UCE Exhibit 2.1 (DT)
[COS+RD]
Docket No. 13-035-184

Value of Solar in Utah

Prepared for

Utah Clean Energy

January 7, 2014

Clean Power Research®
Powering Intelligent Energy Decisions®

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Executive Summary

Introduction

Utah Clean Energy contracted with Clean Power Research (CPR) in 2013 to estimate the Value of Solar™ ("VOS") in Utah for the territory served by Rocky Mountain Power (RMP).

The VOS result represents value of gross energy produced by PV (before loads) and includes delivery, generation capacity, transmission capacity, transmission and distribution line losses, and environmental value. The VOS is the sum of several value components, each of which is calculated separately using established methodologies. Economic and technical assumptions were provided by Utah Clean Energy who coordinated data requests to Rocky Mountain Power (UT Docket No. 11-035-104).

Value components included in the study are summarized in Table ES-1.

Table ES-1. Value components included.

Value Component	Basis
Fuel Value	The cost of natural gas fuel to operate a combined cycle gas turbine (CCGT) plant operating on the margin to meet electric loads and T&D losses.
Plant O&M Value	Costs associated with operations and maintenance of the CCGT plant.
Generation Capacity Value	Capital cost of generation to meet peak load.
Avoided T&D Capacity Cost	Cost of money savings resulting from deferring T&D capacity additions.
Avoided Environmental Cost	Cost to comply with environmental regulations and policy objectives.
Fuel Price Guarantee Value	Cost of eliminating uncertainty in fuel price fluctuations.

CPR used its DGValuator™ platform to perform the study. DGValuator is a tool that models hourly PV production, calculates line losses and loss savings, and determines value components based on user input data. It has been designed to: (1) enable objective and transparent analysis; (2) employ established methodologies; (3) embody correlated solar data; and (4) empower end-users. As a result, it was determined that DGValuator would provide the appropriate level of modeling detail that would support the objectives of this project.

PV Production Data

A sample PV system definition was selected as a 1 kW-AC south-facing system with a 40° tilt located in Salt Lake City, Utah. Hourly production for 2012 was obtained by modeling this system using SolarAnywhere® satellite-based meteorological data. The calculated VOS corresponds to the energy and effective capacity of this selected system.

Results

The VOS analysis was performed by separating the analysis into economic and technical components. The economic value is calculated based on perfect load match and no losses. The result is then modified as required using “Load Match” factors to reflect the match between PV production profiles and utility loads. Finally a “Loss Savings” factor is applied to reflect the distributed nature of the resource. Results are presented in Table ES-2 and Figure ES-1.

For example, the Generation Capacity value is first calculated as $0.021 per kWh for a perfect centrally located (non-distributed) resource. The ELCC of the PV resource is determined to be 53% of the perfect resource, so this factor is included. Finally, an ELCC-specific loss factor[1] is determined to be 25% to take into account marginal hourly loss savings provided by PV. When these factors are considered, the Generation Capacity value is re-calculated as $0.011 per kWh.

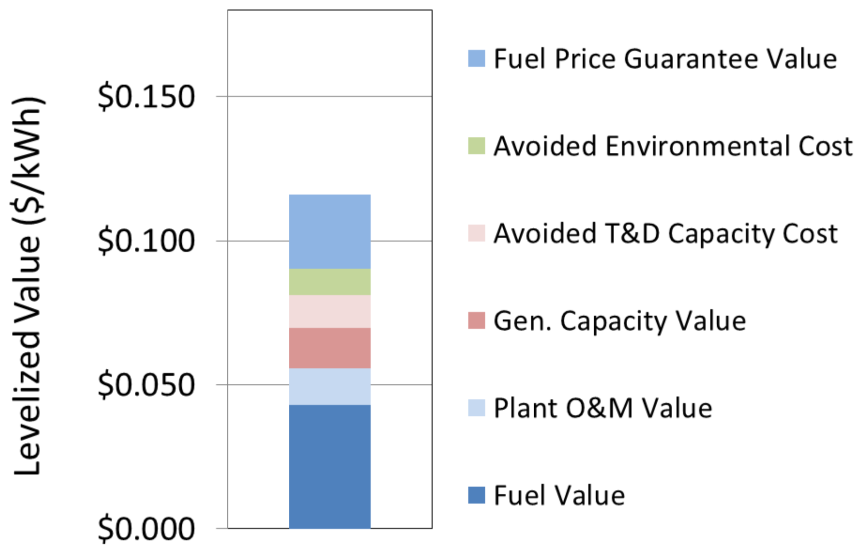
The total VOS with all components included is calculated as $0.116 per kWh. This value is a levelized value representing all avoided costs over a 25-year assumed PV life.

Table ES-2. Levelized value of ideal resource and distributed PV ($ per kWh)

	Economic Value ($/kWh)	Load Match (No Losses) (%)	Distributed Loss Savings (%)	Distributed PV Value ($/kWh)
Fuel Value	$0.037		16%	$0.043
Plant O&M Value	$0.011		16%	$0.013
Gen. Capacity Value	$0.021	53%	25%	$0.014
Avoided T&D Capacity Cost	$0.017	53%	25%	$0.011
Avoided Environmental Cost	$0.009		0%	$0.009
Fuel Price Guarantee Value	$0.022		16%	$0.026
	$0.118			$0.116

[1] The loss factor is calculated by calculating the ELCC both with (65.8%) and without (52.7%) T&D losses. When including loss savings, the losses are calculated hourly based on the PV output for that hour, and determining the marginal losses. The loss model is a quadratic form with coefficients determined such that the annual average losses and peak hour losses are in agreement with the input data.

Figure ES-1. Levelized value of solar at ($ per kWh)



Contents

Introduction to VOS

This report quantifies the value of distributed solar power production by behind-the-meter PV systems in the Utah service territory of Rocky Mountain Power (RMP). The Value of Solar (VOS) is the value of PV production, before serving load, from the utility perspective. It uses methodologies and analytical tools that have been developed by Clean Power Research over several years.

The framework supposes that PV is located in the distribution system. PV that is located close to the loads provides the highest value per unit of energy to the utility because line losses are avoided, thereby increasing the value of solar relative to centrally-located resources.

Framing a VOS analysis requires answers to two fundamental questions. First, what benefits should be included? This requires defining the benefits, identifying the recipients, and making a selection as to what should be included. Second, how should the benefits calculated? This includes defining methodology and selecting input assumptions.

Value Components Included

The first question is, "What benefits should be included?" The two broad categories of benefit recipients are the utility and ratepayers/taxpayers. This study only examines the utility's perspective. The value components included in the study are summarized in Table 1. Thus, the VOS from RMP's perspective may be considered to be the sum of the value components presented in Table 1.

Table 1. Value components included.

Value Component	Basis
Fuel Value	The cost of natural gas fuel to operate a gas turbine (CCGT) plant operating on the margin to meet electric loads and T&D losses.
Plant O&M Value	Costs associated with operations and maintenance of the CCGT plant.
Generation Capacity Value	Capital cost of generation to meet peak load.
Avoided T&D Capacity Cost	Cost of money savings resulting from deferring T&D capacity additions.
Avoided Environmental Cost	Cost to comply with environmental regulations and policy objectives.
Fuel Price Guarantee Value	Cost of eliminating uncertainty in fuel price fluctuations.

The following sections provide brief descriptions of these components.

Fuel Value

Distributed PV generation offsets the cost of power generation. Each kWh generated by PV results in one less unit of energy that the utility needs to purchase or generate. In addition, distributed PV reduces losses in the transmission and distribution systems so that the cost of the wholesale generation that would have been lost is also a contributor to value.

Under this study, the value is defined as the cost of natural gas fuel that would otherwise have to be purchased to operate a gas turbine (CCGT) plant and meet electric loads and overcome T&D losses. The study presumes that the energy delivered by PV displaces energy at this plant for each hour of the study period with loss calculations being based on each hour.

Whether the utility receives the fuel savings directly by avoiding fuel purchases, or indirectly by reducing wholesale power purchases, the method of calculating the value is the same.

Plant O&M Value

For the same reasons described for Fuel Value, the utility realizes a savings in O&M costs due to decreased use of the CCGT plant. The cost savings are assumed to be proportional to the avoided energy, including loss savings.

Generation Capacity Value

In addition to the fuel and O&M savings, the total cost of power includes the capital cost of the generation plant. To the extent that PV displaces the need for generation capacity, it would be valued as the capital cost of displaced generation. The key to valuing this component is to determine the effective load carrying capability (ELCC) of the PV resource. This is accomplished through an analysis of hourly PV production relative to utility generation.

Avoided T&D Capacity Cost

PV has the potential to provide savings on T&D infrastructure investments. As in the case of generation capacity, the timing PV production is important relative to the loading on the line, and the ELCC is used here as well as a measure of effective line capacity relief.

Avoided Environmental Cost

PV has the potential to reduce costs that the utility incurs in satisfying environmental compliance goals or state laws. Environmental value calculated here assumes no benefit on line loss savings, similar to REC definitions.

Fuel Price Guarantee Value

PV displaces energy generated from a marginal unit, so it avoids the cost of fuel associated with this generation. Furthermore, the PV system is assumed to have a service life of 25 years, so the uncertainty in fuel price fluctuations is also eliminated over this period. This component indicates the value of the elimination of uncertainty in fuel price fluctuations.

Calculation tool

CPR used its DGValuator™ V2 platform to perform the study. DGValuator is a tool that models hourly PV production, calculates line losses and loss savings, and determines value components based on user input data. It has been designed to: (1) enable objective and transparent analysis; (2) employ established methodologies; (3) embody correlated solar data; and (4) empower end-users. As a result, it was determined that DGValuator would provide the appropriate level of modeling detail that would support the objectives of this project.

Economic Assessment

The VOS analysis includes both economic and technical analyses. The overall approach is to calculate the economic value for an "Ideal Resource" and then to modify this result as necessary based on the "Load Match" for capacity-based benefits to reflect the match between PV and utility loads and "Loss Savings" to reflect the distributed nature of the resource.

Table 2 summarizes key assumptions for the economic assessment. The study period was assumed to be 25 years. The assumed life of PV systems is 25 years with output degrading at 0.5 percent per year. The discount rate used is 6.882 percent.

PV is assumed to displace power generated from a combined cycle combustion turbine (CCCT)[2]. In the data request, RMP provided data for a simple cycle combustion turbine (SCCT); however this was not used as the baseline VOS case. The SCCT has a lower capital cost (resulting in a lower generation capacity cost) but a significantly higher heat rate (resulting in a significantly higher fuel value. The heat rate was the dominant factor, and CPR believes that the CCCT would be more representative of the resource displaced by solar over its operating hours. Therefore, the CCCT was used as the baseline, but a separate case is included in the Appendix using the SCCT for completeness.

Capital cost, installation year, O&M, heat rate, and escalation values are all presented in the table. In addition, a reserve planning margin is included because solar is located in the distribution system, reducing the overall loads that would be used for determining reserve requirements.

Utah Clean Energy provided the avoided environmental cost.

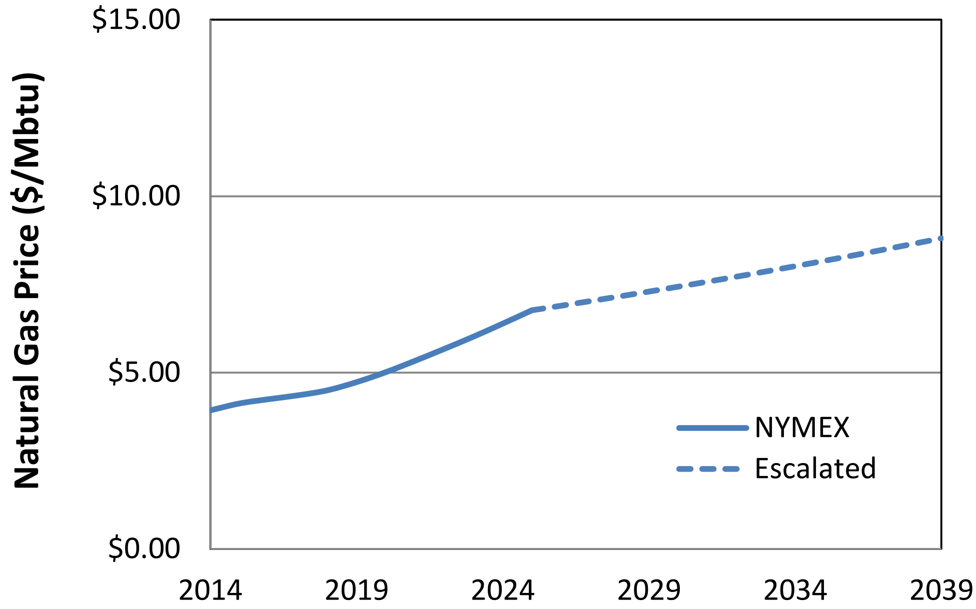
Natural gas prices are the NYMEX futures prices as of August 27, 2013, with a 1.9% escalation assumed for years beyond the 12-year NYMEX product availability. These are shown in Figure 1.

[2] Integrated Resource Plan, 423 MW CCCT "J" Adv 1x1 (1,500 AFSL).

Table 2. Input data provided by RMP and UCE.

Economic Factors		
Start Year	2014	
Discount Rate	6.882%	per year
General Escalation Rate	1.90%	per year
PV Assumptions		
PV Degradation	0.50%	per year
PV Life	25	years
Utility-Owned Generation		
Capacity		
Generation Overnight Capacity Cost	$962	per kW
Years Until New Gen Capacity Is Needed	11	years
Capacity Cost Escalation Rate	1.90%	per year
Generation Life	30	years
Reserve Planning Margin	13%	
Energy		
Heat Rate	6495	BTU per kWh
Heat Rate Degradation	0.000%	per year
O&M cost (first Year) - Fixed	$31.29	per kW-yr
O&M cost (first Year) - Variable	$0.0024	$ per kWh
O&M cost escalation rate	1.90%	per year
Environmental		
Avoided Environmental Cost	$0.00931	per kWh
Transmission & Distribution		
Capacity-related transmission capital cost	$34.8	per kW-yr
Years until new transmission capacity is needed	1	years
Transmission lifetime	58	years
Transmission capital cost escalation	1.90%	per year

Figure 1. Fuel price forecasts.



The study includes UCE's assumed environmental savings of $9.31 per MWh, levelized. This represents the cost premium for a solar PPA over the cost for conventional generation.

Technical Assessment

Overview

This section provides an overview of the methods used to perform a technical assessment of the match between PV production and generation, and the effect of losses.

The assessment is accomplished in four steps.

1. Obtain historical load data.
2. Obtain PV production data.
3. Quantify the match between PV and load.
4. Calculate loss savings.

Step 1: Obtain Historical Load Data

RMP provided hourly load data for Utah.

Step 2: Obtain PV Production Data

PV production data was simulated for each hour of 2012 for a fixed, 40-degree tilt system located in Salt Lake City.

Step 3: Quantify Load Match

The third step is to quantify the match between PV and the load. The match is calculated using the Effective Load Carrying Capability (ELCC) method for generation capacity and the Peak Load Reduction (PLR) method for the T&D system.

ELCC Method

ELCC measures how PV production matches the generation profile using a Loss of Load Probability (LOLP) approach. It is defined as the rating of a perfectly operating baseload plant that results in the same loss of load probability as the PV resource. The ELCC is expressed as a percentage of the PV resource rating. For example, a 1,000 MW PV resource with a 50 percent ELCC would provide the same generation portfolio reliability as a 500 MW baseload unit.

Peak Load Reduction Method

The Peak Load Method determines the ability of PV to directly reduce the load at the peak time of the year. It is calculated by finding peak generation without PV, calculating hourly generation with PV as described in the previous section, and determining the new peak load. Note that the day and time of the new (reduced) peak may be different than the original peak. The difference between these two numbers is the peak load reduction. It is a very stringent test in that it is a “worst case” analysis.

For example, suppose the utility’s annual peak was 10,000 MW at 6 pm on August 15 and that the addition of 1,000 MW of distributed PV reduces the peak to 9,500 MW at 7 pm on July 14, then the resource would have an effective reduction of 500 MW, or 50 percent of rated capacity.

Step 4: Quantify Loss Savings

The final step is to quantify loss savings. Loss savings are calculated by comparing the difference between the results for the distributed and central PV from the previous step. For example, if distributed PV has a 60 percent ELCC and central PV has a 50 percent ELCC for central PV, loss savings equal 20 percent (60%/50% - 100% = 20%).

Loss Savings Analysis

Hourly losses (combined transmission and distribution losses) were calculated using a model in the form **A + B*Load^{2}**. Model coefficients were determined using data from the Pacificorp Utah “2009 Analysis of System Losses”[3] and hourly load data provided by RMP. Annual average losses were calculated to be 8.53%[4] and be losses were calculated to be 11.4%.[5]

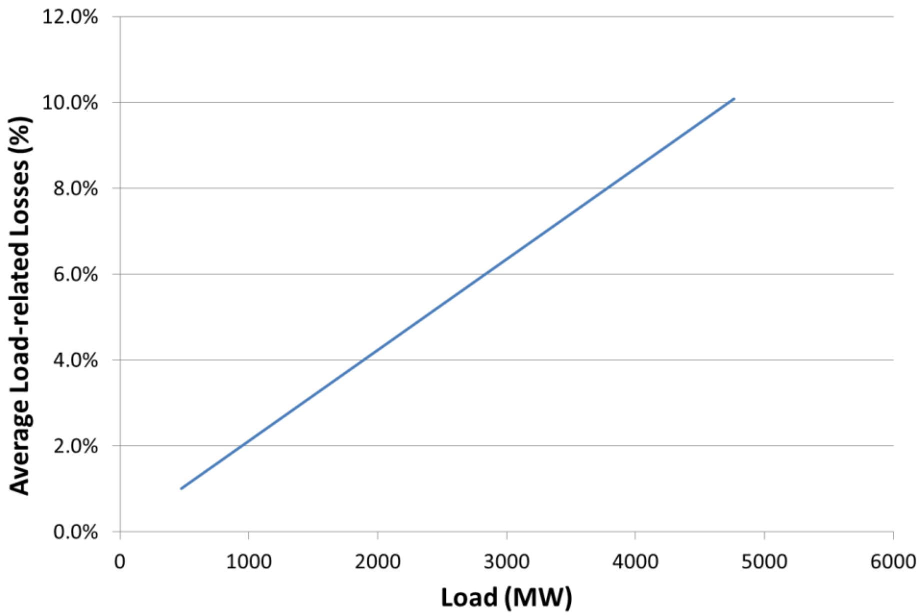
Figure 2 shows load-related losses used in the loss-savings analysis. No-load losses cancel out of the analysis because they are incurred whether PV is present or not.

[3] Prepared by Management Applications Consulting, Inc., Nov. 2011.

[4] Appendix B, Exhibit 1, “Summary of Loss Factors” gives the secondary loss factor of 1.09322. From this, the average losses are calculated as (1.09322-1)/1.09322 = 8.53%. PV is assumed to be located on secondary voltages.

[5] Estimated as follows: Hourly loads were summed for 2012, and annual losses were calculated using the 8.53% figure above. Of these total losses, 25% were assumed to be no-load losses, and 75% are assumed to be load-related losses. Losses were assumed to be of the form A+B*Load^2, so A is calculated as the annual no-load losses divided by 8784 hours in 2012. B is then determined such that the model results sum to the total annual losses. With A and B known, on-peak losses are calculated by applying the model on the peak hour. The on-peak losses divided by the on-peak load gives 11.4%.

Figure 2. Load-related losses as a function of load used in loss-savings calculations.



Technical Results

The resulting DGValuator technical results are shown in Table 3.

Table 3. Loss savings

	Incl. Losses	No Losses
ELCC (%)	65.8%	52.7%
PLR (%)	87.4%	69.8%
Loss Savings (Percent of PV Production)		
ELCC	24.9%	
PLR	25.3%	
Energy	15.8%	

Summary Results

This section summarizes the results of the analysis. Table 4 presents the results in terms of the levelized value of solar, broken down by component. The total levelized value is $0.116 per kWh. These results are presented graphically in Figure 2.

The table presents the economic value of the “ideal resource,” the load match and loss savings factors, and the final distributed PV value.

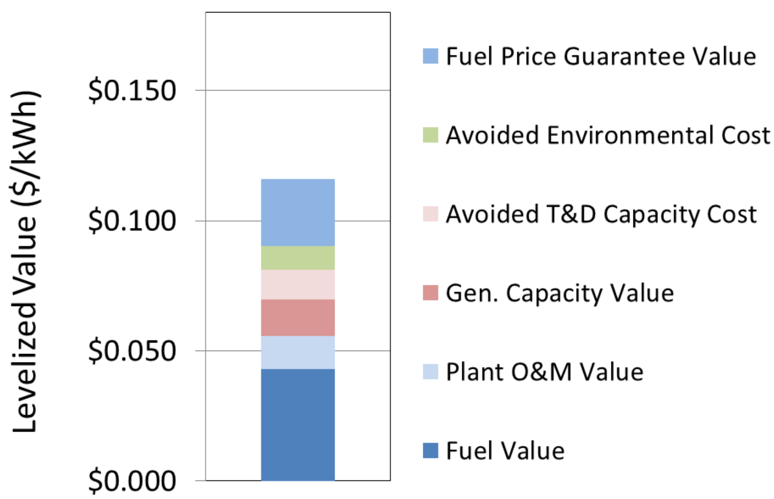
For example, the Generation Capacity value is first calculated as $0.021 per kWh for a perfect centrally located (non-distributed) resource. The ELCC of the PV resource is determined to be 53% of the perfect resource, so this factor is included. Finally, an ELCC-specific loss factor is determined to be 25% to take into account marginal hourly loss savings provided by PV. When these factors are considered, the Generation Capacity value is re-calculated as $0.011 per kWh.

Loss savings (not to be confused with average loss percentages) account for the cost of energy that would have otherwise been lost. Note that there are four separate loss savings percentages used, depending on category: energy, ELCC, PRL, and environmental (i.e., “none”).

Table 4. Levelized value of solar ($ per kWh).

	Economic Value ($/kWh)	Load Match (No Losses) (%)	Distributed Loss Savings (%)	Distributed PV Value ($/kWh)
Fuel Value	$0.037		16%	$0.043
Plant O&M Value	$0.011		16%	$0.013
Gen. Capacity Value	$0.021	53%	25%	$0.014
Avoided T&D Capacity Cost	$0.017	53%	25%	$0.011
Avoided Environmental Cost	$0.009		0%	$0.009
Fuel Price Guarantee Value	$0.022		16%	$0.026
	$0.118			$0.116

Figure 2. Levelized value of solar ($ per kWh).



Conclusions

Using assumptions and data provided by Rocky Mountain Power and Utah Clean Energy, the value of solar in RMP’s service territory in Utah is calculated to be a levelized $0.116 per kWh over 25 years. Several observations and conclusions may be made:

- The value is based on avoided utility costs based on the electricity produced by distributed PV. It is irrespective of ownership (commercial or residential). It presumes that all PV production is metered separately from customer usage.
- The value does not include societal benefits that may provide additional value, such as economic development, greenhouse gas reduction or disaster recovery benefits. These benefits were not included because they do not represent savings to the utility.
- The levelized value represents the long term contract rate at which a utility would be economically indifferent, based on the assumptions of this study. In other words, if a utility were to credit customers with a fixed amount of $0.116 per kWh produced by distributed PV production over 25 years, the amount paid would offset the savings to the utility in generating and delivering the energy to the customer.
- The value corresponds to a fixed, south-facing PV system with a 40-degree tilt. In reality, distributed PV systems are oriented in multiple ways (e.g., east- and west-facing), so the profile of the aggregate “fleet shape” would differ from the assumed shape. Fleet modeling was not conducted for this study.
- Another variant on value would be to consider the value of export energy only. While the methods for valuing export-only energy would be similar, the results would be different because the timing of the export energy would not be the same as that of gross production. The value of export energy was not addressed in this study.
- The value represents today’s costs based on existing loads. In the future, loads will grow, and PV capacity will grow. This has the potential to change the utility load shape, and affect future year value.

Appendix

The body of the report covers the baseline VOS calculation. It is based on the costs associated with a CCCT. However, RMP provided data for an SCCT, and the associated input assumptions and results are shown here. The SCCT has a lower capital cost (resulting in lower generation capacity value) but also a higher heat rate (resulting in a higher fuel value). The heat rate is the dominant effect.

Table 4. Input assumptions.

	SCCT Case	CCCT Case (Baseline)	
Capacity			
Generation Overnight Capacity Cost	$762	$962	per kW
Years Until New Gen Capacity Is Needed	11	11	years
Capacity Cost Escalation Rate	1.90%	1.90%	per year
Generation Life	30	30	years
Reserve Planning Margin	13%	13%	
Energy			
Heat Rate	9950	6495	BTU per kWh
Heat Rate Degradation	0%	0%	per year
O&M cost (first Year) - Fixed	$34.66	$31.29	per kW-yr
O&M cost (first Year) - Variable	$0.0102	$0.0024	$ per kWh

Table 5. Levelized value of solar (SCCT case).

	Economic Value ($/kWh)	Load Match (No Losses) (%)	Distributed Loss Savings (%)	Distributed PV Value ($/kWh)
Fuel Value	$0.057		16%	$0.066
Plant O&M Value	$0.021		16%	$0.024
Gen. Capacity Value	$0.017	53%	25%	$0.011
Avoided T&D Capacity Cost	$0.017	53%	25%	$0.011
Avoided Environmental Cost	$0.009		0%	$0.009
Fuel Price Guarantee Value	$0.034		16%	$0.039
	$0.155			$0.161