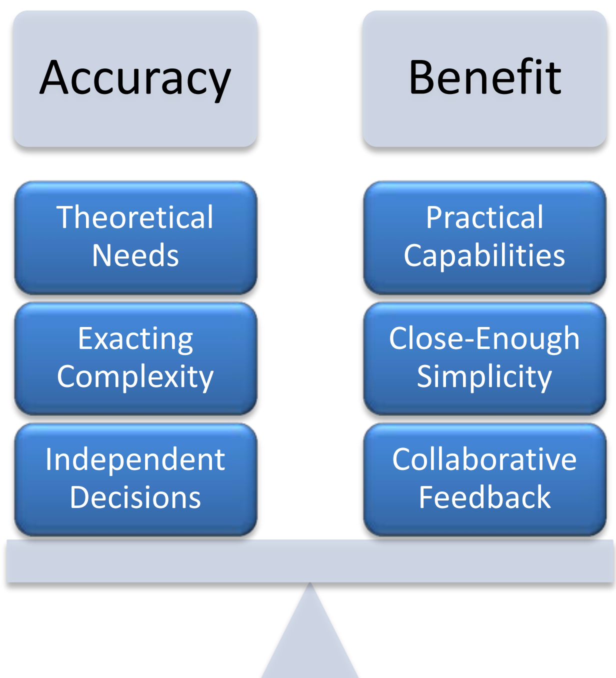



**Figure 7.VOS program design balance considerations**

[23] Different types of VOS rates could include those for residential customers versus non-residential customers (or those with and without demand charges), and distinct rates or adders for customers installing distributed solar in preferred locations on the electricity system.

These types of decisions include technical accuracy, but also program design rules. For example, historical rebate programs were very prescriptive about installation details to promote long-term performance given upfront ratepayer or taxpayer investments. Under a VOS tariff, a utility only pays for actual electricity produced at a rate that represents its calculated value. Thus, will the VOS program design rules try to maximize system performance, or are the administrative and transaction costs of setting up and managing VOS program applications enough to warrant greater involvement in ensuring system performance? Throughout the program design phase, these types of needs and interests of stakeholders (e.g., utilities, the solar industry and electricity customers) will be balanced against one another. The degree of independent decisions by the utility versus collaborative feedback from solar stakeholders and decision makers will vary significantly according to the type of program implemented and the program's goals.

## 5.2 Installation Details

A VOS program will typically include administrative rules on a range of design issues, such as participant eligibility and project or program size limits. However, although the VOS concept is often regarded as a distinct *alternative* to NEM, the design of and lessons learned from NEM and other existing policies provide useful information to guide the development of a VOS program. For example, one comprehensive list of renewable energy policy design options is found in a report on Feed-in-Tariff (FIT) designs, called *A Policymaker's Guide to Feed-in-Tariff Policy Design* (Couture et al. 2010).[24] Even though it is focused on FIT policies, the design and implementation options are widely applicable to other policies, whether they are rates or incentives. Another example is provided in *Distributed Solar Incentive Programs: Recent Experience and Best Practices for Design and Implementation* (Bird, Reger, and Heeter 2012). In fact, details from both of these documents were used as a foundation to consider VOS program design options in the subsections below.

### *Eligible Participants*

Options for VOS participant eligibility include:

1. **Residential and small business customers** (i.e., energy-only rate customers): The driving interest behind VOS programs as an alternative to NEM (from some stakeholder perspectives) is separating consumption from generation and remedying concerns of fixed cost recovery. Typically, residential customers (and often small businesses) pay virtually all of the system's fixed costs through the volumetric energy rates (i.e., on a kWh basis). As such, residential customers are the main target participants for a VOS program.
2. **Non-residential customers** (i.e., any that have demand charge rate structures): Customers with a demand charge generally pay for a higher proportion (though not all) of the system fixed costs than customers on all-energy rates. A VOS program may still be of interest to ensure appropriate compensation for DGPV generation contributed to the system, and to make sure that all utility costs are paid to the utility. A different VOS rate may need to be set for customers that are subject to demand charges.
3. **Third-party-owned solar installed on electricity customer property**: The third-party ownership (TPO) model, in which customers sign leases or energy contracts with solar

[24] See Table ES-1 on p. xi of the Executive Summary of the report.

companies rather than purchasing or financing the solar installation outright, is popular in U.S. states where it is allowed. VOS program designers may need to specify whether TPO systems will be eligible for a VOS rate, and might look for precedents set by existing state or utility policies. If the TPO model is already active in an area and these systems are eligible for existing policies (e.g. net metering), backing out of this precedent could be disruptive to the market and raise stakeholder concerns. If the TPO model is not active in an area, either by explicit utility or regulatory decision or local market conditions, the VOS program design may represent a point of (re)consideration. Some utilities have expressed concern around TPO activity because as regulated monopolies, they have exclusive rights to sell electricity to customers in their service territories, something which is clouded when TPOs sell solar electricity to the same customers. Under the VOS mechanism, electricity consumption and solar generation are separated, which may reduce regulatory concerns.

4. **Third-party company on non-load locations**: Independent solar projects on greenfield or brownfield sites could also be considered. These are akin to a community solar or distributed solar merchant plants, which are common in feed-in tariff markets. In theory, the value that a solar installation provides to the system is independent of any tie to a particular customer. This development option could potentially expand the solar market significantly, especially in suburban and rural areas where suitable land can be found. One potential concern with this option, however, is the possibility that a limited number of customers could rapidly fully subscribe to the program, or that a few customers could reach distribution circuit penetration limits, essentially crowding out other eligible customers. One can envision a project developer that finds the VOS rate economic and installs dozens of projects in one territory, blocking others from participating in the program. Another consideration is that this option may not be feasible until the transition from net metering (which is clearly tied to a specific customer load) to a VOS tariff (which is not necessarily tied to a specific load) is complete. If this project type is excluded altogether, VOS policy designers would need to pay attention to the definition of the customer type or define the on-site load (e.g., is one streetlight sufficient?) in tandem with individual project size limits.

### Individual Project Size

Project size limits have historical origins in net metering, which are often based on the size of the solar system relative to the customer's usage. VOS rates are dissociated from customer use and projects would be limited more by interconnection penetration limits on distribution feeders.[25] However, limits might also be considered as part of an overall goal to provide the opportunity for broader customer participation by prohibiting one or two large projects from fully subscribing to the program (if capacity or budget limits exist) or distribution circuit level penetration limits (to spread out and diversify geographic participation).

Any individual project could be limited in capacity based on the participant or customer type or expected generation relative to historical customer use or load. From a program operation perspective, simple size limits by customer type would be most easily administered (e.g., residential 10 kW; small business 50 kW; or 100% or 120% of total on-site annual load).

[25] Austin Energy's VOS rate is compensated through bill credit, which effectively correlates project size to the annual bill, depending on bill credit rollover rules.

### Aggregate Program Size

The concept of creating an aggregate VOS program size limit could be related historically to either utility or state incentive program limits, based on defined annual program budgets, or to state or utility net metering program caps. However, a VOS program could be theoretically self-limiting and may not need an aggregate limit. A VOS rate is based on the anticipated monetary value to the utility system, so in theory, there are no customer cross-subsidization or lost revenue issues. In other words, a perfectly designed VOS tariff is equivalent to a point of indifference for the electric system and ratepayers, where they will take as much distributed solar energy as the market can provide at that price point, or that makes sense on any particular feeder or substation. Greater solar supply or a change in natural gas prices would increase or decrease some of the VOS rate components accordingly. For example, as solar penetration goes up, the solar capacity value goes down under most capacity value calculation methods (Hoff et al. 2008). However, in reality, this is only true if the VOS rate is adjusted in short time intervals (even real-time) rather than in more practical intervals, such as annually (see also 'Contract and Rate Treatment' section below). In most cases there will be a lag between the solar energy installed, the VOS rate adjustment, and the future solar market response to the rate change. This could be handled with shorter rate interval adjustments, but these could be disruptive to the solar market as solar developers and consumers are planning projects or securing financing. Another option is to forecast future VOS rates so that the market can internalize upcoming changes, but this can create a market rush if there is a significant drop anticipated.

Even still, there will be a lag between the payment for the solar electricity and the value it provides--and when that value to the utility system and society is monetized by the utility. This will vary by VOS category, with energy value savings occurring more or less in real-time, with costs for deferred capacity, grid infrastructure deferrals, or environmental costs occurring on longer time cycles.

In a more practical sense, interconnection penetration rules and limits (outside the scope of the VOS rate) may themselves limit DG on individual distribution feeders and, by association, the overall VOS program activity.

If the VOS program sponsor decided to limit program size, a variety of options are possible, including solar capacity targets, annual budgetary expenditure limits, calibrating to utility demand or demand growth, or similar metrics.

### Generation Technologies

VOS programs by definition include solar PV technologies and are dominantly applied to flat panel, fixed PV systems. However, concentrating PV could also be considered while non-PV generation technologies like micro-CSP, wind, or fuel cells may be technologies to consider in the future since they may offer different utility value profiles than the VOS tariff (and thus would require their own unique VOS tariff calculation and VOS program design).

### Supporting Technologies or Installation Configurations

A variety of supporting technologies and installation configurations could be considered for compatibility with a VOS program and could be encouraged under a VOS tariff. Single- or dual-axis PV tracking will increase solar capacity and extend the shoulders of the solar generation curve into the evening hours. Allowing tracking to be included in a VOS program does not represent a significant philosophical or administrative hurdle, but the appropriate compensation may need to be considered since the initial capital cost increases as a result. Tracking will increase annual performance and the system will receive additional revenue at the VOS rate. Tracking can also enhance the solar capacity value. A variable VOS rate based on time-of-use or critical-peak pricing is also possible, but creates additional administrative, metering, and billing complexity. Program designers will have to determine whether to offer enhanced value for tracking or other supporting technologies.

Smart inverters hold the promise of increased visibility and control at the edge of the grid. Advanced inverter functions allow for more elaborate monitoring and communication of the grid status, the ability to receive operation instructions from a centralized location, and the capability to make autonomous decisions to improve grid stability, support power quality, and provide ancillary services (NREL 2014b). To the extent that the utility is able to dispatch smart inverters to provide voltage-amp-reactive (VAR) power support rather than kilowatt-hours, for example, a differentiated value proposition could be created for that class of customer. These value streams would need to be calculated and applied in the VOS rate calculation methodology, and then metered and compensated appropriately.[26]

For energy storage, some combination of program rules, interconnection configurations, and performance monitoring would be needed to isolate the battery to solar-only charging. Under a simplified, bundled VOS rate, a battery is unlikely to produce an economic arbitrage scenario for providing dispatchable capacity that is worth the incremental cost in the near term. But if the VOS rate included time-of-day or critical-peak capacity performance bonuses, it could become economic in the future.

Other configurations may also enhance overall system performance. A solar project's design can influence the potential value streams by orienting panels toward the west to coincide with peak system demand. Another configuration that is becoming more common, would be to oversize the array relative to the inverter size to increase the delivered capacity and overall performance. Under a bundled, all-energy VOS rate, this would not be compensated, but if a VOS rate was unbundled and capacity was a separate line item, program designers may want to consider this potential design.

### *Interconnection*

Interconnection and safety issues will likely be defined in the utility's standard interconnection process, outside of the VOS program. Similarly, high penetration scenarios on individual distribution feeders are largely handled and defined by interconnection processes, not the VOS program. There may be reasons to adjust the VOS rate based on high penetration congestion (discussed later under "rate treatment"), but the technical interconnection components are distinct from the VOS program. Utilities and/or states should review the interconnection requirements to ensure compatibility.

[26] One could also envision the packaging of generation and consumption capabilities, such as a VOS and demand response to critical system capacity needs. They probably will remain separated from a program design standpoint, but their presentation and packaging to consumers may be related, and their program impacts on the other could be considered together, if not coordinated.

Table 7 shows an overview of the VOS program design elements described above.

**Table 7. Summary of VOS Program Design Options**

| Category | Options<br>(The options under each category are not mutually exclusive) |
|---|---|
| Eligible participants | Residential and small business (or other energy-only rate customers)<br>Non-residential (any demand-charge customer)<br>Third-party on customer sites<br>Third-party on brownfield or greenfield sites |
| Individual project size | No limit<br>Sized by customer or participant type<br>Expected generation relative to historical customer use<br>Solar capacity relative to historical customer peak load (e.g., 100% or 120%) |
| Aggregate program size | No limits<br>Total program capacity<br>Annual budgetary expenditures<br>Relative to utility demand or demand growth |
| Technologies | Flat panel PV<br>Concentrating PV<br>Micro-concentrating solar power (CSP) |
| Supporting technologies or installation configurations | Smart inverter<br>Energy storage<br>Panel orientation, tracking, or array: inverter ratios |
| Interconnection | Engineering and safety standards on the distribution grid are distinct from the VOS program, though it might make sense to tightly coordinate and communicate between the two (unless interconnection standards do not exist) |

**Text Box 2. Design Application: Installation Details**

Table 8 outlines the different approaches each hypothetical utility took regarding the installation details, given their respective goals on eligible participants (e.g., residential-only versus all customers) and supporting technologies for Utility B (e.g., smart inverters for larger systems in anticipation of future grid integration interests). Other differing categories, such as project size and performance assurances, are less goal-related and indicative of natural decision leading to differences across organizations. Neither utility opted to limit aggregate program size, though Utility A's program will naturally slow if price-support funding runs out since projects would be uneconomic.

**Table 8. Summary of Installation Details Application by Hypothetical Utilities**

| Category | Utility A | Utility B |
|---|---|---|
| **Eligible Participants** | Residential only<br>Load-only | All Customer Classes<br>Load-only |
| **Individual project size** | ≤ 120% peak load | ≤ 100% average annual consumption |
| **Aggregate program size** | No limit other than annual incentive budget; program continues without incentives | No limit |
| **Technologies** | PV only | PV only |
| **Supporting Technologies or System Configurations** | None | Require smart inverters for systems over 10 kW<br>Provide a supplemental rate for W-SW facing systems |
| **Performance** | Eligible equipment lists | Eligible equipment lists<br>On-site inspections for systems over 10 kW |
| **Interconnection** | NA | NA |

## 5.3 VOS Rate and Contract Treatment

Automatic adjustments to the VOS rate and eligibility criteria can be incorporated into the program design decision process in a variety of ways. This section focuses on the underlying VOS program structure, automatic rate adjustment, and how the rate may be treated over time.

### *VOS Program Structure*

As discussed in Section 3.1, the VOS program could be designed as a buy-all, sell-all program, where the consumer purchases all electricity consumed at one rate and sells all solar generation at the VOS rate. This design is used by Austin Energy and is proposed in Minnesota, where it is called a "full transaction." One attraction of the buy-all, sell-all design is that, if a utility wants to purchase solar to address customer preferences or its own policy requirements, a properly designed VOS program can address some key concerns with existing purchasing mechanisms, such as net metering. Under the buy-all, sell-all design, electricity purchases are decoupled from solar payments and each customer pays for the utility services he or she uses. And as long as the VOS rate includes the cost of solar power integration and fixed T&D costs to the utility, there is less likelihood of revenue erosion or cross-subsidization between solar and non-solar customers as a result of growth in distributed solar.

Alternatively, a VOS tariff can be designed to create a net excess transaction, where customers offset their own consumption with self-generated power before selling the net excess generation to the utility at the VOS rate (Keyes and Rábago 2013; Starrs 2014). This could be considered a hybridized approach between net metering and a VOS tariff. In this structure, the utility would provide a kWh bill credit for solar generation that meets the customer needs, either as it is produced or over a defined time period, such as monthly or annually, just like net metering. For any net excess generation, the VOS tariff would be applied for financial compensation ("buy-net, sell-net"). The self-generator is able to hold on to the RECs or sell them to the utility or another market participant.

There are some potential downsides to the net excess program design. First, since it does not separate the solar customers' purchase of electricity from the sale of their solar generation, this design does not necessarily address the cross-subsidy and cost-recovery issue that has sometimes been attributed to net metering (Kind 2013). In addition, in certain markets, the net excess approach could result in higher program costs than the buy-all sell-all design. If the total cost of PV systems is not competitive with retail rates, which is likely in the near term in many locations, the incremental incentive needed for a system to be economic may be larger than under the buy-all sell-all design. This is because the additional incentive is applied to a smaller portion of the power generated by a solar system (i.e., the net excess). Furthermore, if the utility wants to use distributed generation systems in its jurisdiction to meet RPS requirements (e.g., solar or DG set-asides), but is only able to purchase RECs associated with the net excess generation of each system, it would end up purchasing RECs from a greater number of systems. Incentivizing a larger number of systems in order to meet RPS requirements would add program cost if the solar systems are not yet price-competitive.

Another variation in the way VOS rates are applied is related to the side of the meter on which the PV system is located. The solar system could be connected on the customer side of the meter. In this case, solar generation is metered, the VOS rate is applied to this generation, and the customers receive financial credit on their bills. Austin Energy's program is structured this way for a variety of reasons. Remaining on the customer side of the meter requires no changes to existing interconnection procedures and policies, requires minimal solar industry or customer education (e.g., interconnection processes are not revised), and prevents the customer from receiving a taxable revenue stream since it mimics net metering. Again, when located on the customer side, both buy-all sell-all and net excess generation transactions would work. Under either structure it may be important to consider the total costs of solar integration onto the system and the fixed T&D costs to keep the utility whole.

The solar generation can also be metered on the utility side of the meter, and the transaction may be completely separate from the consumption and customer billing process. In this case, the utility can provide a check to the customer to pay for his or her generation. The legality of this structure may need to be evaluated for particular jurisdictions to assess whether it is in accordance with existing regulations. The possibility of providing an electric bill credit may be possible, but must also be investigated further. Notably, locating a system on the utility side of the meter likely limits the program design to a buy-all, sell-all transaction. Other challenges to this structure include: it would create a taxable revenue stream for the customer that would need to be reported to the IRS, and interconnection procedures would need to be revised, which might add confusion to the installation and program participation.

Other structural variations may also exist and could be considered.

### *Number and Kind of VOS Rates*

The majority of this section, and the program design decisions succeeding it, are predicated on two critical decisions. The first is the number of VOS rates a program might incorporate. There are dozens of variables outlined below that could create a menu of rates for consumers to utilize–different rates by the location or performance capabilities of any particular solar system. The easiest option, from the standpoint of operation may be a single rate across the entire VOS program, but some of the ideas presented below offer enough value to consider applying more than one rate. Another option is the creation of adders to the VOS rate to encourage customer behavior such as encouraging system placement in desirable locations or the deployment of value-added elements such as storage. This adder could be applied on top of a single VOS rate.

In theory, there could be a submenu of value components that are all priced separately, and the utility or customer could sell or purchase them individually.[27] Unbundling the pricing of solar value components may be driven by competition (i.e., the availability of more economic options for the supply of the components). The most likely component for unbundling is environmental attributes, whereby the customer might keep such green attributes as renewable energy or carbon credits and sell only the primary electricity components. Other components may be defined for voltage control or other grid support services that can be provided by storage or smart inverter functions associated with a distributed solar system. Certain customers, such as a corporation with carbon mitigation goals or a broker selling RECs into an established REC market, may make more use of such unbundled pricing schedules than residential customers.[28]

A bundled VOS rate and the option to unbundle the rate into separate components increases the complexity of the VOS program design and administration. The limited experience of utilities with VOS programs to date in Austin, Texas and Minnesota has indicated an avoidance of both of these options in favor of keeping a single, bundled rate. As more experience is gained, the concepts of bundled rates and separating components may be worth assessing to see if they help meet VOS rate design goals.

[27] This concept is akin to the potential future of unbundled rates for electricity consumption in which some electricity components are separately purchased. For example, a home with on-site battery storage may not need firm capacity from the utility, and avoids a demand charge, but may need ongoing energy to charge the storage and to provide emergency backup power.

[28] REC ownership appropriation under net metering varied significantly across states from utility-owned to customer-owned to a hybrid approach, sometimes differentiated based on whether an incentive was provided by the utility. Under a VOS mechanism, a similar determination will need to be made. If an environmental value is included in the VOS rate, this is a strong indicator that the utility is purchasing the RECs from the generator in the transaction. The contract likely will make ownership explicit, whether bundled or otherwise.

### *Future Value (or Cost) Components*

A VOS program could also be designed to be flexible, with a built-in option to reconsider the value or cost components and the opportunity to add or subtract components in the future. In order to assure investors that the VOS rate will not vary substantially more or less every year, the intentions of these updates should be made clear prior to execution. For example, the use of smart inverters to provide distributed grid support, such as voltage and VAR power support, may become more common, and a new component associated with this value may become desirable.

In a similar vein, variable generation integration costs could potentially increase in areas with high deployment. Smart inverter and battery operations could also be optimized to provide targeted value to the electricity system and system operator or owner. How these technologies translate into the VOS price signal and rate structure can get complicated quickly. Considerations include how these new costs and benefits are valued, whether the components are considered to be a new add-on to the existing VOS rate or whether the rate is updated, and the timeframe during which these changes will occur. It is important to balance the countering complexities that would be introduced by these changes, and to consider the potential impacts on capital availability (i.e., increased risk to the investor likely will increase the cost of capital and could decrease the number of investors).

### *Rate and Contract Adjustments over Time*

The VOS rate components (i.e., energy, capacity, etc.) are calculated and set at a distinct point in time. Some of the components are monetized in real-time as solar is generated (e.g., energy), while others have a lag in realizing the real dollars saved (e.g., infrastructure deferral). In utilizing bundled VOS rates, the utility is paying for all value up front. In theory, unbundled rates would offer the capability to pay varying components based on the realized dollars at varying points in time. Practically, this would likely prove excessively complex and costly on the administrative side. It could also discourage investment by third-party investors who require greater certainty in their returns.

The VOS component values can also be recalculated at various intervals based on updated analysis. The frequency of the update could have up- or down-side costs for the utility or the participant. For example, Austin Energy's VOS rate was set at 12.8 ¢/kWh in 2012 when it was first enacted, but fell to 10.7 ¢/kWh in 2014 based on natural gas price changes, but the trend could go the other direction just as easily based on category cost factors (CPR 2013). Financing a solar installation under this design could prove more difficult due to the potential variability and associated uncertainty, neither of which are favored by investors.

The VOS rate can be levelized (reflecting the long-term value of the resource addition as a fixed value over time) or annualized (showing annual changes in value over time) based on, for example, anticipated system performance and the discount rate. The high-case VOS rate could be fixed at 11 ¢/kWh over 20 years on a levelized basis. Alternatively, the rate could start at 7 ¢/kWh in Year 1 and escalate to 18 ¢/kWh in Year 20, for example, and be equal with regards to the net present value basis (Figure 8). A contract could still range from one to twenty years with these varying payment structures written into the contract. Over long-term contracts, there are other options, such as front-loading, that represent the same real-dollar amount.

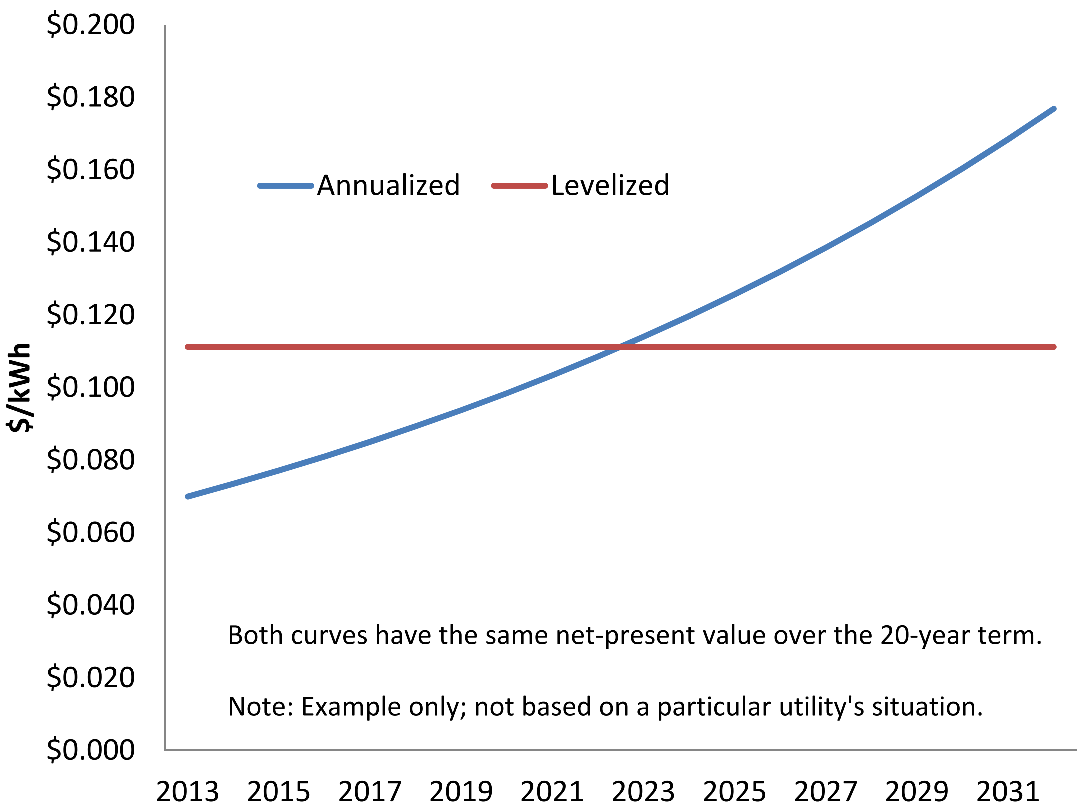



**Figure 8. Example of annualized versus levelized VOS rate**

Whether the VOS rate update is applied to existing participants or only to new participants depends on the contract period and terms used. For practicality, customer contracts could be set to match the frequency of the VOS rate updates (short duration). Alternatively, the contract could match the expected life of the PV installation. Developing a fixed VOS rate over a 20-year period would create a class cohort of participants ("2014 vintage") and a portfolio of contracts at varying parameters. Shorter update periods would more accurately reflect the actual value to the utility system by removing the long-term uncertainty of modeling assumptions and distributing the risk between the utility and the participant. While shorter valuation periods create more technically accurate values, longer contracts lessen the unknowns to the participant and the project investor because the utility takes on greater risk. Participants and their investors likely prefer longer contract periods that lock a customer into a 'vintage' of a VOS rate since this reduces uncertainty that can translate into predictable costs, particularly with project financing. However, over such long time periods, market conditions and the actual VOS realized can change drastically. Austin Energy and the Minnesota process represent the bookends of these decisions, the former varying annually and the latter fixed for 25 years. An alternative between the extremes would be medium term contract intervals, such as five or ten years; a medium term may balance the risk between customers, utilities, and market uncertainty.

### *Rate Differentiation Options*

The limited experience to date includes a single, bundled rate for all eligible participants, showing a preference for a basic, streamlined VOS rate design. However, numerous options could include the development of two or more rates based on localized factors that materially impact the costs or benefits of the value categories. Historical FIT design created different rates based on solar installations costs (Couture et al. 2010; EIA 2013b). Larger solar system owners enjoyed economies of scale and were typically offered lower FIT rates than residential systems, while ground-mounted systems were offered lower FIT rates due to lower presumed installation costs than roof-mounted systems. The goal of this policy design is to make the rate of return consistent across a variety of project sizes and locations.

In a VOS construct, differentiation among rates might make sense if these differences are based on issues that materially change the value of the solar energy to either the utility system or to society. This means that roof-mounted versus ground-mounted systems or ownership types are likely immaterial to the value proposition. However, PV located in electrically congested urban centers is likely more valuable than PV in less constrained suburban areas. A utility could give differentiated VOS rates for different ownership types, but that decision would need to be justified through calculated value or cost differences. Some of the indirect installation details could be included as part of eligibility criteria, rather than being managed through differentiated rates.

One option that likely does influence VOS categories is the time of performance, which could be either intraday, daily, or seasonally. A utility's costs of energy, capacity, or other components vary by the time of delivery. In a similar fashion, system configurations like panel tilt or azimuth, and whether tracking mechanisms are utilized, are actually proxies for intraday performance characteristics related to energy and capacity benefits that vary based on time. However, the benefits (from an alternative VOS rate) that a customer receives for solar system configurations that sync performance with the utility system would need to compensate for any potential loss in revenue caused by reduced system performance. If a PV system will lose 5% in annual performance and gain only 2% from an alternative VOS rate, it may not warrant changing the system configuration.

Program design might also look at locational differences beyond a single, system-wide price. For example, regional price differences might exist across wholesale locational marginal pricing nodes that may change the energy value. In a similar fashion, certain regions or even distribution feeders may have different amounts of solar penetration or demand patterns that increase costs or value based on locational or other characteristics.

To reiterate, creating multiple or unbundled VOS rates based on different value or cost streams to the utility system is certainly possible. However, the benefit of more technically accurate and granular information may be balanced against the administrative costs of calculating and managing more complex programs, as well as communicating the program complexities to consumers. Cost or value sensitivity analyses could be performed on the candidate design options to assess the magnitude of change and then applied to likely consumer behavior based on the value spread.

The summary of the VOS rate options is shown in Table 9 below.

**Table 9. Summary of VOS Rate and Contract Options**

| Category | Options |
|---|---|
| VOS structure | • Buy all electricity for consumption, sell all solar generation under VOS tariff<br>• Buy net electricity for consumption, sell net excess solar generation under VOS tariff |
| Number and kind of rates | • Single or multiple, bundled rates<br>• Single or multiple, unbundled rates |
| Future VOS categories | • Consider future new value or cost categories, calculation, management and transition |
| Adjustments over time | • Compensating unbundled VOS categories at different points in time<br>• Levelization versus annualization of the VOS rate in the customer transaction<br>• Frequency of recalculating the VOS rate<br>• Length of contract<br>• Present value of the contract |
| Time of generation | • Time of day<br>• Daily<br>• Seasonal<br>• Panel orientation<br>• Fixed versus tracking capabilities |
| Locational differences | • Single, system-wide price<br>• Regional price variation based on utility costs or value (i.e., congestion)<br>• Individual, types or categories of distribution feeder pricing |
| Indirect value options | • Customer segments<br>• Rate tariff types (demand, three-phase, etc.)<br>• Solar project size<br>• Ownership type (customer, third-party, etc.)<br>• On-site location (roof, ground, etc.) |

**Text Box 3. Design Application: Rate and Contract Treatment**

Utility B decided to utilize PV systems as generating capacity tools by using multiple rates for both time of day performance and smart inverter control capabilities—while recognizing that optimal implementation will not be realized on day one. Utility A kept things simple, employing one rate, but added a bonus VOS category for distribution grid congestion relief areas, which may change over time (hence, creating a flexible adder and not a permanent rate). Each utility took a different approach on contract period (5 or 20 years) and how frequently the VOS rate is updated (annually versus a typical 2-3-year cycle with integrated resource planned). Both use a levelized rate, but Utility B also included an inflation adjustment.

**Table 10. Summary of Rate and Contract Application by Hypothetical Utilities**

| Category | Utility A | Utility B |
|---|---|---|
| **Number and kind of rates** | Single, bundled rate | Multiple, bundled rates<br>* Standard rate<br>* W-SW rate<br>* Smart inverter rate |
| **Future VOS categories** | NA | Consider how VAR, voltage, and curtailment adders could be implemented in a future VOS tariff |
| **Adjustments over time** | Levelized, 20 year contract<br>Updated with IRP cycle | Inflation adjusted, levelized, 5-year contract<br>Updated annually |
| **Time of performance** | NA | Capacity value for projects that are oriented at 225-270 degrees |
| **Locational differences** | 10% VOS bonus on feeders that need generation/congestion relief (highlighted on website) | NA |
| **Indirect value options** | NA | NA |

## 5.4 Potential Additional Price Support

Based on the previous analysis of the potential differentials between the VOS rate and the LCOE-PV, many locations currently will be in price-support markets where the VOS is less than the LCOE-PV. If one of the program goals is to sustain existing markets or create new solar market activity, an additional incentive of some kind may be necessary.

Why would a utility want to offer an incentive in addition to the VOS tariff?

- Provide solar market stability in transition from NEM to the VOS mechanism
- Provide a multi-year transition to an incentive-free VOS rate
- Adopt a compromise position with stakeholders during the transition to a VOS program

- Provide an explicit incentive amount on top of the VOS rate that is transparent to all stakeholders.

Obviously, a transition incentive represents one option, and the details of whether and how to offer an incentive depends on the solar and utility market conditions, the state policy and regulatory conditions, the nature of the utility's relationship with stakeholders, and the short- versus long-term goals of the transition process.

Assuming there are compelling reasons to add transitional price supports to a VOS rate, the goal of rebates or production incentives over a multi-year transition period might be to fill the gap between the VOS and LCOE-PV. There is a long programmatic and research history of incentive programs, and this report will not reiterate all of the options and best practices in incentive program design.[29] Generally speaking, the incentive program could be structured to encourage cost reductions and efficiencies in solar installations over time, much like California's incentive programs did with both their performance and rebate incentives. However, a number of incentive categories do deserve further discussion in the context of a VOS program.

### *Incentive Benchmark*

If a jurisdiction decides to transition from its current policy construct to a VOS policy, that transition will have the greatest chance of success if it is carefully structured and clearly conveyed in advance. Setting the initial incentive to complement the VOS rate will require a target benchmark, which can be determined using a variety of approaches.

First, the benchmark can be a recreation of the NEM *status quo*, either relative to the LCOE-PV or an alternative measurement like retail rates. Using either can create nuances in design that could be weighed and considered with earlier decisions regarding eligibility or payment amounts. Setting the incentive to recreate the NEM *status quo* means different things to different customers. The VOS could be higher than retail energy rates for commercial customers but lower than the LCOE-PV, improving market conditions for this segment (compared to what was offered under NEM). For residential customers, the VOS is more likely to be below both retail rates and LCOE-PV. If the goal was to recreate the NEM financial *status quo*, the commercial customers may not need an additional incentive, but residential customers could. However, if the incentive was benchmarked against the LCOE-PV and both customer segments were eligible, an incentive might be calculated as necessary, but at different payment levels for residential versus commercial customers. Note that this implies that although the VOS rate may not be differentiated by size or customer type, the incentive amount may be, depending on the utility's transition goal and VOS program rules.

In addition, if the benchmark is the LCOE-PV, the incentive level may consider known and unknown federal and state policies that may change in the future, such as the federal ITC. The ITC drops from 30% to 10% for commercial and third-party residential installations and to 0% for customer-owned residential installations on January 1, 2017 (DSIRE 2014a). If the NEM *status quo* was used as the benchmark, the incentive program is not tied to external market changes that would occur regardless of the NEM-VOS transition.

[29] Notable papers for incentive program design reference include Bird, Reger, and Heeter (2012) and Couture et al. (2010) (Table ES-1 in particular).

### Incentive Type

The incentive itself also could be structured as either a performance incentive (¢/kWh) or capacity incentive ($/W or % costs). In order to compare the two and understand the potential value, the capacity incentive could be converted by program administrators into a net present value in ¢/kWh (in practice it would be administered using the capacity structure).

Historically, incentives consisted of a one-time upfront payment, such as a $2/W rebate, a payment based on actual performance over a fixed time period, such as a 10 ¢/kWh for 5 years, or a below-market interest loan or buy-down, such as reducing a solar loan rate from 5% to 2.5%. Outside of the VOS conversation, rebates were initially popular with utility and state program managers in the 2000's, especially with the residential segment. But performance incentives have increased in popularity at the commercial and, increasingly, residential scale. Performance incentives appeal to program managers because funds are only dispersed for actual solar production, but there are higher transaction costs in meter reading, billing, and payments. In the context of VOS, performance incentives probably align more easily with the VOS rate, both being paid per kWh.

### Incentive Reductions

Once the initial incentive is set, there are a variety of ways to both trigger a reduction and to determine the amount of the reduction. These methods parallel past incentive program experience and include market targets such as installed amounts of capacity (e.g. California Solar Initiative), achieving certain metrics on the LCOE-PV or the installed price, or alternatively, simply stepping down a certain amount at fixed time intervals. Time intervals provide predictability, but if the market shifts more rapidly than planned, such as through a rapid solar panel cost reduction period, incentives may be larger than needed to encourage new projects. Using capacity as the metric will step the incentive down once a pre-determined amount of capacity is installed, and will change more quickly if the installations are more rapid than anticipated.

The goals are to aim for transparency and predictability and to include sufficient lead times for the solar industry to adjust. Depending on the benchmark, it will be important to the solar industry to have a standard, defined method and readily available data sources that can be used to calculate the initial and future incentives. A summary of VOS incentive options is shown in Table 11.

**Table 11. Summary of VOS Incentive Options**

| Category | Options |
|---|---|
| Incentive benchmark | • Equivalent to pre-VOS NEM financial *status quo*<br>• LCOE-PV benchmark<br>• Plan for non-VOS market changes, such as federal or state policy (if known) |
| Incentive type | • Upfront payment ($/W)<br>• Performance-based incentive (¢/kWh)<br>• Below market interest loan or buy-down |
| Incentive reductions | • Aim for transparency and predictability with lead times<br>• Reduce incentives based on achieving a certain LCOE-PV, installed capacity, installed price, known time periods<br>• Reductions can occur in percentage, whole number, or other bases<br>• Adjustments can be made on pre-determined schedule or certain number of days following event (announcement, approval, etc.) |
| Incentive differentiation | • Project size<br>• Customer segment<br>• Technology<br>• Time of delivery |

**Text Box 4. Design Application: Price Support**

Utility A is in a price-support market, and therefore utilized an incentive through an upfront rebate. Utility B does not require an incentive because it is in a price-competitive market. Utility A opted to calculate the incentive such that the NEM-to-VOS transition should have no net effect on the pre-VOS localized market activity, but planned for quarterly adjustments as prices or non-utility incentives change. The rebate is calculated as the present value (PV) of the summed difference between the VOS tariff and the LCOE-PV over 20 years of performance (the present value of the difference between the VOS tariff and the LCOE multiplied by the annual production of the system over the 20 year term of the program). To manage unexpected price declines, the incentive is capped at a percentage of installed costs. The utility will need to plan for the large change in required incentives if the federal ITC is not renewed and for the transition period when the VOS tariff approaches the LCOE-PV, and decide whether to increase the incentive to fill the gap and maintain market growth targets.

**Table 12. Summary of Price-support Application by Hypothetical Utilities**

| Category | Utility A | Utility B |
|---|---|---|
| **Incentive benchmark** | Incentive required to generate market for 20 MW of installations, which was the pre-VOS activity | No incentive required |
| **Incentive type** | Rebate | NA |
| **Incentive reductions** | Modify incentive level quarterly based on forecast targets for annual market growth of 15% until VOS tariff reaches LCOE-PV | NA |
| **Incentive differentiation** | Incentive capped at % of installed costs | NA |

## 5.5 Administrative Issues

There are a number of administrative issues that can position a VOS program for success, and they are best considered as the program is built and deployed. These include a transition plan, accounting issues, and stakeholder engagement.

### *VOS Transition Plan*

Transitioning from a current solar tariff rate (most likely NEM) to a VOS rate would require advanced planning, both internally within the utility and externally with stakeholders.

#### *Contracts and Materials*

A VOS program contract could be developed that outlines the product being purchased as well as pricing structure, contract length, and other details. Existing power purchase agreements and portions of the NEM contract—as well as external examples from other VOS or feed-in tariff programs—could provide a basis for developing the contract. Historically, length and complexity of NEM contracts and interconnection agreements have been a barrier to participation and a point of contention for some solar stakeholders. This concern could be addressed through the design of the VOS program contract process. Doing so could reduce the possibility of potential participants feeling intimidated or overwhelmed by the more technical and complex contract document. It could also help reduce the transaction costs of explaining and answering questions about the contract to hundreds—or even thousands—of potential participants.

In a similar fashion, interconnection agreements may need to be updated if the point of interconnection changes from the customer to the utility side of the meter. This may also lead to changes in interconnection requirements and the way interconnection requests are processed within the utility.  Proposed changes to existing interconnection policies may also create the need for additional dialogue between the utility and the solar industry.

### *Communications*

The utility may want to consider communicating with separate audiences during the transition period:

1. **Customers**: The website, call center scripts, and other materials likely will be updated to communicate the program changes. Especially in the case of residential rooftop solar customers, simplicity and transparency in VOS program implementation may be crucial.
2. **Solar industry**: The solar industry may desire more detailed information on program details or training through workshops, presentations, or other outreach events. Time spent upfront on education will likely pay dividends in reduced customer service due to confusion and fewer program material revisions.
3. **Public notice**: New electric rates sometimes require public notice through billing inserts, public meetings, or other means of communication.

New program marketing materials could  be developed to support these communication efforts. The utility could consider reviewing all existing materials, print or online, to remove legacy references or materials to NEM.

### *Timing*

Depending on the level of stakeholder involvement, regulatory process, or public notification requirements, the program may or may not be well advertised outside of the utility. The program can be implemented over a variety of time periods, and can become available for participant registration either immediately or on an announced date in the future. A defined transition plan to the new VOS program could be clearly laid out, but may represent a complete switch from NEM to a VOS mechanism, or the two programs could run in parallel during a transition period or even on a permanent basis.

## *Cost Accounting*

While the VOS rate is determined based on the benefits of distributed solar to the utility, there are a variety of costs to be allocated and accounted. They fall into two general categories, addressed below.

### *Administrative and Management Costs*

Typically, administrative and management costs are rolled into normal utility business accounting unless the utility has a renewable energy cost recovery adjustor. In theory, the program administrative costs could be initially estimated and later calculated and subtracted from the VOS rate. However, this method would be atypical of normal electric utility accounting practices, in which similar costs are socialized across all ratepayers.

#### *Interconnection and Metering*

Interconnection and metering costs may be based on legacy NEM practices to allocate costs between the utility and the solar developer. If the interconnection point or process substantially changes because of the change to VOS, such as new code, metering changes, performance monitoring, or study requirements on the utility side of the meter, these costs could be revisited to determine the appropriate costs and benefits. For example, the base requirements for solar metering may be the responsibility of the customer, but any enhanced or upgraded costs for a more sophisticated meter or communication based on the VOS tariff may be the responsibility of the utility. This is one example – there are many other variations that could be considered.

### *Stakeholder Interests*

Stakeholders will approach a VOS program from different perspectives; each will have unique objectives driven by their organization's needs. Table 2 listed the objectives and concerns for a wide variety of stakeholders, including the utility, PV generating customers, non-solar customers, policy makers, the solar industry, and society. That table focuses specifically on policy goals and concerns. Four main VOS policy themes emerged: 1) pay the utility sufficient revenues for grid services provided to support solar growth, 2) recognize the VOS benefits and costs, and compensate the project owner appropriately, 3) limit cost to customers, both those with solar and those without, and 4) create a transparent VOS rate calculation methodology. These themes could be used not only as policy goals, but also policy design principles.

The approach to program design and the transition implementation may include internal decisions specific to the utility, as well as broader decisions made collaboratively with customers, the industry, and other stakeholders. Some elements may take effect immediately while others may be transitioned in over a predetermined timeframe. Utilities and other decision makers[30] will need to assess the approaches taken and recognize both the technical and political nature of key design elements in order to select the most appropriate approach for each decision point.

Understanding core stakeholder interests and cross checking design decisions against them is an important approach to predicting reactions and guiding design in order to achieve desired outcomes. An obvious example is a scenario in which a utility is implementing a VOS tariff that is significantly lower than the *status quo* net metering retail rate, and then announcing finalized program rules without industry or consumer consultation. Clearly, there may be negative reactions in this situation.

In the end, each jurisdiction will need to determine which stakeholder-driven policy goals will influence VOS policy design principles and how. Most importantly, each stakeholder group involved in formulating a VOS program can voice their opinions to help prioritize its design

[30] "Decision makers" refers to state commissions regulating investor-owned utilities, city councils overseeing municipal utilities, boards of directors overseeing cooperative utilities or public utility districts, or similar authorizing jurisdictions.

principles to make sure the most important goals are adequately addressed. Thus, it is critical to consider stakeholder interests both when deciding on policy goals and also during the policy design phase. Table 13 summarizes VOS administrative issues.

**Table 13. Summary of VOS Administrative Issues**

| Issue | Options |
| --- | --- |
| Transition plan | • Contracts and materials would be developed for VOS tariffs<br>• Create communications plan to serve varying audiences<br>• VOS program can be implemented immediately or over time, potentially in parallel with the NEM program on a transitional or permanent basis |
| Interconnection - side of the meter | • Customer side of the meter<br>• Utility side of the meter |
| Interconnection and administrative cost accounting | • Administrative costs are likely to be spread across all ratepayers barring precedent or regulatory decisions otherwise<br>• Interconnection and metering costs can follow existing allocation practices unless there are material changes in requirements, process, and costs |
| Stakeholder engagement | • Stakeholder interests across the utility, solar industry, and regulatory communities will be different and can be assessed together<br>• Engaging openly and early during the VOS program design process will enhance transparency |

**Text Box 4. Design Application: Administrative Issues**

Utility A and B both planned for a 6 month transition plan, but took a different approach to existing PV systems. Utility A plans to move all customers to the VOS rate, but created a one-year process for existing solar customers for education and adoption. Utility B is grandfathering existing NEM customers (who will stay on the NEM tariff). Both utilities also opted for interconnections for residential customers on the customer-side of the meter and to provide bill credit (not kWh credit), to avoid taxable income for customers. This simplifies some of the transition needs because interconnection requirements, billing arrangements, installer education needs, etc. mimic NEM processes. Utility B did differentiate between larger systems by interconnecting on the utility-side of the meter in order to align with its intention of owning the smart inverters. This unique arrangement will require deeper thought and engagement within the utility and with the solar stakeholder community on costs, risks, and liabilities; hence Utility B is forming a stakeholder working group to discuss and address these issues. Related, Utility B is covering interconnection and metering costs, while Utility A customer pays a flat interconnection fee. Administrative costs for Utility A are subtracted for the VOS rate to recover them, while Utility B absorbs the costs internally.

**Table 14. Summary of Administrative Issues Application by Hypothetical Utilities**

| Issue | Utility A | Utility B |
|---|---|---|
| **Transition plan** | 6-month notice<br>Applies to all customers<br>Existing NEM customers given 1-year transitional period with bill comparisons | 6-month notice<br>Grandfathering existing NEM customers |
| **Interconnection – side of the meter** | Customer side of the meter<br>All transactions are a bill credit | Utility side of the meter > 10 kW<br>Customer side of the meter < 10 kW<br>All transactions are a bill credit |
| **Interconnection and administration cost accounting** | Customer pays flat interconnection fee<br>Other programmatic administrative costs are subtracted from the VOS rate calculation | Utility owns smart inverters<br>Utility pays for interconnection and metering costs |
| **Stakeholder engagement** | Utility develops proposal and incorporates stakeholder comments | Stakeholder working group actively develops plan over 6-month period |

# 6 Analysis Synthesis

The success of VOS tariff implementation will be as dependent upon the program design and structure as it will be on the VOS tariff calculation itself. After providing some key background about the policy, how it relates to existing policies, and the implications of a VOS program for current incentive structures, this report explored various considerations in VOS program design, the implications of the variety of choices, and the potential impact of some of the major components. In the end, jurisdiction-specific input assumptions and market considerations will factor into the design and tariff calculations of a VOS tariff program. While this report does not address the details of any one jurisdiction-level program design, it does help frame the broader decisions and implications that require deliberation.

Specific lessons learned from the existing VOS program in Austin, Texas as well as the VOS policy under development in Minnesota include:

1. Stakeholder involvement and/or transparent VOS calculation methodologies are important for customer and regulator support
2. VOS rates can be an alternative to NEM; cross-subsidies can be addressed by decoupling payments for DGPV generation from the retail rates paid by the customers (e.g., "buy-all, sell all" transactions)
3. The VOS rate in addition to federal incentives are generally not sufficient to encourage additional solar deployment using incentives and electricity prices available today; an incremental solar incentive may be needed–although such a subsidy may be able to ramp down quickly if technology and installation costs continue to decline
4. Rate variability creates uncertainty. In order to create a self-sustaining market, it may be helpful to set a minimum rate as part of VOS tariff design.
5. Third-party solar leases may be compatible with a VOS tariff, if local rules allow
6. Customers can benefit from accumulated solar credits that can be rolled over indefinitely.

Effective VOS program design would encompass the nuts and bolts of how participants (e.g., customers, solar companies, project developers, etc.) access the VOS rate, answering questions such as:

1. What are the overall design philosophies, objectives, and tradeoffs between stakeholder interests?
2. What are the eligibility and installation rules and details for participation?
3. What are the rate and contract terms implemented for a long-term program?
4. Is the VOS rate sufficient to support solar development, given the current market and available incentives? Will a separate price-support mechanism be required to stimulate or sustain solar development?
5. How are stakeholders involved in program development input?
6. How might program design component change as the solar market changes?

Within the realm of program design, the authors explore four major design areas, and discuss a number of individual design considerations available under each, shown in Table 15:

**Table 15. VOS Program Considerations**

| Installation Details | Rate Options | Incentive Options | Administrative Issues |
|---|---|---|---|
| • Eligible participants<br>• Individual project size<br>• Aggregate program size<br>• Technologies<br>• Supporting technologies or system configurations<br>• Performance<br>• Interconnection | • Number and kind of rates<br>• Future VOS rate categories<br>• Adjustments over time<br>• Time of performance<br>• Locational differences<br>• Indirect value options | • Incentive benchmark<br>• Incentive reductions<br>• Incentive differentiation | • Transition plan<br>• Accounting<br>• Stakeholder engagement |

Utilities can, to some extent, draw on experiences from managing other programs that support solar, including NEM programs and other incentive programs such as rebates. However, several areas are unique to the new market transaction structure that a VOS tariff represents. For the jurisdictions that have a combined goal of maintaining a robust solar market and that moves solar from a position of price-support to price-competitive, VOS program designs will require sufficient flexibility to ensure that the utility can maintain market growth without paying more than required for sustained PV deployment.

In configuring a VOS tariff that benefits all stakeholders, decision makers may include some of the factors that have emerged in recent negotiations:

1. Compensating solar customers for generation from their systems and compensating utilities for solar-supporting grid services, while ensuring that utility revenue requirements are met,
2. Recognizing the VOS to the utility system and society,
3. Limiting costs to solar and non-solar customers,
4. Creating a transparent VOS calculation methodology.

A calculation was performed in order to compare a national-level average VOS tariff, with state-level LCOE-PV for each state, as shown in Figure 9. The goal of this high-level analysis was to determine how many markets in the United States are price-support markets (LCOE-PV > VOS tariff, where additional incentives are likely needed), transitional pre-economic markets (LCOE-PV ~ VOS tariff, where few incentives are likely needed), or price-competitive markets (LCOE-PV ≤ VOS tariff, where the VOS program design shifts away from incremental incentives). As shown in Figure 9, the combination of the VOS rate and the incremental incentive will determine whether the VOS rate, plus incentives, is high enough to cover the LCOE-PV, and encourage continuous distributed solar project development. For any particular jurisdiction moving ahead with a VOS rate and program, this calculation would need to be substantially refined to include those values relevant to the utility system and society (which could include generation value and environmental benefits), using local assumptions and an individualized calculation methodology This could occur through a public stakeholder process.

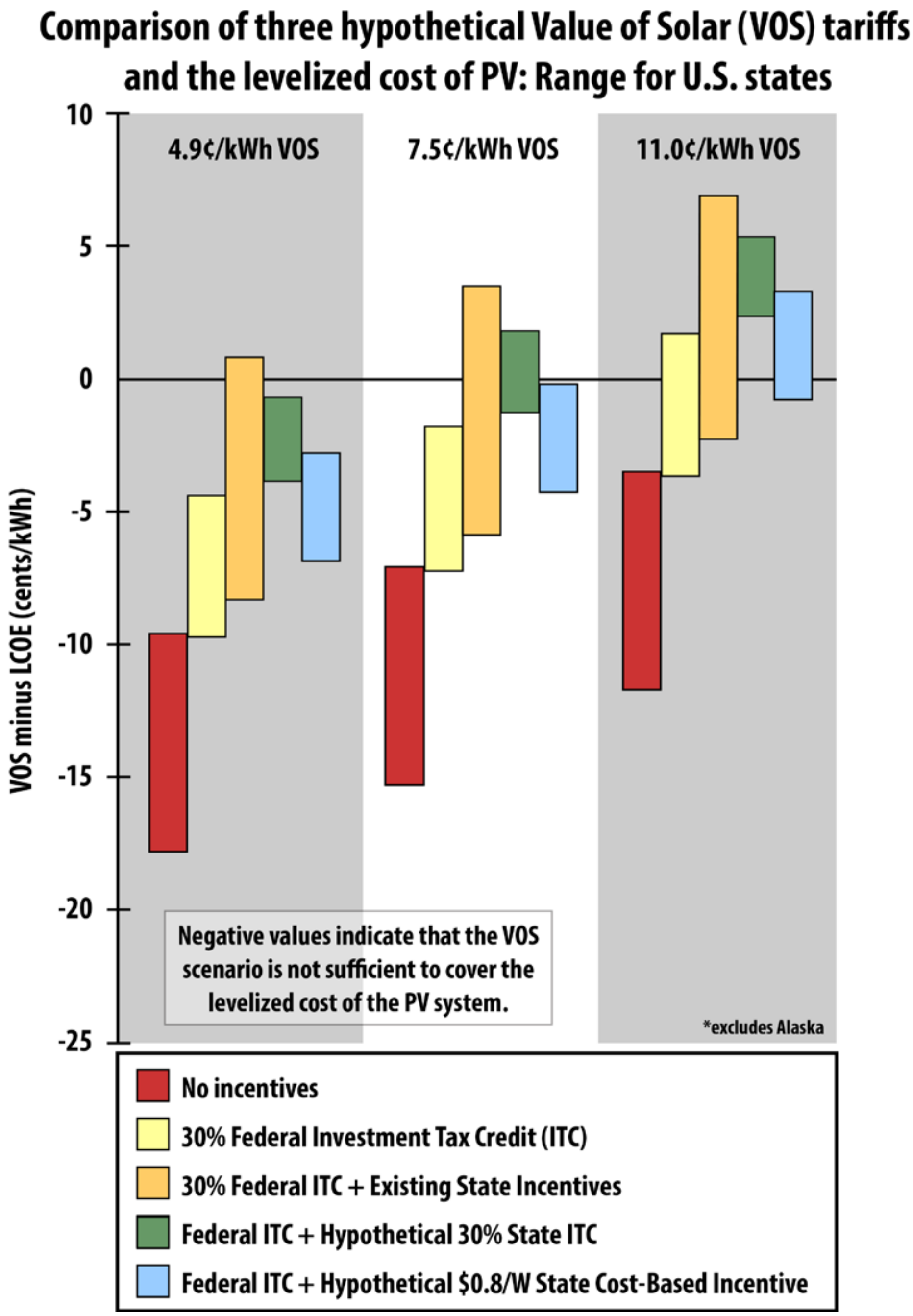



**Figure 9. Comparison of VOS and LCOE-PV**

Today's electricity markets have many more variables that impact the direction of market prices; as markets change dynamically over time and as new policies are investigated, policies that can account for both low and high DGPV penetrations will likely be sought out. With the costs of solar continuing to decline, VOS tariffs are expected to gain more attention as increasing levels of DGPV are deployed at higher penetrations. Given the diversity of markets, local methodologies for rate setting could vary extensively according to goals of decision makers (to encourage more solar growth or to simply value it), market conditions (non-economic, pre-economic, or grid-competitive), and other variables addressed in this report. Early feedback indicates that several key considerations can contribute to VOS program success, including thoughtfully considering new options, engaging stakeholders in discussions, laying out a path for transitioning from existing policies, limiting overall program costs, and creating transparent policy design and implementation. In the end, success will stem from a solid understanding of local market conditions, and how a new VOS policy can contribute to local policy objectives through thoughtful program design.

# Appendix A. Select VOS Calculation Analyses to Date

Several studies have examined the VOS to date. Below are the key calculation structures and takeaways from a few of these analyses.

### *A Regulator's Guidebook: Calculating the Benefits and Costs of Distributed Solar Generation*

*Keyes and Rábago 2013*

This guidebook was published by the Interstate Renewable Energy Council (IREC) to 1) assess lessons learned from the calculation methodologies assessed by RMI in the first edition of its meta-study, and 2) propose to PUCs a standardized cost and benefits calculation methodology for DGPV. The authors point out that their proposed calculation methodology is needed because of the lack of consistency and (sometimes transparency). As summarized by IREC, in San Antonio and in Arizona, utility-led calculations were well below solar industry's estimates of the VOS. The IREC-proposed DGPV calculation methodology focuses on VOS that can be used by a variety of policies including NEM, VOS tariffs, fixed-rate feed-in tariffs, or incentive programs. It suggests some key considerations including:

1. **DG discount rate** based on inflation instead of the utility cost of capital
2. **Only consider DG exports to the grid** instead of total generation produced. Applied to VOS rates, this would mean on the net exported to the grid would receive the VOS rate
3. **Study timeframe** of 30 years--5 years longer than equipment manufacturers' warranties
4. **Utility load** is likely to be lower with behind-the-meter resources
5. **A range of DG market penetration** should be considered, including expected, high, and low
6. **Transparent input models** accessible to all stakeholders are important and non-disclosure agreements can be signed for data sharing sensitivities
7. Characterize the **broader geographical area** selected for the study to account for the range in local values
8. Consider **adjacent utility systems,** especially at DG penetrations above 10%
9. **Multiple perspectives of benefits and costs** should be considered, including utility rate impacts and societal benefits and costs
10. **Levelized approach** to estimate benefits and costs
11. **Utility-provided inputs,** both for current and future data could be required as input assumptions, including:
    A. 5-10 year price of natural gas
    B. Customer class-based hourly load shapes
    C. DG hourly production profiles
    D. Hourly line losses
    E. Capital cost, fixed and variable O&M for the utility's marginal units

i. Distribution system planning upgrade costs (capital, fixed and variable O&M)

ii. Individual distribution circuit hourly load data.

IREC suggests that there are several main components required to properly calculate a VOS rate, including:

- Avoided energy benefits
- System losses
- Avoided capacity
- T&D capacity
- Grid support (ancillary) services
- Financial services: fuel price hedge or guarantee
- Financial services: market price response
- Security services: reliability and resiliency
- Environmental services
- Social services: economic development.

In the end, IREC has three major conclusions that are likely to have the largest impact on the calculation of VOS rate:

1. Distributed solar generation (DSG) primarily offsets combined-cycle natural gas facilities, which can be reflected in avoided energy costs.
2. DSG installations are predictable and can be included in utility forecasts of capacity needs, so DSG can be credited with a capacity value upon interconnection.
3. The societal benefits of DSG policies, such as job growth, health benefits, and environmental benefits, can be included in valuations, as these were typically among the reasons for policy enactment in the first place.

### Methods for Analyzing the Value of Distributed Photovoltaic Generation

*Denholm et al. 2014*

This report examines the variety of ways to estimate the value—the costs and benefits—of DGPV. Previous value estimates assumed low DGPV penetrations (and other aging assumptions); moreover, previous methods for valuation are becoming inadequate for analyzing today's electricity systems. First, existing methods for calculating DGPV value are assessed. The authors examine the input data assumptions, calculation methodologies and tools available to conduct VOS estimates, term by term. Next, how these methods could evolve with increasing DGPV is discussed—which could require improvements in data, tools, and transparency as well as a higher level of effort and expense. Finally, gaps in current value-analysis capabilities are identified. Methods for analyzing PV value were considered by E3 in California, CPR in Minnesota, and in RMI's second edition meta-study (Hansen, Lacy, and Glick 2013). The methods range from the simple (quick, inexpensive, and requiring basic or no tools) to the complex (time consuming, expensive, and requiring sophisticated tools) for each of seven VOS term categories:

- Energy
- Emissions
- T&D losses
- Generator capacity
- T&D capacity
- Ancillary services
- Other costs and benefits.

No single tool or method can capture the interactions among generators, distribution, transmission, and regional grid systems, or the effect of DGPV on the long-term generation mix and system stability requirements. However, it is possible to envision a "full" DGPV value study in which these interconnected elements are considered, shown in Figure 10 (Denholm et al. 2014).

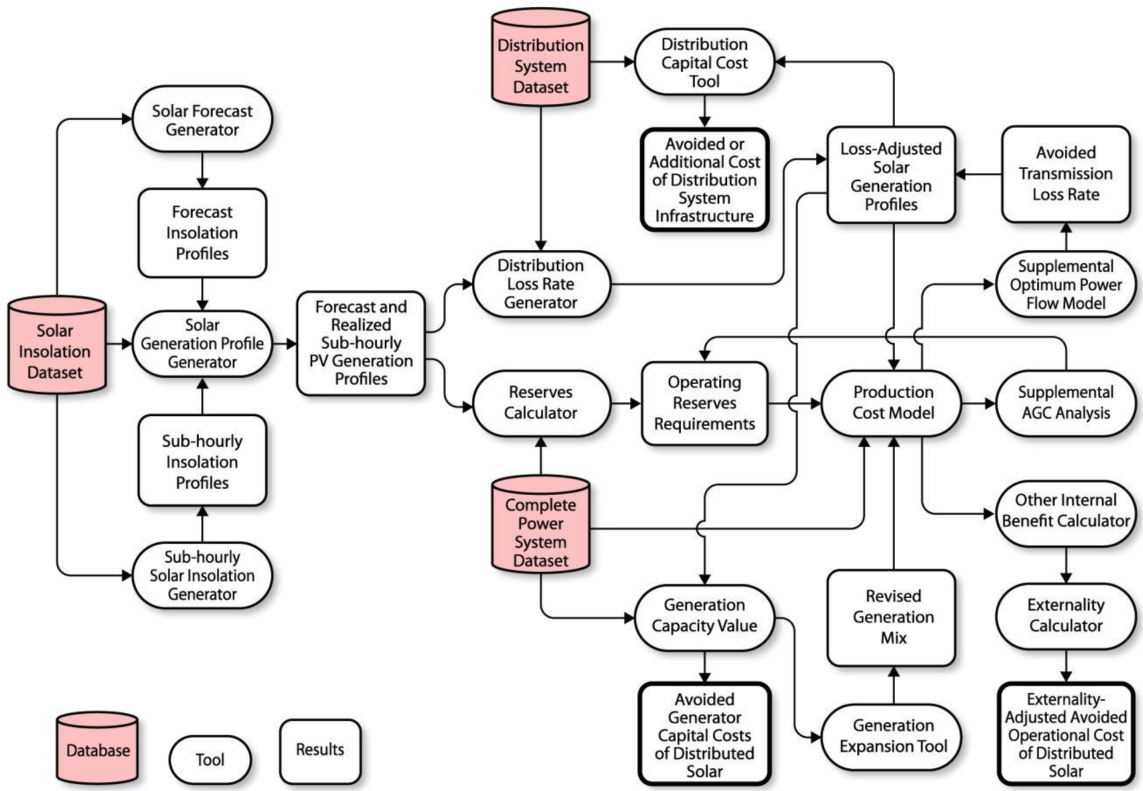



**Figure 10. Possible flow of an integrated DGPV study**

Source: Denholm et al. (2014)

## *A Review of Solar PV Benefit and Cost Studies: Second Edition*

*Hansen, Lacy, and Glick 2013*

RMI created a meta-study that reviewed 16 DPV benefit/cost studies (circa 2005-2013) by utilities, national labs, and other organizations. This second edition added an examination of the 2013 Xcel study in Colorado. According to RMI, none of these studies was comprehensive –and several acknowledged that some benefits and costs could be difficult or impossible to quantify.

For most studies, the overall approach and terms to include in the analysis generally appear to be in agreement, but the calculation methodology for distribution system value, grid support services, and unmonetized terms (e.g., financial risk, environment, and social value) have less agreement. As further clarified in the document, “there is a significant range of estimated value across studies, driven primarily by differences in local context, input assumptions, and methodological approaches…Because of these differences, comparing results across studies can be informative, but can be done with the understanding that results must be normalized for context, assumptions, or methodology” (Hansen, Lacy, and Glick 2013, p. 4). The results across all studies are shown in Figure 11.

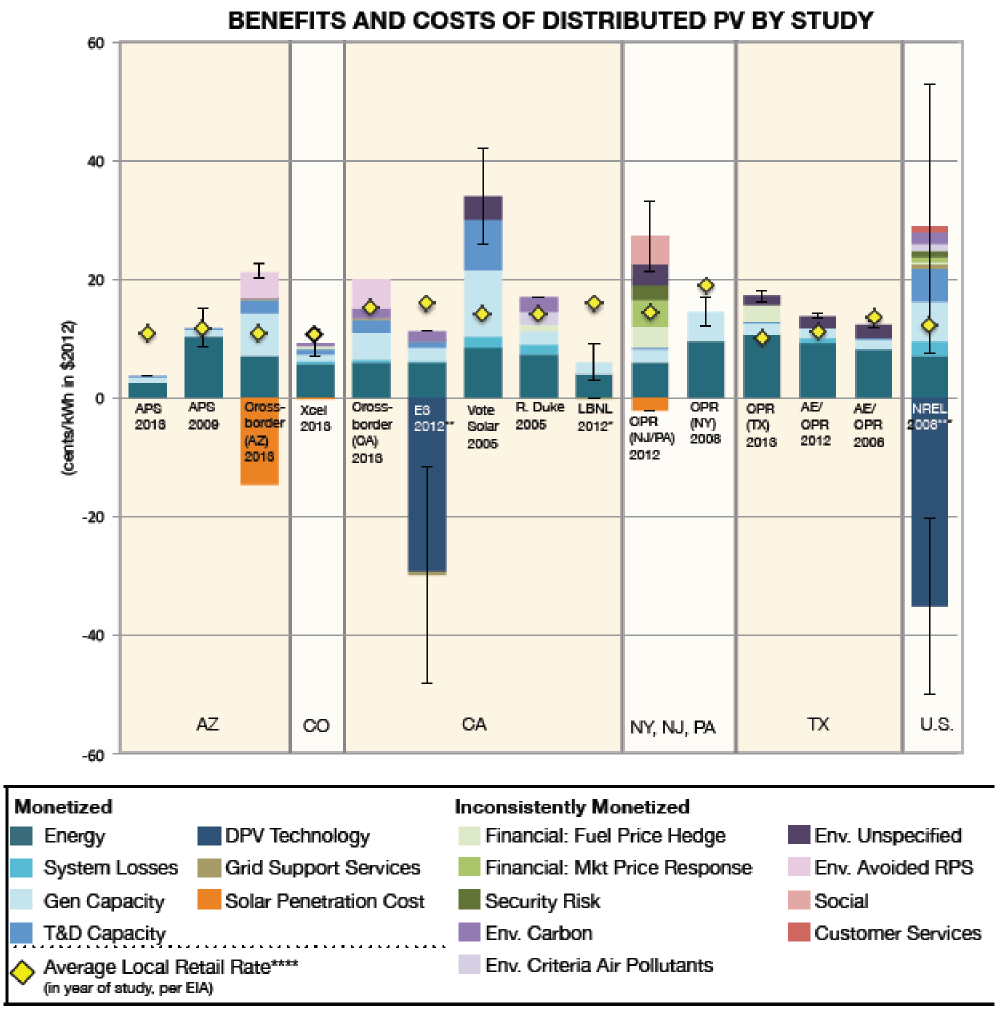



**Figure 11. RMI meta-study: benefits and cost of distributed PV, by study**

Original RMI Notes on the figure: *The LBNL study only gives the net value for ancillary services

** E3's DPV technology cost includes LCOE + interconnection cost

*** The NREL study is a meta-analysis, and not a research study. Customer Services, defined as the value to [the] customer of a green option, was only reflected in the NREL 2008 meta-analysis and not included elsewhere in this report.

****Average retail rate included for reference; it is not appropriate to compare the average retail rate to total benefits presented without also reflecting costs (i.e., net value) and any material differences within rate designs (i.e., not average).

Also Note: E3 2012 study not included in this chart because that study did not itemize results.

Source: Hansen, Lacy, and Glick (2013)

As shown, there are many different ways to perform VOS calculations. This is why it is critical for any jurisdiction contemplating a VOS policy to think about their prioritized policy goals so that the VOS program calculation and policy design can best achieve those objectives.

# Appendix B. VOS Scenario Calculation Assumptions

## Generic Assumptions

- Real discount rate – 7.5% (which leads to a nominal rate of 9.3%)
- Present value of accelerated depreciation – 78.4%
- Tax rate – 35% federal and 6% state
- Solar system life – 25 years
- Inflation rate – 1.8%
- Average system losses – 7%
- Reserve margin – 15%
- Displaced natural gas heat rate – 8,000 Btu/kWh
- Solar degradation rate – 0.50%/year
- Solar system year 1 capacity factor – 19%
- Effective Load Carrying Capability (ELCC) – 25%
- Nominal discount rate is used for all Present value calculations.

## Sourced Assumptions

1. CT overnight build costs - $910/kW (EIA Table 8.2 "Cost and Performance Characteristics of New Central Station Electricity Generating Technologies")
2. CT construction time – 2 years (EIA Table 8.2 "Cost and Performance Characteristics of New Central Station Electricity Generating Technologies")
3. Natural gas prices – EIA 2013 Annual Energy Outlook, Nominal delivered prices Electrical Power
4. T&D spend – Failure to Act The economic impact of current Investment Trends in Electricity Infrastructure – ASCE (sourced from EEI)
5. Annual retail sales in the United States – EIA retail sales of electricity for all sectors
6. 16 ¢/kWh for non-climate change factors and 1.5 ¢/kWh from carbon at the midpoint of $30/ton all in $2007 from natural gas generation (National Research Council 2010).

# Appendix C. VOS Tariff by Incentive Scenario

This table presents the difference between the three levels of VOS tariffs created for this analysis and the LCOE-PV, as calculated in 50 U.S. locations. The methodology for creating the hypothetical VOS tariffs, the incentive scenarios, and the assumptions that went into the calculation of the LCOE-PV for each location are detailed in Chapter 4 of the report. The LCOE calculations were done using NREL's System Advisor Model, version 2014.1.14, using input data for the most populous city of each state across the U.S. The results of the calculation for each location under each scenario are given in the rows of the table below. The names of the locations have been removed; this because it is not the intent of this report to provide analysis regarding the specific costs of, or market for, solar development in any particular location. Instead, the focus of this analysis is on the range of market types that might exist under three hypothetical VOS tariff levels, given current solar costs. The colors in the table indicate which market type results for each case. If the difference between the VOS and the LCOE-PV is well below zero (pink), there is a price-support market, if it is approaching zero (yellow) there is a transitional market, and if it is positive (green) there is a price-competitive market.

| **LEGEND** |
| --- |
| **Difference between VOS and LCOE of PV < 0** |
| **-3 < Difference between VOS and LCOE of PV > 0** |
| **Difference between VOS and LCOE of PV > -3** |

| WITHOUT INCENTIVES | | | 30% ITC (no State Incentives) | | | WITH 30% ITC + State Incentives as of Jan2014 | | |
|---|---|---|---|---|---|---|---|---|
| VOS-LCOE Differential | | | VOS-LCOE Differential | | | VOS-LCOE Differential | | |
| Low VOS 4.9 ¢/kWh | Medium VOS 7.5 ¢/kWh | High VOS 11¢/kWh | Low VOS 4.9 ¢/kWh | Medium VOS 7.5 ¢/kWh | High VOS 11¢/kWh | Low VOS 4.9 ¢/kWh | Medium VOS 7.5 ¢/kWh | High VOS 11¢/kWh |
| -22.19 | -19.63 | -16.11 | -12.55 | -9.99 | -6.47 | -12.55 | -9.99 | -6.47 |
| -17.83 | -15.27 | -11.75 | -9.70 | -7.14 | -3.62 | -8.35 | -5.79 | -2.27 |
| -16.30 | -13.74 | -10.22 | -8.76 | -6.20 | -2.68 | -8.15 | -5.59 | -2.07 |
| -15.80 | -13.24 | -9.72 | -8.40 | -5.84 | -2.32 | -7.96 | -5.40 | -1.88 |
| -15.71 | -13.15 | -9.63 | -8.35 | -5.79 | -2.27 | -7.42 | -4.86 | -1.34 |
| -15.42 | -12.86 | -9.34 | -8.16 | -5.60 | -2.08 | -7.36 | -4.80 | -1.28 |
| -15.38 | -12.82 | -9.30 | -8.15 | -5.59 | -2.07 | -6.97 | -4.41 | -0.89 |
| -15.12 | -12.56 | -9.04 | -7.96 | -5.40 | -1.88 | -6.89 | -4.33 | -0.81 |
| -15.10 | -12.54 | -9.02 | -7.95 | -5.39 | -1.87 | -6.83 | -4.27 | -0.75 |
| -15.10 | -12.54 | -9.02 | -7.94 | -5.38 | -1.86 | -6.82 | -4.26 | -0.74 |
| -14.83 | -12.27 | -8.75 | -7.77 | -5.21 | -1.69 | -6.79 | -4.23 | -0.71 |
| -14.51 | -11.95 | -8.43 | -7.57 | -5.01 | -1.49 | -6.79 | -4.23 | -0.71 |
| -14.48 | -11.92 | -8.40 | -7.55 | -4.99 | -1.47 | -6.76 | -4.20 | -0.68 |
| -14.38 | -11.82 | -8.30 | -7.49 | -4.93 | -1.41 | -6.68 | -4.12 | -0.60 |
| -14.38 | -11.82 | -8.30 | -7.48 | -4.92 | -1.40 | -6.64 | -4.08 | -0.56 |
| -14.32 | -11.76 | -8.24 | -7.45 | -4.89 | -1.37 | -6.57 | -4.01 | -0.49 |
| -14.32 | -11.76 | -8.24 | -7.44 | -4.88 | -1.36 | -6.32 | -3.76 | -0.24 |
| -14.28 | -11.72 | -8.20 | -7.42 | -4.86 | -1.34 | -6.22 | -3.66 | -0.14 |
| -14.18 | -11.62 | -8.10 | -7.36 | -4.80 | -1.28 | -6.03 | -3.47 | 0.05 |
| -14.13 | -11.57 | -8.05 | -7.33 | -4.77 | -1.25 | -6.02 | -3.46 | 0.06 |
| -14.08 | -11.52 | -8.00 | -7.29 | -4.73 | -1.21 | -5.86 | -3.30 | 0.22 |
| -13.98 | -11.42 | -7.90 | -7.24 | -4.68 | -1.16 | -5.65 | -3.09 | 0.43 |
| -13.73 | -11.17 | -7.65 | -7.07 | -4.51 | -0.99 | -5.57 | -3.01 | 0.51 |
| -13.72 | -11.16 | -7.64 | -7.07 | -4.51 | -0.99 | -5.49 | -2.93 | 0.59 |
| -13.68 | -11.12 | -7.60 | -7.04 | -4.48 | -0.96 | -5.31 | -2.75 | 0.77 |
| -13.57 | -11.01 | -7.49 | -6.97 | -4.41 | -0.89 | -5.27 | -2.71 | 0.82 |
| -13.45 | -10.89 | -7.37 | -6.89 | -4.33 | -0.81 | -5.19 | -2.63 | 0.89 |
| -13.43 | -10.87 | -7.35 | -6.87 | -4.31 | -0.79 | -5.03 | -2.47 | 1.05 |
| -13.41 | -10.85 | -7.33 | -6.86 | -4.30 | -0.78 | -4.85 | -2.29 | 1.23 |
| -13.36 | -10.80 | -7.28 | -6.83 | -4.27 | -0.75 | -4.68 | -2.12 | 1.40 |
| -13.30 | -10.74 | -7.22 | -6.81 | -4.25 | -0.73 | -4.67 | -2.11 | 1.41 |
| -13.28 | -10.72 | -7.20 | -6.79 | -4.23 | -0.71 | -4.22 | -1.66 | 1.86 |
| -13.11 | -10.55 | -7.03 | -6.68 | -4.12 | -0.60 | -3.98 | -1.42 | 2.10 |
| -13.06 | -10.50 | -6.98 | -6.64 | -4.08 | -0.56 | -3.92 | -1.36 | 2.16 |
| -13.03 | -10.47 | -6.95 | -6.62 | -4.06 | -0.54 | -3.90 | -1.34 | 2.18 |
| -12.95 | -10.39 | -6.87 | -6.57 | -4.01 | -0.49 | -3.59 | -1.03 | 2.49 |
| -12.84 | -10.28 | -6.76 | -6.50 | -3.94 | -0.42 | -3.42 | -0.86 | 2.66 |
| -12.57 | -10.01 | -6.49 | -6.32 | -3.76 | -0.24 | -3.30 | -0.74 | 2.78 |
| -12.49 | -9.93 | -6.41 | -6.28 | -3.72 | -0.20 | -3.21 | -0.65 | 2.87 |
| -12.39 | -9.83 | -6.31 | -6.22 | -3.66 | -0.14 | -2.84 | -0.28 | 3.24 |
| -12.36 | -9.80 | -6.28 | -6.19 | -3.63 | -0.11 | -1.43 | 1.13 | 4.65 |
| -12.12 | -9.56 | -6.04 | -6.06 | -3.50 | 0.02 | -1.31 | 1.25 | 4.77 |
| -11.85 | -9.29 | -5.77 | -5.86 | -3.30 | 0.22 | -1.18 | 1.38 | 4.90 |
| -11.84 | -9.28 | -5.76 | -5.86 | -3.30 | 0.22 | -1.06 | 1.50 | 5.02 |
| -11.38 | -8.82 | -5.30 | -5.57 | -3.01 | 0.51 | -0.97 | 1.59 | 5.11 |
| -11.28 | -8.72 | -5.20 | -5.50 | -2.94 | 0.58 | -0.84 | 1.72 | 5.24 |
| -11.27 | -8.71 | -5.19 | -5.48 | -2.92 | 0.60 | -0.65 | 1.91 | 5.43 |
| -9.92 | -7.36 | -3.84 | -4.61 | -2.05 | 1.47 | -0.22 | 2.34 | 5.86 |
| -9.76 | -7.20 | -3.68 | -4.51 | -1.95 | 1.57 | 0.01 | 2.57 | 6.09 |
| -9.58 | -7.02 | -3.50 | -4.40 | -1.84 | 1.68 | 0.91 | 3.47 | 6.99 |

| Federal ITC + Hypothetical State ITC of 30% | | | Federal ITC + Hypothetical State $0.80/W CBI | | |
|---|---|---|---|---|---|
| VOS-LCOE Differential | | | VOS-LCOE Differential | | |
| Low VOS 4.9 ¢/kWh | Medium VOS 7.5 ¢/kWh | High VOS 11¢/kWh | Low VOS 4.9 ¢/kWh | Medium VOS 7.5 ¢/kWh | High VOS 11¢/kWh |
| -5.61 | -3.05 | 0.47 | -8.98 | -6.42 | -2.90 |
| -3.85 | -1.29 | 2.23 | -6.86 | -4.30 | -0.78 |
| -3.32 | -0.76 | 2.76 | -6.26 | -3.70 | -0.18 |
| -3.07 | -0.51 | 3.01 | -6.03 | -3.47 | 0.05 |
| -3.04 | -0.48 | 3.04 | -5.87 | -3.31 | 0.21 |
| -2.96 | -0.40 | 3.12 | -5.76 | -3.20 | 0.32 |
| -2.92 | -0.36 | 3.16 | -5.63 | -3.07 | 0.45 |
| -2.81 | -0.25 | 3.27 | -5.63 | -3.07 | 0.45 |
| -2.80 | -0.24 | 3.28 | -5.62 | -3.06 | 0.46 |
| -2.79 | -0.23 | 3.29 | -5.50 | -2.94 | 0.58 |
| -2.69 | -0.13 | 3.39 | -5.49 | -2.93 | 0.59 |
| -2.58 | -0.02 | 3.50 | -5.30 | -2.74 | 0.78 |
| -2.56 | 0.00 | 3.52 | -5.29 | -2.73 | 0.79 |
| -2.52 | 0.04 | 3.56 | -5.28 | -2.72 | 0.80 |
| -2.52 | 0.04 | 3.56 | -5.26 | -2.70 | 0.82 |
| -2.51 | 0.05 | 3.57 | -5.24 | -2.68 | 0.84 |
| -2.49 | 0.07 | 3.59 | -5.20 | -2.64 | 0.88 |
| -2.48 | 0.08 | 3.60 | -5.10 | -2.54 | 0.98 |
| -2.45 | 0.11 | 3.63 | -5.05 | -2.49 | 1.03 |
| -2.43 | 0.13 | 3.65 | -5.04 | -2.48 | 1.04 |
| -2.41 | 0.15 | 3.67 | -5.04 | -2.48 | 1.04 |
| -2.38 | 0.18 | 3.70 | -5.02 | -2.46 | 1.06 |
| -2.29 | 0.27 | 3.79 | -4.85 | -2.29 | 1.23 |
| -2.28 | 0.28 | 3.80 | -4.84 | -2.28 | 1.24 |
| -2.25 | 0.31 | 3.83 | -4.73 | -2.17 | 1.35 |
| -2.22 | 0.34 | 3.86 | -4.70 | -2.14 | 1.38 |
| -2.17 | 0.39 | 3.91 | -4.70 | -2.14 | 1.38 |
| -2.15 | 0.41 | 3.93 | -4.68 | -2.12 | 1.40 |
| -2.15 | 0.41 | 3.93 | -4.67 | -2.11 | 1.41 |
| -2.15 | 0.41 | 3.93 | -4.65 | -2.09 | 1.43 |
| -2.13 | 0.43 | 3.95 | -4.59 | -2.03 | 1.49 |
| -2.10 | 0.46 | 3.98 | -4.57 | -2.01 | 1.51 |
| -2.05 | 0.51 | 4.03 | -4.52 | -1.96 | 1.56 |
| -2.03 | 0.53 | 4.05 | -4.50 | -1.94 | 1.58 |
| -2.00 | 0.56 | 4.08 | -4.48 | -1.92 | 1.60 |
| -1.98 | 0.58 | 4.10 | -4.40 | -1.84 | 1.68 |
| -1.94 | 0.62 | 4.14 | -4.35 | -1.79 | 1.73 |
| -1.82 | 0.74 | 4.26 | -4.27 | -1.71 | 1.81 |
| -1.81 | 0.75 | 4.27 | -4.18 | -1.62 | 1.90 |
| -1.77 | 0.79 | 4.31 | -4.17 | -1.61 | 1.91 |
| -1.74 | 0.82 | 4.34 | -4.13 | -1.57 | 1.95 |
| -1.70 | 0.86 | 4.38 | -3.94 | -1.38 | 2.14 |
| -1.56 | 1.00 | 4.52 | -3.92 | -1.36 | 2.16 |
| -1.54 | 1.02 | 4.54 | -3.88 | -1.32 | 2.20 |
| -1.38 | 1.18 | 4.70 | -3.67 | -1.11 | 2.41 |
| -1.35 | 1.21 | 4.73 | -3.56 | -1.00 | 2.52 |
| -1.31 | 1.25 | 4.77 | -3.49 | -0.93 | 2.59 |
| -0.80 | 1.76 | 5.28 | -2.86 | -0.30 | 3.22 |
| -0.73 | 1.83 | 5.35 | -2.68 | -0.12 | 3.40 |
| -0.67 | 1.89 | 5.41 | -2.66 | -0.10 | 3.42 |

# References

Ardani, K.; Seif, D., Margolis, R., Morris, J., Davidson, C, Truitt, S. and Torbert, R. (2013). *Non-Hardware ("Soft") Cost-Reduction Roadmap for Residential and Small Commercial Solar Photovoltaics, 2013-2020*. NREL/TP-7A40-59155. Golden, CO: NREL. Accessed September 2014: http://www.nrel.gov/docs/fy13osti/59155.pdf.

Austin Energy (n.d.) "City of Austin Electric Rate Schedules: Residential Solar." Accessed September 2014: http://www.austinenergy.com/wps/wcm/connect/c6c8ad20-ee8f-4d89-be36-2d6f7433edbd/ResidentialSolar.pdf?MOD=AJPERES.

Bird, L.; Reger, A.; Heeter, J. (2012). *Distributed Solar Incentive Programs: Recent Experience and Best Practices for Design and Implementation*. NREL-TP-6A20-56308. Golden, CO: NREL. Accessed September 2014: http://www.nrel.gov/docs/fy13osti/56308.pdf.

Clean Power Research (CPR). (2013). "2014 Value of Solar at Austin Energy." Austin Energy. Accessed September 2014: http://www.austintexas.gov/edims/document.cfm?id=199131.

Cliburn, J.; Bourg, J.; Deffner, D.; Mahrer, E.; Sterling, J.; Taylor, M. (2013). "Ratemaking, Solar Value and Solar Net Energy Metering—A Primer." Solar Electric Power Association. Accessed September 2014: http://www.solarelectricpower.org/media/51299/sepa-nem-report-0713-print.pdf.

Cory, K.; Swezey, B. (2007). "Renewable Portfolio Standards in the States: Balancing Goals and Rules." *The Electricity Journal* 20 (7); pp. 21-32. Accessed September 2014: http://www.sciencedirect.com/science/article/pii/S1040619007000358.

Couture, T. (2014). Personal communication in May.

Couture, T.; Cory, K.; Kreycik, C.; Williams, E. (2010). *A Policymaker's Guide to Feed-in Tariff Policy Design. National Renewable Energy Laboratory.* NREL/TP-6A2-44849. Golden, CO: NREL. Accessed September 2014: http://www.nrel.gov/docs/fy10osti/44849.pdf.

Database for State Renewable and Efficiency Incentives (DSIRE). (2013). "Summary Map: RPS Policies with Solar/DG Provisions." U.S. Department of Energy, Interstate Renewable Energy Council and North Carolina Solar Center. Last updated March 2013. Accessed August 2014: http://www.dsireusa.org/solar/summarymaps/.

DSIRE. (2014a). "Business Energy Investment Tax Credit (ITC)." North Carolina Clean Energy Technology Center. Accessed August 2014: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F.

DSIRE. (2014b). North Carolina Clean Energy Technology Center. Accessed August 2014: http://www.dsireusa.org/solar/.

Denholm, P.; Margolis, R.; Palmintier, B.; Barrows, C.; Ibanez, E.; Bird, L.; Zuboy, J. (2014). *Methods for Analyzing the Benefits and Costs of Distributed Photovoltaic Generation to the U.S. Electric Utility System*. NREL/TP-6A20-62477. Golden, CO: NREL. Accessed October 6, 2014: http://www.nrel.gov/docs/fy14osti/62447.pdf.

Energy Information Administration. (2013a). *Annual Energy Outlook 2013 with Projections to 2040*. DOE/EIA-0383(2013). Washington, D.C.: EIA. Accessed August 2014: http://www.eia.gov/forecasts/aeo/pdf/0383(2013).pdf.

Energy Information Administration. (2013b). "Feed-in tariff: A policy tool encouraging deployment of renewable electricity technologies." Accessed October 2014: http://www.eia.gov/todayinenergy/detail.cfm?id=11471.

Grant, B. Deputy Commissioner, Department of Commerce at State of Minnesota. (2014). "Minnesota Value of Solar," presentation at the Solar Electric Power Association Utility Solar Conference.

Hamilton, T. (2013). "CPS Energy, solar industry will work together on SunCredit program." CPS Energy. Accessed August 2014: http://newsroom.cpsenergy.com/blog/renewables/cps-energy-solar-industry/.

Hansen, L.; Lacy, V.; Glick, D. (2013). *A Review of Solar PV Benefit & Cost Studies. Rocky Mountain Institute*. Accessed August 2014: http://www.rmi.org/cms/Download.aspx?id=10793&file=eLab_DERBenefitCostDeck_2nd_Edition&title=A+Review+of+Solar+PV+Benefit+and+Cost+Studies.

Harvey, T. Vice President, Distributed Energy Services, Austin Energy. (2014). "VOS and AE's Residential Solar Rate," presentation at the Solar Electric Power Association Utility Solar Conference.

Hoff, T.; Perez, R.; Ross, J.; Taylor, M. (2008). *Photovoltaic Capacity Valuation Methods*. Solar Electric Power Association. # 02-08. Accessed September 2014: http://www.solarelectricpower.org/media/8181/sepa-pv-capacity.pdf.

Keyes, J.; Rábago, K. (2013). *A Regulator's Guidebook: Calculating the Benefits and Costs of Distributed Solar Generation*. Interstate Renewable Energy Council. Accessed September 2014: http://votesolar.org/wp-content/uploads/2013/09/IREC_Rabago_Regulators-Guidebook-to-Assessing-Benefits-and-Costs-of-DSG1.pdf.

Kind, P. (2013). *Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business*. Prepared by Energy Infrastructure Advocate for Edison Electric Institute. Accessed September 2014: http://www.eei.org/ourissues/finance/documents/disruptivechallenges.pdf.

Lantz, E.; Doris, E. (2009). *State Clean Energy Practices: Renewable Energy Rebates*. NREL/TP-6A2-45039. Golden, CO: NREL. Accessed August 2014: http://www.nrel.gov/docs/fy09osti/45039.pdf.

Minnesota Department of Commerce (MN DOC). (n.d.). “Value of Solar Tariff Methodology.” Minnesota Dept. of Commerce, Division of Energy Resources. Accessed July 1, 2014: http://mn.gov/commerce/energy/topics/resources/energy-legislation-initiatives/value-of-solar-tariff-methodology%20.jsp.

MN DOC. (2014). “Minnesota Value of Solar: Methodology.” Minnesota Dept. of Commerce, Division of Energy Resources. Accessed August 2014: http://mn.gov/commerce/energy/images/MN-VOS-Methodology-FINAL.pdf.

Morgan, P. (Revised 2013). A Decade of Decoupling for US Energy Utilities: Rate Impacts, Designs, and Observations. Graceful Systems.

NREL. (2014a). “System Advisor Model.” Accessed September 2014: https://sam.nrel.gov.

NREL. (2014b). “Advanced Inverter Functions to Support High Levels of Distributed Solar.” NREL/BR-6A20-62612. Golden, CO: NREL. Accessed February 2015: http://www.nrel.gov/docs/fy15osti/62612.pdf.

National Research Council. (2010). *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. The National Academies Press. Accessed August 2014: http://www.nap.edu/openbook.php?record_id=12794.

Rábago, K; Libby, L.; Harvey, T.; Norris, B.; Hoff, T. (2012) “Designing Austin Energy’s Solar Tariff Using a Distributed Value Calculator.” Accessed September 2014: www.rabagoenergy.com/files/value-of-solar-rate.pdf.

Solar Electric Industry Association (SEIA) and GTM Research. (2014). “U.S. Solar Market Insight Report: Q3 2014.” December 2014.

Starrs, T. Vice President Market Strategy and Policy, SunPower Corporation. (2014) Personal communication in September with Karlynn Cory.

Tennessee Valley Authority.(TVA). (n.d.). “Distributed Generation-Integrated Value.” Accessed September 2014: http://www.tva.gov/dgiv/.

TVA. (2014). “TVA Studies Value of Distributed Generation from Small Providers.” Accessed September 2014: http://www.tva.com/news/releases/aprjun14/distributed_generation.html.

Voosen, P. (2009). “Spain’s Solar Market Crash Offers a Cautionary Tale About Feed-In Tariffs.” New York Times. Accessed September 2014: http://www.nytimes.com/gwire/2009/08/18/18greenwire-spains-solar-market-crash-offers-a-cautionary-88308.html?pagewanted=all.