The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania

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November 2012

Prepared for:

Mid-Atlantic Solar Energy Industries Association

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Acknowledgements

This report was funded by the following organizations:

- The Reinvestment Fund's Sustainable Development Fund
- Mid Atlantic Solar Energy Industries Association
- Advanced Solar Products
- SMA Americas
- Vote Solar
- Renewable Power
- Geoscape Solar

The authors wish to express their gratitude to Rachel Hoff for collecting and analyzing FERC filings from the six utilities, producing the PV fleet simulations, and conducting the peak load day analysis; also to Phil Gruenhagen for researching and preparing the PJM load and pricing data.

Executive Summary

This report presents an analysis of value provided by grid-connected, distributed PV in Pennsylvania and New Jersey. The analysis does not provide policy recommendations except to suggest that each benefit must be understood from the perspective of the beneficiary (utility, ratepayer, or taxpayer).

The study quantified ten value components and one cost component, summarized in Table ES- 1. These components represent the benefits (and costs) that accrue to the utilities, ratepayers, and taxpayers in accepting solar onto the grid. The methodologies for quantifying these values are described further in Appendix 2.

Table ES- 1. Value component definitions.

Value Component	Basis
Fuel Cost Savings	Cost of natural gas fuel that would have to be purchased for a gas turbine (CCGT) plant operating on the margin to meet electric loads and T&D losses.
O&M Cost Savings	Operations and maintenance costs for the CCGT plant.
Security Enhancement Value	Avoided economic impacts of outages associated due to grid reliability of distributed generation.
Long Term Societal Value	Potential value (defined by all other components) if the life of PV is 40 years instead of the assumed 30 years.
Fuel Price Hedge Value	Cost to eliminate natural gas fuel price uncertainty.
Generation Capacity Value	Cost to build CCGT generation capacity.
T&D Capacity Value	Financial savings resulting from deferring T&D capacity additions.
Market Price Reduction	Wholesale market costs incurred by all ratepayers associated with a shift in demand.
Environmental Value	Future cost of mitigating environmental impacts of coal, natural gas, nuclear, and other generation.
Economic Development Value	Enhanced tax revenues associated with net job creation for solar versus conventional power generation.
(Solar Penetration Cost)	Additional cost incurred to accept variable solar generation onto the grid.

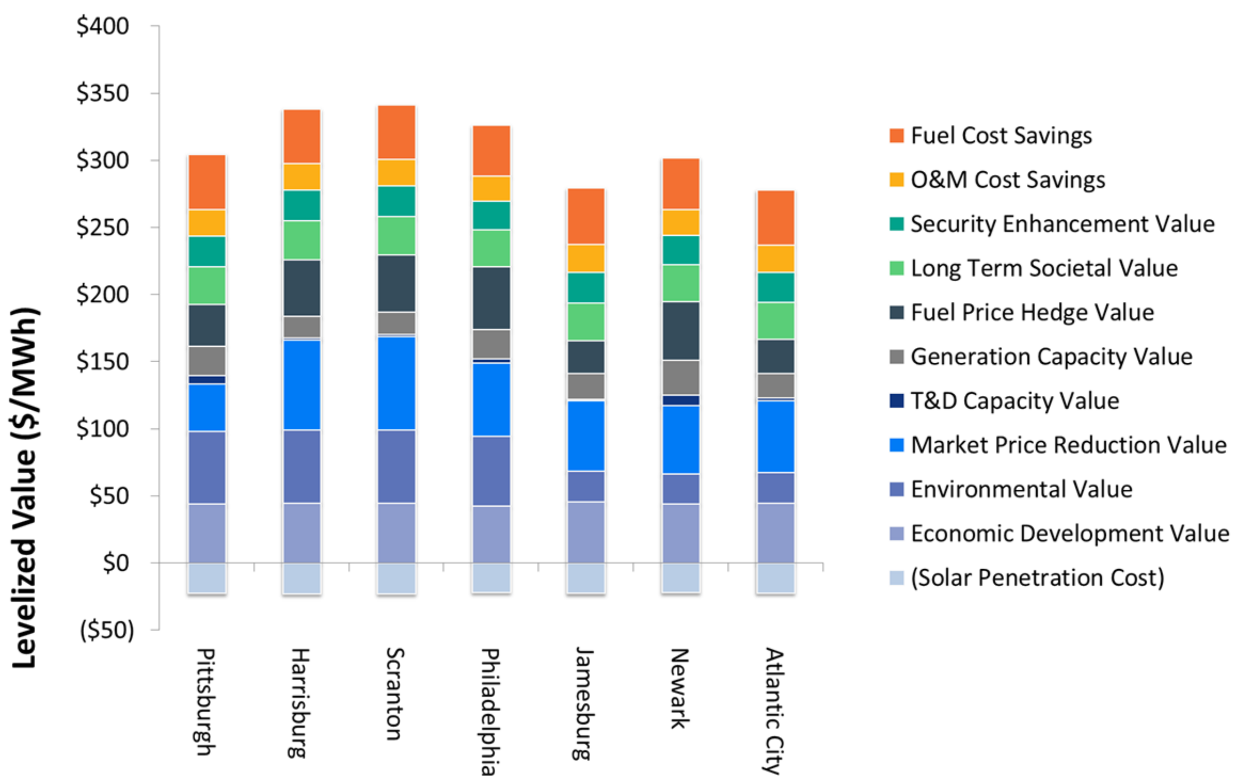
The analysis represents the value of PV for a “fleet” of PV systems (that is, a large set of systems generating into the grid). Four different fleet configurations (e.g., fixed, south-facing, 30-degree tilt angle) were evaluated at each of seven locations (Pittsburgh, PA; Harrisburg, PA; Scranton, PA;

Philadelphia, PA; Jamesburg, NJ; Newark, NJ; and Atlantic City, NJ). These locations represent a diversity of geographic and economic assumptions across six utility service territories (Duquesne Light Co., PPL Utilities Corp, PECO Utilities Corp, Jersey Central P&L, PSE&G, and Atlantic Electric).

The analysis represented a moderate assumption of penetration: PV was to provide 15% of peak electric load for each study location (higher penetration levels result in lower value per MWh). PV was modeled using SolarAnywhere®, a solar resource data set that provides time- and location-correlated PV output with loads. Load data and market pricing was taken from PJM for the six zones, and utility economic inputs were derived from FERC submittals. Additional input data was taken from the EIA and the Bureau of Labor Statistics (producer price indices).

Levelized value results for the seven locations are shown in Figure ES- 1 and Table ES- 2. Detailed results for all scenarios are included in Appendix 3.

Figure ES- 1. Levelized value ($/MWh), by location (South-30).



The following observations and conclusions may be made:

- **Total Value**. The total value ranges from $256 per MWh to $318 per MWh. Of this, the highest value components are the Market Price Reduction (averaging $55 per MWh) and the Economic Development Value (averaging $44 per MWh).
- **Market Price Reduction**. The two locations of highest total value (Harrisburg and Scranton) are noted for their high Market Price Reduction value. This may be the result of a good match between LMP and PV output. By reducing demand during the high priced hours, a cost savings is realized by all consumers. Further investigation of the methods may be warranted in light of two arguments put forth by Felder [32]: that the methodology does address induced increase in demand due to price reductions, and that it only addresses short-run effects (ignoring the impact on capacity markets).
- **Environmental Value**. The state energy mix is a differentiator of environmental value. Pennsylvania (with a large component of coal-fired generation in its mix) leads to higher environmental value in locations in that state relative to New Jersey.
- **T&D Capacity Value**. T&D capacity value is low for all scenarios, with the average value of only $3 per MWh. This may be explained by the conservative method taken for calculating the effective T&D capacity.
- **Fuel Price Hedge**. The cost of eliminating future fuel purchases—through the use of financial hedging instruments—is directly related to the utility's cost of capital. This may be seen by comparing the hedge value in Jamesburg and Atlantic City. At a utility discount rate of 5.68%, Jersey Central Power & Light (the utility serving Jamesburg) has the lowest calculated cost of capital among the six utilities included in the study. In contrast, PSE&G (the utility serving Newark) has a calculated discount rate of 8.46%, the highest among the utilities. This is reflected in the relative hedge values of $24 per MWh for Jamesburg and $44 per MWh for Newark, nearly twice the value.
- **Generation Capacity Value**. There is a moderate match between PV output and utility system load. The effective capacity ranges from 28% to 45% of rated output, and this is in line with the assigned PJM value of 38% for solar resources.

Table ES- 2. Levelized Value of Solar ($/MWh), by Location.

	Pittsburgh	Harrisburg	Scranton	Philadelphia	Jamesburg	Newark	Atlantic City
Energy							
Fuel Cost Savings	$41	$41	$41	$38	$42	$39	$41
O&M Cost Savings	$20	$20	$20	$18	$21	$19	$20
Total Energy Value	$61	$60	$60	$56	$63	$58	$61
Strategic							
Security Enhancement Value	$23	$23	$23	$22	$23	$22	$22
Long Term Societal Value	$28	$29	$29	$27	$28	$28	$28
Total Strategic Value	$51	$52	$52	$49	$51	$50	$50
Other							
Fuel Price Hedge Value	$31	$42	$42	$47	$24	$44	$25
Generation Capacity Value	$22	$16	$17	$22	$19	$26	$18
T&D Capacity Value	$6	$1	$1	$3	$1	$8	$2
Market Price Reduction Value	$35	$67	$69	$54	$52	$51	$54
Environmental Value	$54	$55	$55	$52	$23	$22	$23
Economic Development Value	$44	$45	$45	$42	$45	$44	$45
(Solar Penetration Cost)	($23)	($23)	($23)	($22)	($23)	($22)	($22)
Total Other Value	$170	$203	$206	$199	$143	$173	$144
Total Value	**$282**	**$315**	**$318**	**$304**	**$257**	**$280**	**$256**

Contents

Introduction: The Value of PV

This report attempts to quantify the value of distributed solar electricity in Pennsylvania and New Jersey. It uses methodologies and analytical tools that have been developed 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.

The value of PV may be considered the aggregate of several components, each estimated separately, described below. The methods used to calculate value are described in more detail in the Appendices.

Fuel Cost Savings

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 system losses so that the cost of the wholesale generation that would have been lost must also be considered.

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 T&D losses. The study presumes that the energy delivered by PV displaces energy at this plant.

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

O&M Cost Savings

Under the same mechanism described for Fuel Cost Savings, 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 energy avoided, including loss savings.

Security Enhancement Value

The delivery of distributed PV energy correlated with load results in an improvement in overall system reliability. By reducing the risk of power outages and rolling blackouts, economic losses are reduced.

Long Term Societal Value

The study period is taken as 30 years (the nominal life of PV systems), and the calculation of value components includes the benefits provided over this study period. However, it is possible that the life can be longer than 30 years, in which case the full value would not be accounted for. This "long term societal value" is the potential extended benefit of all value components over a 10 year period beyond the study period. In other words, if the assumed life were 40 years instead of 30, the increase in total value is the long term societal value.

Fuel Price Hedge Value

PV generation is insensitive to the volatility of natural gas or other fuel prices, and therefore provides a hedge against price fluctuation. This is quantified by calculating the cost of a risk mitigation investment that would provide price certainty for future fuel purchases.

Generation Capacity Value

In addition to the fuel and O&M cost savings, the total cost of power generation includes capital cost. 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 fleet, and this is accomplished through an analysis of hourly PV output relative to overall utility load.

T&D Capacity Value

In addition to capital cost savings for generation, PV potentially provides utilities with capital cost savings on T&D infrastructure. In this case, PV is not assumed to displace capital costs but rather defer the need. This is because local loads continue to grow and eventually necessitate the T&D capital investment. Therefore, the cost savings realized by distributed PV is merely the cost of capital saved in the intervening period between PV installation and the time at which loads again reach the level of effective PV capacity.

Market Price Reduction

PV generation reduces the amount of load on the utility systems, and therefor reduces the amount of energy purchased on the wholesale market. The demand curve shifts to the left, and the market clearing price is reduced. Thus, the presence of PV not only displaces the need for energy, but also reduces the cost of wholesale energy to all consumers. This value is quantified through an analysis of the supply curve and the reduction in demand.

Environmental Value

One of the primary motives for PV and other renewable energy sources is to reduce the environmental impact of power generation. Environmental benefits covered in this analysis represent future savings for mitigating environmental damage (sulfur dioxide emissions, water contamination, soil erosion, etc.).

Economic Development Value

Distributed PV provides local jobs (e.g., installers) at higher rates than conventional generation. These jobs, in turn, translate to tax revenue benefits to all taxpayers.

Solar Penetration Cost

In addition to the value provided by PV, there are costs that must be factored in as necessary to accept variable solar generation onto the grid. Infrastructural and operational expenses will be incurred to manage the flow of non-dispatchable PV resources. These costs are included as a negative value.

Value Perspective

The value of solar accrues either to the electric utility or to society (ratepayers and taxpayers), depending upon component. For example, PV reduces the amount of wholesale energy needed to serve load, resulting in savings to the utility. On the other hand, environmental mitigation costs accrue to society.

Approach

Locations

Seven locations were selected to provide broad geographical and utility coverage in the two states of interest (see Table 1). Four locations were selected in Pennsylvania representing three utilities[1] and three locations were selected in New Jersey, each served by a separate utility.

Table 1. Study location summary.

		Location	Utility	2011 Utility Peak Load (MW)	PV Fleet Capacity (MW)
PA	1	Pittsburgh	Duquesne Light Co.	3,164	475
	2	Scranton	PPL Utilities Corp.	7,527	1,129
	3	Harrisburg	PPL Utilities Corp.	7,527	1,129
	4	Philadelphia	PECO Energy Co.	8,984	1,348
NJ	5	Jamesburg	Jersey Central P&L	6,604	991
	6	Newark	PSE&G	10,933	1,640
	7	Atlantic City	Atlantic City Electric	2,956	443

These locations represent a diversity of input assumptions:

- The locations span two states: PA and NJ. These states differ in generation mix (percentage of coal, gas, nuclear, etc.), and this is reflected in different environmental cost assumptions (see Appendix 2).
- The locations differ in solar resource.

[1] Scranton and Harrisburg are both served by PPL Utilities.

- The locations represent six different utility service territories. Each of these utilities differ by cost of capital, hourly loads, T&D loss factors, distribution expansion costs, and growth rate.

Penetration Level

Fleet capacity was set to 15% of the utility peak load. This assumption was intended to represent a moderate long-term penetration level.

The value of solar per MWh decreases with increasing penetration for several reasons:

- The match between PV output and loads is reduced. As more PV is added to the resource mix, the peak shifts to non-solar hours, thereby limiting the ability of PV to support the peak.
- Line losses are related to the square of the load. Consequently, the greatest marginal savings provided by PV is achieved with small amounts of PV. By adding larger and larger quantities of PV, the loss savings continue to be gained, but at decreasing rates.
- Similarly, the market prices are non-linear, and PV is most effective in causing market price reduction with small PV capacity.

Based on the above considerations, this study is intended to represent a moderate level of long-term PV penetration. With penetration levels less than 15%, the value of solar would be expected to be higher than the results obtained in this study.

Peak loads for each utility were obtained from hourly load data corresponding to PJM load zones, and these were used to set the fleet capacity as shown in the table.

Fleet Configurations

Four PV system configurations were included in the study:

- South-30 (south-facing, 30-degree tilt, fixed)
- Horizontal (fixed)
- West-30 (west facing, 30-degree tilt, fixed)
- 1-Axis (tracking at 30-degree tilt)

These were selected in order to capture possible variations in value due to the different production profiles. For example, West-facing systems are sometimes found to be the best match with utility loads and have the potential to provide more capacity benefits. On the other hand, tracking systems deliver more energy per unit of rated output, so they have the potential to offer more energy benefits (e.g., fuel cost savings).

Scenarios and Fleet Modeling

Value was determined for each of 28 scenarios (four fleet configurations at each of seven locations). For modeling purposes, fleets were described by latitude and longitude coordinates, AC rating, a module derate factor (90%), inverter efficiency (95%) and other loss factor (90%). These factors were consistent across all scenarios.

Fleets were modeled for all hours of 2011 using SolarAnywhere® satellite-derived irradiance data and simulation model with a 10 km x 10 km pixel resolution. [2] Under this procedure, the fleet output for each scenario is location- and time-correlated with hourly PJM zonal loads.

[2] http://www.solaranywhere.com.

Results

Utility Analysis

Utility analysis results are shown in Table 2, obtained from an analysis of FERC filings and PJM hourly data using methods developed previously for NYSERDA.[3] These include:

- Utility discount rate
- Utility system loss data
- Distribution expansion costs (present value)
- Distribution load growth rate
- Distribution loss data

Note that actual utility costs are used in this analysis because they are the basis of value. For this reason, the utility cost of capital is required (e.g., an "assumed" or "common" value cannot be used). The results may therefore differ, in part, due to differences in utility discount rate.

PV Technical Analysis

A summary of fleet technical performance results is presented in Table 3. Annual energy production is the modeled output for 2011. Capacity factor is the annual energy production relative to a baseload plant operating at 100% availability with the same rated output. Generation capacity is Effective Load Carrying Capability (ELCC) expressed as a percentage of rated capacity. T&D Capacity is a measure of the direct annual peak-load reduction provided by the PV system expressed as a percentage of rated capacity.

[3] Norris and Hoff, "PV Valuation Tool," Final Report (DRAFT), NYSERDA, May 2012.

Table 2. Utility analysis results.

		Pittsburgh	Scranton	Harrisburg	Philadelphia	Jamesburg	Newark	Atlantic City
Utility		Duquesne Light Co.	PPL Utilities Corp.	PPL Utilities Corp.	PECO Energy Co.	Jersey Central P&L	PSE&G	Atlantic City Electric
UtilityID		DUQ	PPL	PPL	PECO	JCPL	PSEG	AECO
UTILITY DATA								
Economic Factors								
Discount Rate	percent per year	6.63%	8.08%	8.08%	9.00%	5.68%	8.46%	5.88%
Utility System								
Load Loss Condition	MW	1,757	4,786	4,786	4,958	2,893	5,435	1,369
Avg. Losses (at Condition)	percent	5.84%	6.55%	6.55%	4.23%	6.35%	4.86%	5.61%
Distribution								
Distribution Expansion Cost	$ PW	$485,009,880	$423,994,174	$423,994,174	$722,046,118	$446,914,440	$573,820,751	$288,330,547
Distribution Expansion Cost Escalation	percent per year	3.89%	3.89%	3.89%	3.89%	3.89%	3.89%	3.89%
Distribution Load Growth Rate	MW per year	30.9	98.3	98.3	110.7	93.4	91.4	39.5
Load Loss Condition	MW	1,757	4,786	4,786	4,958	2,893	5,435	1,369
Avg. Losses (at Condition)	percent	5.84%	6.55%	6.55%	4.23%	6.35%	4.86%	5.61%

Table 3. Technical results, by location (South-30).

	Pittsburgh	Harrisburg	Scranton	Philadelphia	Jamesburg	Newark	Atlantic City
Fleet Capacity (MWac)	475	1129	1129	1348	991	1640	443
Annual Energy Production (MWh)	716,621	1,809,443	1,698,897	2,339,424	1,675,189	2,677,626	827,924
Capacity Factor (%)	17%	18%	17%	20%	19%	19%	21%
Generation Capacity (% of Fleet Capacity)	41%	28%	28%	38%	45%	45%	46%
T&D Capacity (% of Fleet Capaccity)	31%	14%	14%	21%	29%	56%	36%

Value Analysis

Figure 1 shows the value results in levelized dollars per MWh generated. Figure 2 shows the data in dollars per kW installed. This data is also presented in tabular form in Table 4 and Table 5. Detailed results for individual locations are shown in Appendix 3.

The total value ranges from $256 per MWh to $318 per MWh. Of this, the highest value components are the Market Price Reduction (averaging $55 per MWh) and the Economic Development Value (averaging $44 per MWh).

The differences between Table 4 and Table 5 are due to differences in the cost of capital between the utilities. For example, Atlantic City has the highest value per installed kW, but Atlantic City Electric has one of the lowest calculated discount rates (Table 2). Therefore, when this value is levelized over the 30 year study period, it represents a relatively low value.

Other observations:

- **Market Price Reduction**. The two locations of highest total value (Harrisburg and Scranton) are noted for their high Market Price Reduction value. This may be the result of a good match between LMP and PV output. By reducing demand during the high priced hours, a cost savings is realized by all consumers. Further investigation of the methods may be warranted in light of two arguments put forth by Felder [32]: that the methodology does address induced increase in demand due to price reductions, and that it only addresses short-run effects (ignoring the impact on capacity markets).
- **Environmental Value**. The state energy mix is a differentiator of environmental value. Pennsylvania (with a large component of coal-fired generation in its mix) leads to higher environmental value in locations in that state relative to New Jersey. As described in Appendix 2, the PA generation mix is dominated by coal (48%) compared to NJ (10%).
- **T&D Capacity Value**. T&D capacity value is low for all scenarios, with the average value of only $3 per MWh. This may be explained by the conservative method taken for calculating the effective T&D capacity.
- **Fuel Price Hedge**. The cost of eliminating future fuel purchases—through the use of financial hedging instruments—is directly related to the utility's cost of capital. This may be seen by comparing the hedge value in Jamesburg and Atlantic City. At a rate of 5.68%, Jersey Central Power & Light (the utility serving Jamesburg) has the lowest calculated cost of capital among the

six utilities included in the study. In contrast, PSE&G (the utility serving Newark) has a calculated discount rate of 8.46%, the highest among the utilities. This is reflected in the relative hedge values of $24 per MWh for Jamesburg and $44 per MWh for Newark, nearly twice the value.

Figure 1. Levelized value ($/MWh), by location (South-30).

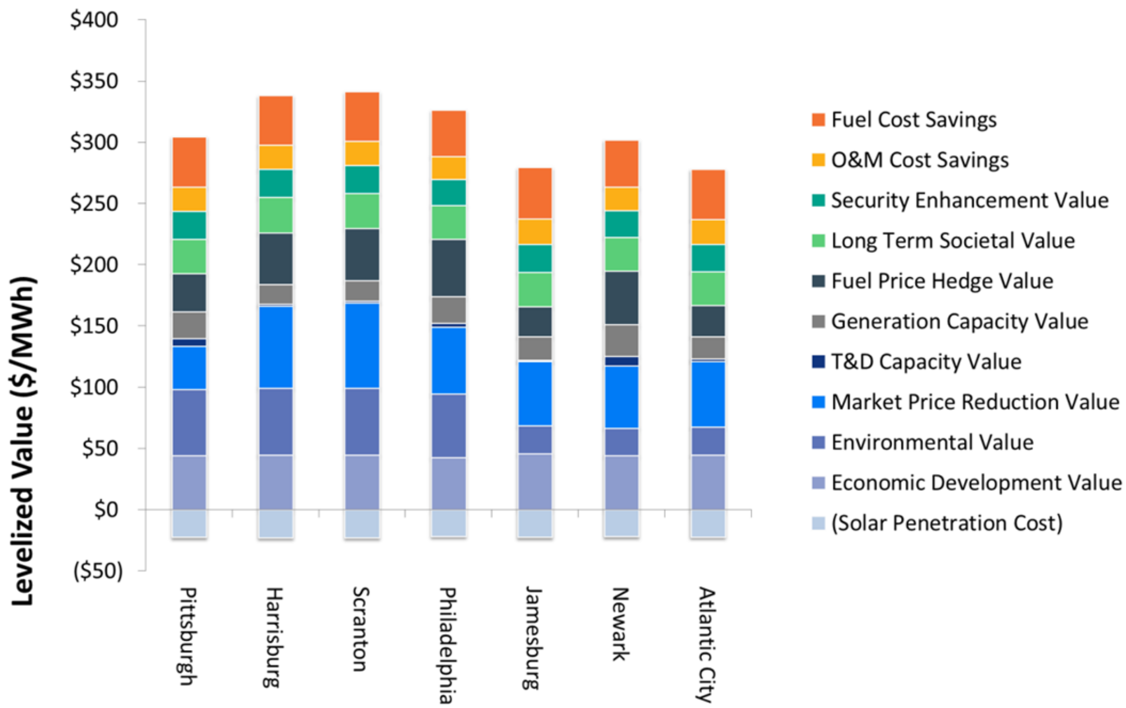


Figure 2. Value ($/kW), by location (South-30).

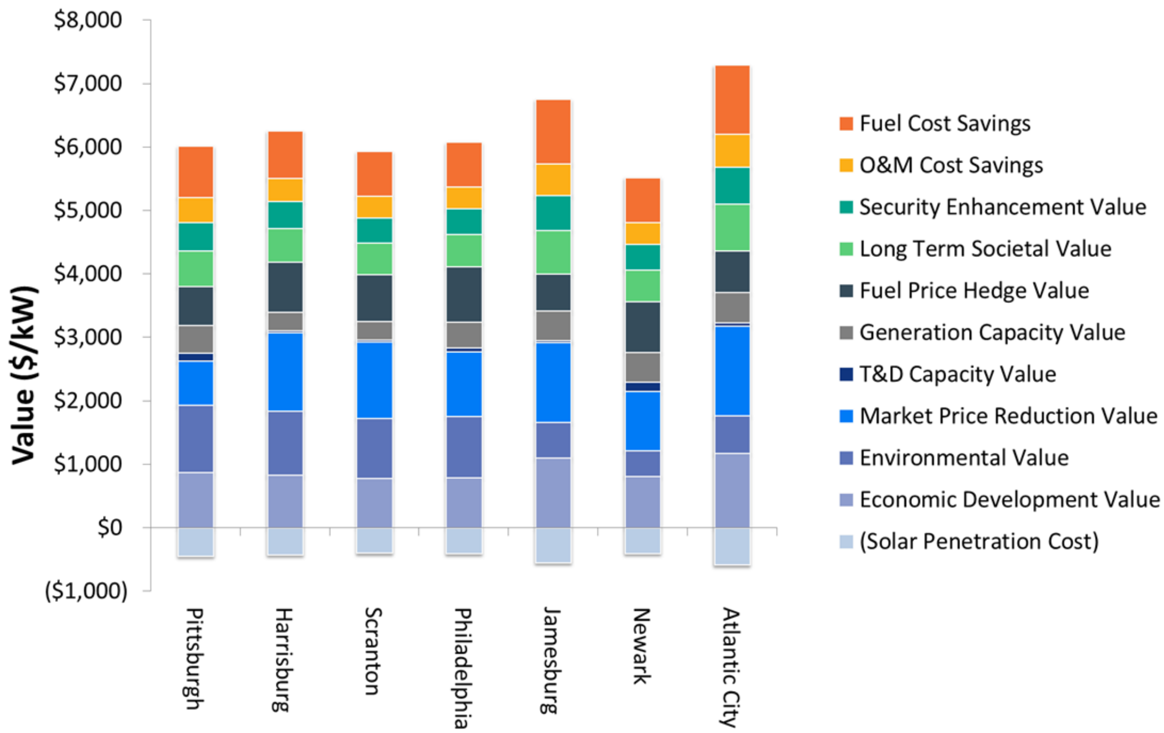


Table 4. Value (levelized $/MWh), by location (South-30).

	Pittsburgh	Harrisburg	Scranton	Philadelphia	Jamesburg	Newark	Atlantic City
Energy							
Fuel Cost Savings	$41	$41	$41	$38	$42	$39	$41
O&M Cost Savings	$20	$20	$20	$18	$21	$19	$20
Total Energy Value	$61	$60	$60	$56	$63	$58	$61
Strategic							
Security Enhancement Value	$23	$23	$23	$22	$23	$22	$22
Long Term Societal Value	$28	$29	$29	$27	$28	$28	$28
Total Strategic Value	$51	$52	$52	$49	$51	$50	$50
Other							
Fuel Price Hedge Value	$31	$42	$42	$47	$24	$44	$25
Generation Capacity Value	$22	$16	$17	$22	$19	$26	$18
T&D Capacity Value	$6	$1	$1	$3	$1	$8	$2
Market Price Reduction Value	$35	$67	$69	$54	$52	$51	$54
Environmental Value	$54	$55	$55	$52	$23	$22	$23
Economic Development Value	$44	$45	$45	$42	$45	$44	$45
(Solar Penetration Cost)	($23)	($23)	($23)	($22)	($23)	($22)	($22)
Total Other Value	$170	$203	$206	$199	$143	$173	$144
Total Value	**$282**	**$315**	**$318**	**$304**	**$257**	**$280**	**$256**

Table 5. Value ($/kW), by location (South-30).

	Pittsburgh	Harrisburg	Scranton	Philadelphia	Jamesburg	Newark	Atlantic City
Energy							
Fuel Cost Savings	$813	$751	$706	$706	$1,020	$709	$1,081
O&M Cost Savings	$396	$366	$344	$344	$497	$345	$527
Total Energy Value	$1,209	$1,117	$1,050	$1,049	$1,517	$1,054	$1,609
Strategic							
Security Enhancement Value	$446	$424	$398	$405	$549	$403	$584
Long Term Societal Value	$557	$530	$498	$507	$686	$504	$730
Total Strategic Value	$1,003	$954	$896	$912	$1,234	$907	$1,314
Other							
Fuel Price Hedge Value	$613	$786	$738	$876	$586	$798	$662
Generation Capacity Value	$432	$297	$290	$401	$468	$470	$478
T&D Capacity Value	$127	$24	$24	$65	$23	$147	$49
Market Price Reduction Value	$696	$1,241	$1,206	$1,013	$1,266	$927	$1,412
Environmental Value	$1,064	$1,011	$950	$967	$560	$411	$596
Economic Development Value	$870	$827	$777	$790	$1,097	$806	$1,168
(Solar Penetration Cost)	($446)	($424)	($398)	($405)	($549)	($403)	($584)
Total Other Value	$3,355	$3,761	$3,586	$3,706	$3,451	$3,156	$3,781
Total Value	**$5,568**	**$5,832**	**$5,532**	**$5,667**	**$6,202**	**$5,117**	**$6,704**

Future Work

In the course of conducting this study, several observations were made that suggest further refinement to these results should be considered:

- The market price reduction estimated as part of the present study will have to be ascertained as PV develops and penetrates the NJ and PA grids. In particular, the impact of PV-induced price reduction on load growth, hence feedback secondary load-growth induced market price increase as suggested by Felder [32] should be quantified. In addition, the feedback of market price reduction on capacity markets will have to be investigated.

- In this study 15% PV capacity penetration was assumed-- amounting to a total PV capacity of 7GW across the seven considered utility hubs. Since both integration cost increases and capacity value diminishes with penetration, it will be worthwhile to investigate other penetration scenarios. This may be particularly useful for PA where the penetration is smaller than NJ. In addition, it may be useful to see the scenarios with penetration above 15%. For these cases, it would be pertinent to establish the cost of displacing (nuclear) baseload generation with solar generation[4] since this question is often brought to the forefront by environmentally-concerned constituents in densely populated areas of NJ and PA.

- Other sensitivities may be important to assess as well. Sensitivities to fuel price assumptions, discount rates, and other factors could be investigated further. In particular the choice made here to use documented utility-specific discount rates and its impact on the per MWh levelized results[5] could be quantified and compared to an assumption using a common discount rate representative of average regional business practice.

- The T&D values derived for the present analysis are based on utility-wide average loads. Because this value is dependent upon the considered distribution system's characteristics – in particular load growth, customer mix and equipment age – the T&D value may vary considerably from one distribution feeder to another. It would therefore be advisable to take this study one step further and systematically identify the highest value areas. This will require the collaboration of the servicing utilities to provide relevant subsystem data.

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[4] Considering integration solutions including storage, wind/PV synergy and gas generation backup.

[5] Note that the per kW value results are much less dependent upon the discount rate

Appendix 1: Detailed Assumptions

Input assumptions that are common across all of the scenarios are shown in Table 6.

Table 6. Input assumptions and units common to all scenarios.

INPUT ASSUMPTIONS		
PV Characteristics		
PV Degradation	0.50%	per year
PV System Life	30	years
Generation Factors		
Gen Capacity Cost	$1,045	per kW
Gen Heat Rate (First Year)	7050	BTU/kWh
Gen Plant Degradation	0.00%	per year
Gen O&M Cost (First Year)	$12.44	per MWh
Gen O&M Cost Escalation	3.38%	per year
Garver Percentage	5.00%	Pct of Ann Peak
NG Wholesale Market Factors		
End of Term NG Futures Price Escalation	2.33%	per year

PV degradation is assumed to be 0.50% per year indicating that the output of the system will degrade over time. This is a conservative assumption (PV degradation is likely to be less than 0.5% per year). Studies often ignore degradation altogether because the effect is small, but it is included here for completeness.

The study period is taken as 30 years, corresponding to typical PV lifetime assumptions.

PV is assumed to displace power generated from peaking plants fueled by natural gas. Gas turbine capital, O&M, heat rate, and escalation values are taken from the EIA.[6] Plant degradation is assumed to be zero.

[6] Updated Capital Cost Estimates for Electricity Generation Plants, U.S. Energy Information Administration, November 2010, available at http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf. Taken from Table 1, page 7. Costs are escalated to 2012 dollars.

Costs for generation O&M are assumed to escalate at 3.38%, calculated from the change in Producer Price Index (PPI) for the “Turbine and power transmission equipment manufacturing” industry[7] over the period 2004 to 2011.

Natural gas prices used in the fuel price savings value calculation are obtained from the NYMEX futures prices. These prices, however, are only available for the first 12 years. Ideally, one would have 30 years of futures prices. As a proxy for this value, it is assumed that escalation after year 12 is constant based on historically long term prices to cover the entire 30 years of the PV service life (years 13 to 30). The EIA published natural gas wellhead prices from 1922 to the present.[8] It is assumed that the price of the NG futures escalates at the same rate as the wellhead prices.[9] A 30-year time horizon is selected with 1981 gas prices at $1.98 per thousand cubic feet and 2011 prices at $3.95. This results in a natural gas escalation rate of 2.33%.

[7] PPI data is downloadable from the Bureau industry index selected was taken as the most representative of power generation O&M. BLS does publish an index for “Electric power generation” but this is assumed.

[8] US Natural Gas Prices (Annual), EIA, release date 2/29/2012, available at http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm.

[9] The exact number could be determined by obtaining over-the-counter NG forward prices.

Appendix 2: Methodologies

Overview

The methodologies used in the present project drew upon studies performed by CPR for other states and utilities. In these studies, the key value components provided by PV were determined by CPR, using utility-provided data and other economic data.

The ability to determine value on a site-specific basis is essential to these studies. For example, the T&D Capacity Value component depends upon the ability of PV to reduce peak loads on the circuits. An analysis of this value, then, requires:

Hour by hour loads on distribution circuits of interest.

- Hourly expected PV outputs corresponding to the location of these circuits and expected PV system designs.
- Local distribution expansion plan costs and load growth projections.

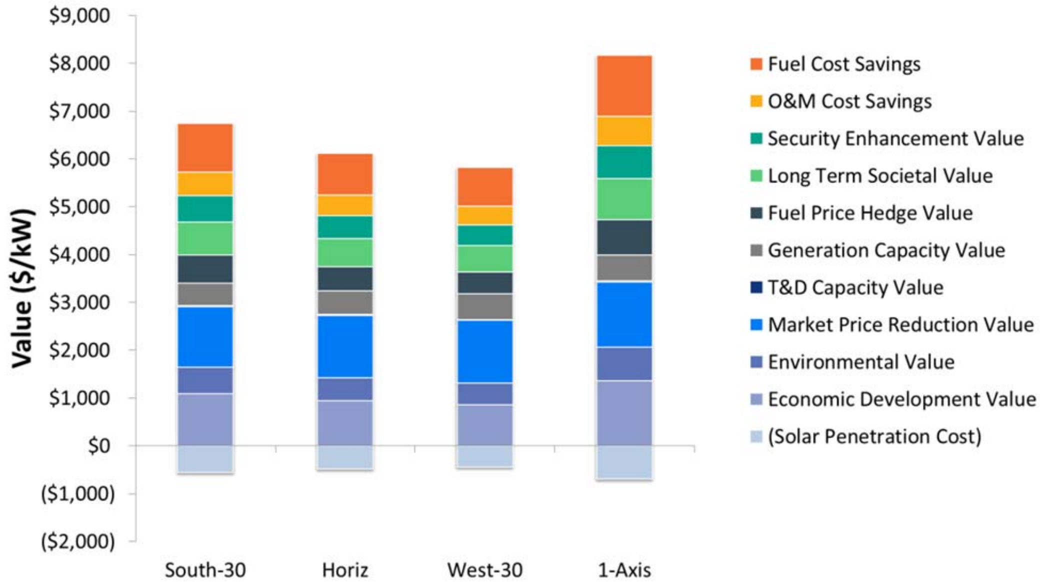
Units of Results

The discounting convention assumed throughout the report is that energy-related values occur at the end of each year and that capacity-related values occur immediately (i.e., no discounting is required).[10]

The Present Value results are converted to per unit value (Present Value $/kW) by dividing by the size of the PV system (kW). An example of this conversion is illustrated in Figure 3 for results from a previous study. The y-axis presents the per unit value and the x-axis presents seven different PV system configurations. The figure illustrates how value components can be significantly affected by PV system configuration. For example, the tracking systems, by virtue of their enhanced energy production capability, provide greater generation benefits.

[10] The effect of this will be most apparent in that the summations of cash flows start with the year equal to 1 rather than 0.

Figure 3. Sample results.



The present value results per unit of capacity ($/kW) are converted to levelized value results per unit of energy ($/MWh) by dividing present value results by the total annual energy produced by the PV system and then multiplying by an economic factor.

PV Production and Loss Savings

PV System Output

An accurate PV value analysis begins with a detailed estimate of PV system output. Some of the energy-based value components may only require the total amount of energy produced per year. Other value components, however, such as the energy loss savings and the capacity-based value components, require hourly PV system output in order to determine the technical match between PV system output and the load. As a result, the PV value analysis requires time-, location-, and configuration-specific PV system output data.

For example, suppose that a utility wants to determine the value of a 1 MW fixed PV system oriented at a 30° tilt facing in the southwest direction located at distribution feeder "A". Detailed PV output data that is time- and location-specific is required over some historical period, such as from Jan. 1, 2001 to Dec. 31, 2010.

Methodology

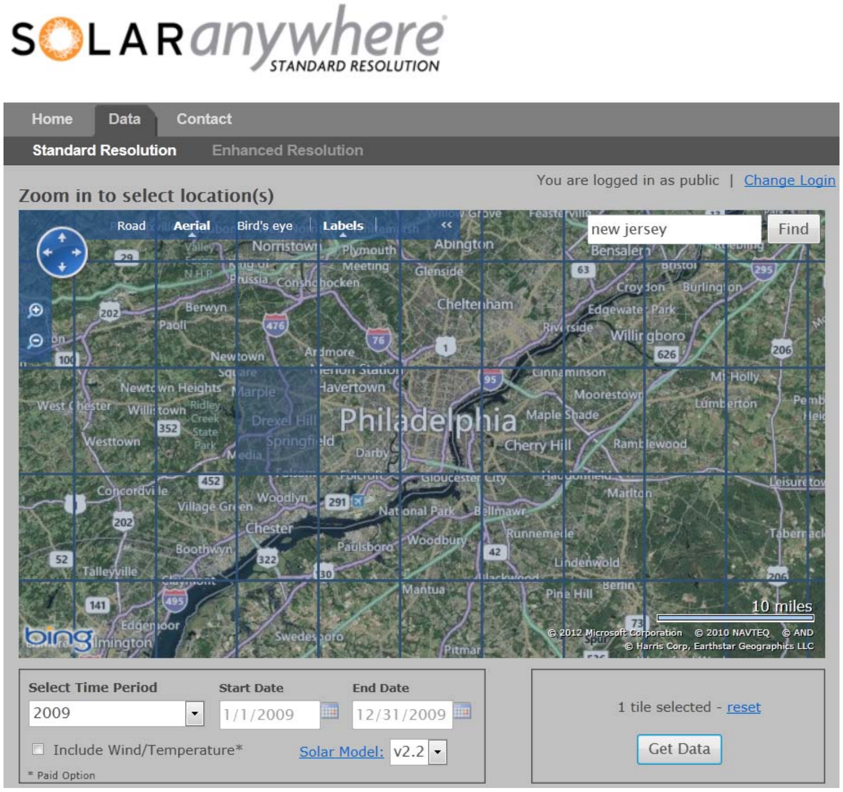
It would be tempting to use a representative year data source such as NREL's Typical Meteorological Year (TMY) data for purposes of performing a PV value analysis. While these data may be representative of long-term conditions, they are, by definition, not time-correlated with actual distribution line loading on an hourly basis and are therefore not usable in hourly side-by-side comparisons of PV and load. Peak substation loads measured, say, during a mid-August five-day heat wave must be analyzed alongside PV data that reflect the same five-day conditions. Consequently, a technical analysis based on anything other than time- and location-correlated solar data may give incorrect results.

CPR's SolarAnywhere® and PVSimulator™ software services will be employed under this project to create time-correlated PV output data. SolarAnywhere is a solar resource database containing almost 14 years of time- and location-specific, hourly insolation data throughout the continental U.S. and Hawaii. PVSimulator, available in the SolarAnywhere Toolkit, is a PV system modeling service that uses this hourly resource data and user-defined physical system attributes in order to simulate configuration-specific PV system output.

The SolarAnywhere data grid web interface is available at www.SolarAnywhere.com (Figure 4). The structure of the data allows the user to perform a detailed technical assessment of the match between PV system output and load data (even down to a specific feeder). Together, these two tools enable the evaluation of the technical match between PV system output and loads for any PV system size and orientation.

Previous PV value analyses were generally limited to a small number of possible PV system configurations due to the difficulty in obtaining time- and location-specific solar resource data. This new value analysis software service, however, will integrate seamlessly with SolarAnywhere and PVSimulator. This will allow users to readily select any PV system configuration. This will allow for the evaluation of a comprehensive set of scenarios with essentially no additional study cost.

Figure 4. SolarAnywhere data selection map.



Loss Savings

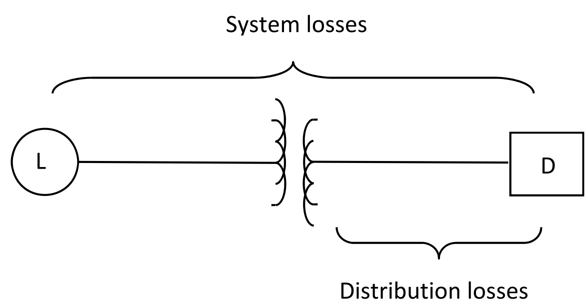
Introduction

Distributed resources reduce system losses because they produce power in the same location that the power is consumed, bypassing the T&D system and avoiding the associated losses.

Loss savings are not treated as a stand-alone benefit under the convention used in this methodology. Rather, the effect of loss savings is included separately for each value component. For example, in the section that covers the calculation of Energy Value, the quantity of energy saved by the utility includes both the energy produced by PV and the amount that would have been lost due to heating in the wires if the load were served from a remote source. The total energy that would have been procured by the utility equals the PV energy plus avoided line losses. Loss savings can be considered a sort of “adder” for each benefit component.

This section describes the methodology for calculating loss savings for each hour. The results of these calculations are then used in subsequent sections. As illustrated in Figure 5, it will be important to note that, while the methodology describes the calculation of an hourly loss result, there are actually two different loss calculations that must be performed: "system" losses, representing the losses incurred on both the transmission and distribution systems (between generation load, L, and end-use demand, D), and "distribution" losses, representing losses specific to distribution system alone.

Figure 5. System losses versus distribution losses.



The two losses are calculated using the same equation, but they are each applicable in different situations. For example, "Energy Value" represents a benefit originating at the point of central generation, so that the total system losses should be included. On the other hand, "T&D Capacity Value" represents a benefit as measured at a distribution substation. Therefore, only the losses saved on the distribution system should be considered.

The selection of "system" versus "distribution" losses is discussed separately for each subsequent benefit section.

Methodology

One approach analysts have used to incorporate losses is to adjust energy- and capacity-related benefits based on the *average* system losses. This approach has been shown to be deficient because it fails to capture the true reduction in losses on a marginal basis. In particular, the approach underestimates the reduction in losses due to a peaking resource like PV. Results from earlier studies demonstrated that loss savings calculations may be off by more than a factor of two if not performed correctly [6].

For this reason, the present methodology will incorporate a calculation of loss savings on a marginal basis, taking into account the status of the utility grid when the losses occur. Clean Power Research has previously developed methodologies based on the assumption that the distributed PV resource is small relative to the load (e.g., [6], [9]). CPR has recently completed new research that expands this methodology so that loss savings can now be determined for any level of PV penetration.

Fuel Cost Savings and O&M Cost Savings

Introduction

Fuel Cost Savings and O&M Cost Savings are the benefits that utility participants derive from using distributed PV generation to offset wholesale energy purchases or reduce generation costs. 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 system losses so that the cost of the wholesale generation that would have been lost must also be considered. The capacity value of generation is treated in a separate section.

Methodology

These values can be calculated by multiplying PV system output times the cost of the generation on the margin for each hour, summing for all hours over the year, and then discounting the results for each year over the life of the PV system.

There are two approaches to obtaining the marginal cost data. One approach is to obtain the marginal costs based on historical or projected market prices. The second approach is to obtain the marginal costs based on the cost of operating a representative generator that is on the margin.

Initially, it may be appealing to take the approach of using market prices. There are, however, several difficulties with this approach. One difficulty is that these tend to be hourly prices and thus require hourly PV system output data in order to calculate the economic value. This difficulty can be addressed by using historical prices and historical PV system output to evaluate what results would have been in the past and then escalating the results for future projections. A more serious difficulty is that, while hourly market prices could be projected for a few years into the future, the analysis needs to be performed over a much longer time period (typically 30 years). It is difficult to accurately project hourly market prices 30 years into the future.

A more robust approach is to explicitly specify the marginal generator and then to calculate the cost of the generation from this unit. This is often a Combined Cycle Gas Turbine (CCGT) powered using natural gas (e.g., [6]). This approach includes the assumption that PV output always displaces energy from the same marginal unit. Given the uncertainties and complications in market price projections, the second approach is taken.

Fuel Cost Savings and O&M Cost Savings equals the sum of the discounted fuel cost savings and the discounted O&M cost savings.

Security Enhancement Value

Because solar generation is closely correlated with load in much of the US, including New Jersey and Pennsylvania [26], the injection of solar energy near point of use can deliver effective capacity, and therefore reduce the risk of the power outages and rolling blackouts that are caused by high demand and resulting stresses on the transmission and distribution systems.

The effective capacity value of PV accrues to the ratepayer (see above) both at the transmission and distribution levels. It is thus possible to argue that the reserve margins required by regulators would account for this new capacity, hence that no increased outage risk reduction capability would occur beyond the pre-PV conditions. This is the reason this value item above is not included as one of the directly quantifiable attributes of PV.

On the other hand there is ample evidence that during heat wave-driven extreme conditions, the availability of PV is higher than suggested by the effective capacity (reflecting of all conditions) -- e.g., see [27], [28], on the subject of major western and eastern outages, and [29] on the subject of localized rolling blackouts. In addition, unlike conventional centralized generation injecting electricity (capacity) at specific points on the grid, PV acts as a load modulator that provides immediate stress relief throughout the grid where stress exists due to high-demand conditions. It is therefore possible to argue that, all conditions remaining the same in terms of reserve margins, a load-side dispersed PV resource would mitigate issues leading to high-demand-driven localized and regional outages.

Losses resulting from power outages are generally not a utility's (ratepayers') responsibility: society pays the price, via losses of goods and business, compounded impacts on the economy and taxes, insurance premiums, etc. The total cost of all power outages from all causes to the US economy has been estimated at $100 billion per year (Gellings & Yeager, 2004). Making the conservative assumption that a small fraction of these outages, 5%, are of the high-demand stress type that can be effectively mitigated by dispersed solar generation at a capacity penetration of 15%,[11] it is straightforward to calculate, as shown below, that, nationally, the value of each kWh generated by such a dispersed solar base would be of the order of $20/MWh to the taxpayer.

The US generating capacity is roughly equal to 1000 GW. At 15% capacity penetration, taking a national average of 1500 kWh (slightly higher nationwide than PA and NJ) generated per year per installed kW, PV would generate 225,000 GWh/year. By reducing the risk of outage by 5%, the value of this energy would thus be worth $5 billion, amounting to $20 per PV-generated MWh.

This national value of $20 per MWh was taken for the present study because the underlying estimate of cost was available on a national basis. In reality, there would be state-level differences from this estimate, but these are not available.

Long Term Societal Value

This item is an attempt to place a present-value $/MWh on the generally well accepted argument that solar energy is a good investment for our children and grandchildren's well-being. Considering:

1. The rapid growth of large new world economies and the finite reserves of conventional fuels now powering the world economies, it is likely that fuel prices will continue to rise exponentially fast for the long term beyond the 30-year business life cycle considered here.
2. The known very slow degradation of the leading (silicon) PV technology, many PV systems installed today will continue to generate power at costs unaffected by the world fuel markets after their guaranteed lifetimes of 25-30 years

One approach to quantify this type of long-view attribute has been to apply a very low societal discount rate (e.g., 2% or less, see [25]) to mitigate the fact that the present-day importance of long-term expenses/benefits is essentially ignored in business as usual practice. This is because discount rates are

[11] Much less than that would have prevented the 2003 NE blackout. See [30].

used to quantify the present worth of future events and that, and therefore, long-term risks and attributes are largely irrelevant to current decision making.

Here a less controversial approach is proposed by arguing that, on average, PV installation will deliver, on average, a minimum of 10 extra years of essentially free energy production beyond the life cycle considered in this study.

The present value of these extra 10 years, all other assumptions on fuel cost escalation, inflation, discount rate, PV output degradation, etc. remaining the same, amounts to ~ $25/MWh for all the cities/PJM hubs considered in this study.

Fuel Price Hedge Value

Introduction

Solar-based generation is insensitive to the volatility of fuel prices while fossil-based generation is directly tied to fuel prices. Solar generation, therefore, offers a "hedge" against fuel price volatility. One way this has been accounted for is to quantify the value of PV's hedge against fluctuating natural gas prices [6].

Methodology

The key to calculating the Fuel Price Hedge Value is to effectively convert the fossil-based generation investment from one that has substantial fuel price uncertainty to one that has no fuel price uncertainty. This can be accomplished by entering into a binding commitment to purchase a lifetime's worth of fuel to be delivered as needed. The utility could set aside the entire fuel cost obligation up front, investing it in risk-fee securities to be drawn from each year as required to meet the obligation. The approach uses two financial instruments: risk-free, zero-coupon bonds[12] and a set of natural gas futures contracts.

Consider how this might work. Suppose that the CCGT operator wants to lock in a fixed price contract for a sufficient quantity of natural gas to operate the plant for one month, one year in the future. First, the operator would determine how much natural gas will be needed. If E units of electricity are to be generated and the heat rate of the plant is H, $E * H$ BTUs of natural gas will be needed. Second, if the corresponding futures price of this natural gas is $P^{NG\ Futures}$ (in $ per BTU), then the operator will need $E *$

[12] A zero coupon bond does not make any periodic interest payments.

$H * P^{NG\ Futures}$ dollars to purchase the natural gas one year from now. Third, the operator needs to set the money aside in a risk-free investment, typically a risk-free bond (rate-of-return of $r^{risk\text{-}free}$ percent) to guarantee that the money will be available when it is needed one year from now. Therefore, the operator would immediately enter into a futures contract and purchase $E * H * P^{NG\ Futures} / (1+ r^{risk\text{-}free})$ dollars worth of risk-free, zero-coupon bonds in order to guarantee with certainty that the financial commitment (to purchase the fuel at the contract price at the specified time) will be satisfied.[13]

This calculation is repeated over the life of the plant to calculate the Fuel Price Hedge value.

Generation Capacity Value

Introduction

Generation Capacity Value is the benefit from added capacity provided to the generation system by distributed PV. Two different approaches can be taken to evaluating the Generation Capacity Value component. One approach is to obtain the marginal costs based on market prices. The second approach is to estimate the marginal costs based on the cost of operating a representative generator that is on the margin, typically a Combined Cycle Gas Turbine (CCGT) powered by natural gas.

Methodology

The second approach is taken here for purposes of simplicity. Future version of the software service may add a market price option.

Once the cost data for the fully-dispatchable CCGT are obtained, the match between PV system output and utility loads needs to be determined in order to determine the effective value of the non-dispatchable PV resource. CPR developed a methodology to calculate the effective capacity of a PV system to the utility generation system (see [10] and [11]) and Perez advanced this method and called it the Effective Load Carrying Capability (ELCC) [12]. The ELCC method has been identified by the utility industry as one of the preferable methods to evaluate PV capacity [13] and has been applied to a variety of places, including New York City [14].

The ELCC is a statistical measure of effective capacity. The ELCC of a generating unit in a utility grid is defined as the load increase (MW) that the system can carry while maintaining the designated reliability

[13] $[E * H * P^{NG\ Futures} / (1+ r^{risk\text{-}free})] * (1+ r^{risk\text{-}free}) = E * H * P^{NG\ Futures}$

criteria (e.g., constant loss of load probability). The ELCC is obtained by analyzing a statistically significant time series of the unit's output and of the utility's power requirements.

Generation Capacity Value equals the capital cost ($/MW) of the displaced generation unit times the effective capacity provided by the PV.

T&D Capacity Value

Introduction

The benefit that can be most affected by the PV system's location is the T&D Capacity Value. The T&D Capacity Value depends on the existence of location-specific projected expansion plan costs to ensure reliability over the coming years as the loads grow. Capacity-constrained areas where loads are expected to reach critical limits present more favorable locations for PV to the extent that PV will relieve the constraints, providing more value to the utility than those areas where capacity is not constrained.

Distributed PV generation reduces the burden on the distribution system. It appears as a "negative load" during the daylight hours from the perspective of the distribution operator. Distributed PV may be considered equivalent to distribution capacity from the perspective of the distribution planner, provided that PV generation occurs at the time of the local distribution peak.

Distributed PV capacity located in an area of growing loads allows a utility planner to defer capital investments in distribution equipment such as substations and lines. The value is determined by the avoided cost of money due to the capital deferral.

Methodology

It has been demonstrated that the T&D Capacity Value can be quantified in a two-step process. The first step is to perform an economic screening of all areas to determine the expansion plan costs and load growth rates for each planning area. The second step is to perform a technical load-matching analysis for the most promising locations [18].

Market Price Reduction Value

Two cost savings occur when distributed PV generation is deployed in a market that is structured where the last unit of generation sets the price for all generation and the price is an increasing function of load. First, there is the direct savings that occur due to a reduction in load. This is the same as the value of energy provided at the market price of power. Second, there is the indirect value of market price reduction. Distributed generation reduces market demand and this results in lower prices to all those purchasing power from the market. This section outlines how to calculate the market savings value.

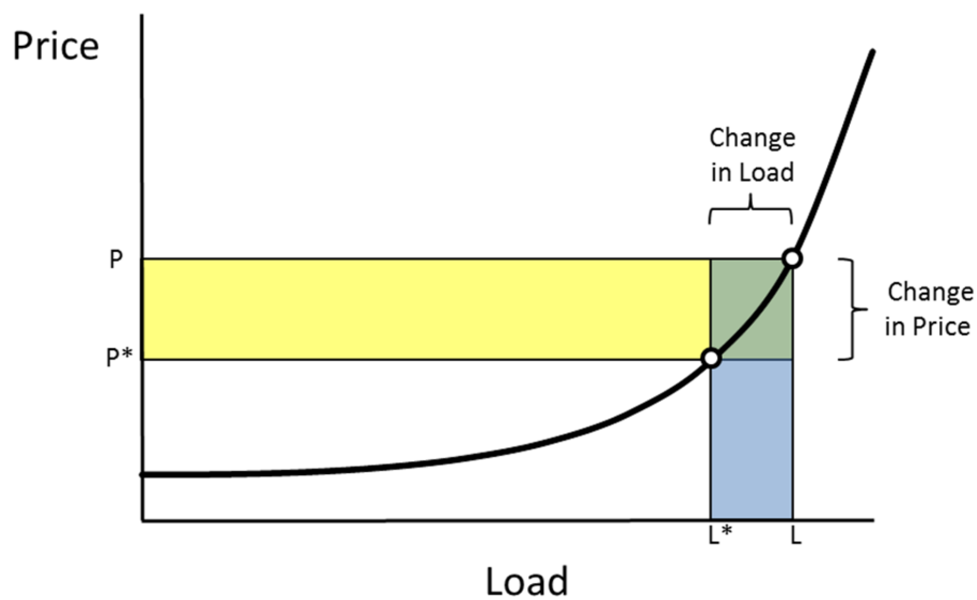
Cost Savings

As illustrated in Figure 6, the total market expenditures at any given point in time are based on the current price of power (P) and the current load (L). The rate of expenditure equals P L. Total market expenditures after PV is deployed equals the new price (P*) times the new load (L*), or P*L*. Cost savings equal the difference between the total before and after expenditures.

$$Cost\ Savings = P\ L - P^{*}L^{*} \quad \textbf{(1)}$$

The figure illustrates that the cost savings occur because there is both a change in load and a change in price.

Figure 6. Illustration of price changes that occur in market as result of load changes.



Equation (1) can be expanded by adding $-P^{*}L + P^{*}L$ and then rearranging the result.

$$Cost\ Savings \quad = P\ L + (-P^{*}L + P^{*}L) - P^{*}L^{*} \quad (2)$$

$$= (P - P^*)L + P^*(L - L^*)$$

$$= \left[\left(\frac{P - P^*}{L - L^*}\right)L + P^*\right](L - L^*)$$

Let $\Delta L = L - L^*$ and $\Delta P = P - P^*$ and substitute into Equation (2). The result is that

$$Cost\ Savings = \left[P + \frac{\Delta P}{\Delta L}L - \Delta P\right]\Delta L \tag{3}$$

Per unit cost savings is obtained by dividing Equation (3) by ΔL.

$$Per\ Unit\ Cost\ Savings = \overbrace{P}^{Direct\ Savings} + \overbrace{\frac{\Delta P}{\Delta L}L - \Delta P}^{Market\ Price\ Reduction\ Value} \tag{4}$$

Discussion

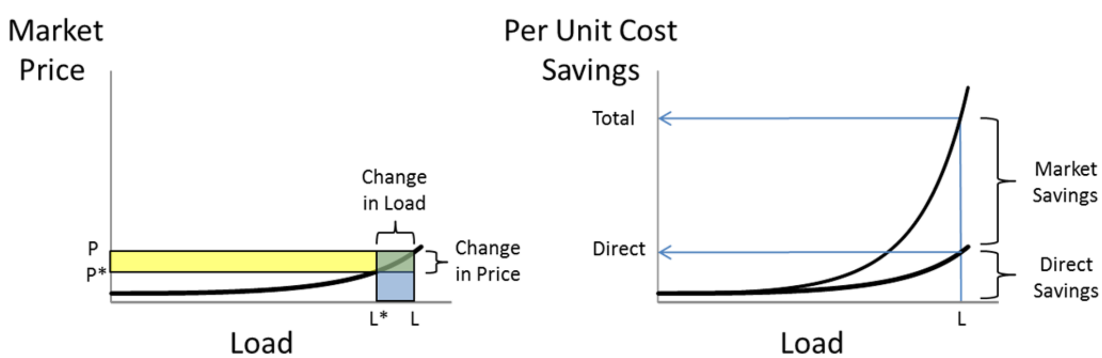
Equation (4) suggests that there are two cost savings components: direct savings and market price suppression. The direct savings equal the existing market price of power. The market price reduction value is the savings that the entire market realizes as a result of the load reduction. These savings depends on the change in load, change in price, and existing load. It is important to note that the change in load and the existing load can be measured directly while the change in price cannot be measured directly. This means that the change in price must be modeled (rather than measured).

It is useful to provide an interpretation of the market price reduction component and illustrate the potential magnitude. The market price reduction component in Equation (4) has two terms. The first term is the slope of the price curve (i.e., it is the derivative as the change in load goes to zero) times the existing load. This is the positive benefit that the whole market obtains due to price reductions. The second term is the reduced price associated with the direct savings.

The left side of Figure 7 presents the same information as in Figure 6, but zooms out on the y-axis scale of the chart. The first term corresponds to the yellow area. The second term corresponds to the overlapping areas of the change in price and change in load effects.

The market price curve can be translated to a cost savings curve. The right side of Figure 7 presents the per unit cost savings based on the information from the market price curve (i.e., the left side of the figure). The lower black line is the price vs. load curve. The upper line adds the market price suppression component to the direct savings component. It assumes that there is the same load reduction for all loads as in the left side of the figure. The figure illustrates that no market price suppression exist when the load is low but the market price suppression exceed the direct cost savings when the load is high. The saving is dependent upon the shape of the price curve and the size of the load reduction.

Figure 7. Direct + market price reduction vs. load (assuming constant load reduction).



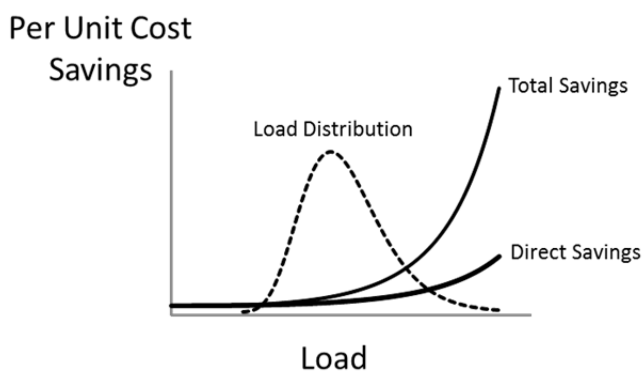
<u>Total Value</u>

The previous sections calculated the cost savings at a specific instant in time. The total cost savings is calculated by summing this result overall all periods in time. The per unit cost savings is calculated by dividing by the total energy. (Note that it is assumed that each unit of time represents 1 unit). The result is that:

$$Per\ Unit\ Cost\ Savings = \frac{Total\ Cost\ Savings}{Total\ Energy} = \frac{\sum_{t=1}^{T} \left[P_t + \frac{\Delta P_t}{\Delta L_t} L_t - \Delta P_t \right] \Delta L_t}{\sum_{t=1}^{T} \Delta L_t} \quad (5)$$

This result can be viewed graphically as the probability distribution of the load times the associate cost savings curves when there is a constant load reduction. Multiply the load distribution by the total per unit savings to obtain the weighted average per unit cost savings.

Figure 8. Apply load distribution to calculate total savings over time.



Application

As discussed above, all of the parameters required to perform this calculation can be measured directly except for the change in price. Thus, it is crucial to determine how to estimate the change in price.

This is implemented in four steps:

1. Obtain LMP price data and develop a model that reflects this data.
2. Use the LMP price model and Equation (4) to calculate the price suppression benefit. Note that this depends upon the size of the change in load.
3. Obtain time-correlated PV system output and determine the distribution of this output relative to the load.
4. Multiply the PV output distribution times the price suppression benefit to calculate the weighted-average benefit.

Historical LMP and time- and location-correlated PV output data are required to perform the analysis. LMPs are obtained from the market and the PV output data are obtained by simulating time- and location-specific PV output using SolarAnywhere.

Figure 9 illustrates how to perform the calculations using measured prices and simulated PV output for PPL in June 2012. The left side of the figure illustrates that the historical LMPs (black circles) are used to develop a price model (solid black line). The center of the figure illustrates how the price model is used with Equation (4) is used to calculate the price suppression benefit for every load level. Since this benefit depends upon the size of the change in the load, the figure presents a range. The solid blue line is the benefit for a very small PV output. The dashed blue line corresponds to the benefit for a 1,000 MW PV output. The right side of the figure (red line) presents the distribution of the PV energy relative to the load (i.e., the amount of PV energy produced at each load level, so higher values correspond to more frequent weighting). The weighted-average price suppression benefit is calculated by multiply the PV output distribution times the price suppression benefit. Note that in practice, the actual calculation is performed for each hour of the analysis since the price suppression benefit is a function of both the load and the PV output.

Figure 9. Illustration of how to calculate benefit using measured data for June 2011.

Step 1:	Step 2:	Step 3:
Develop price model based on measured LMP data	Calculate price reduction benefit (depends on output)	Develop PV output distribution

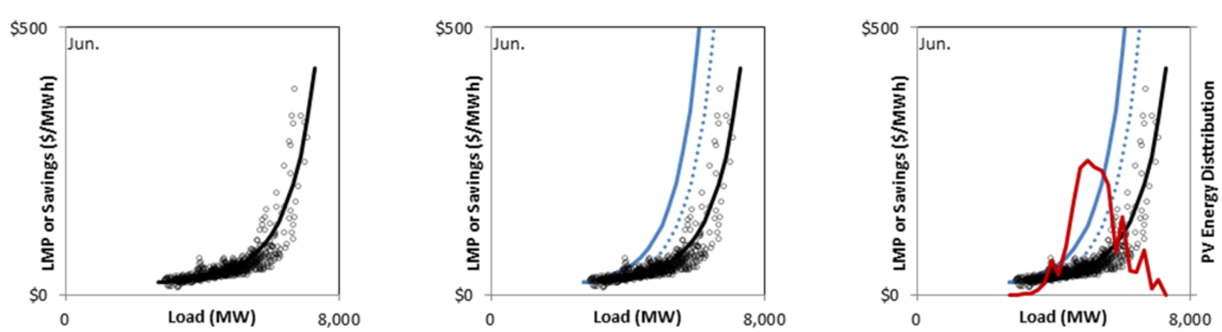
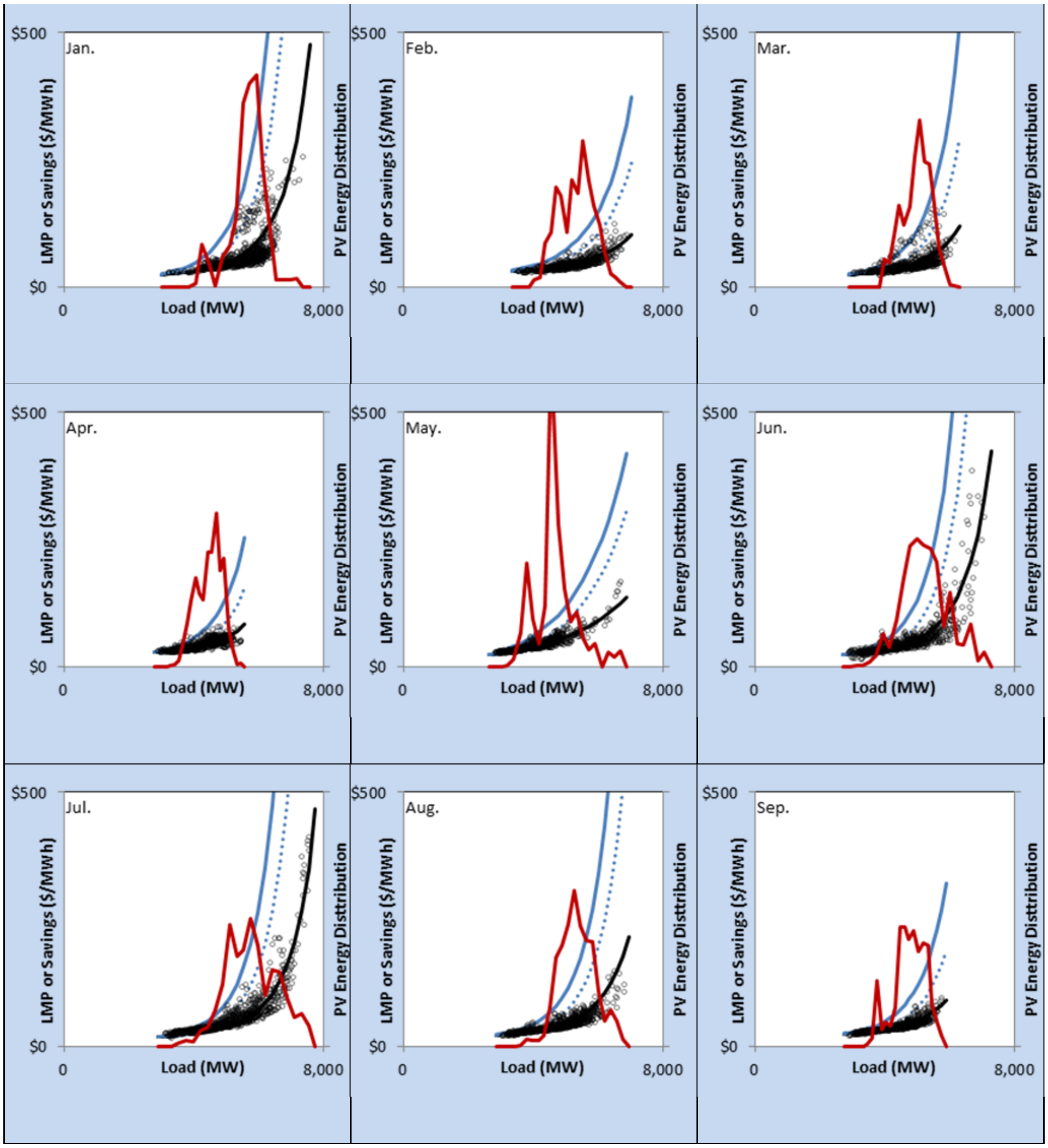
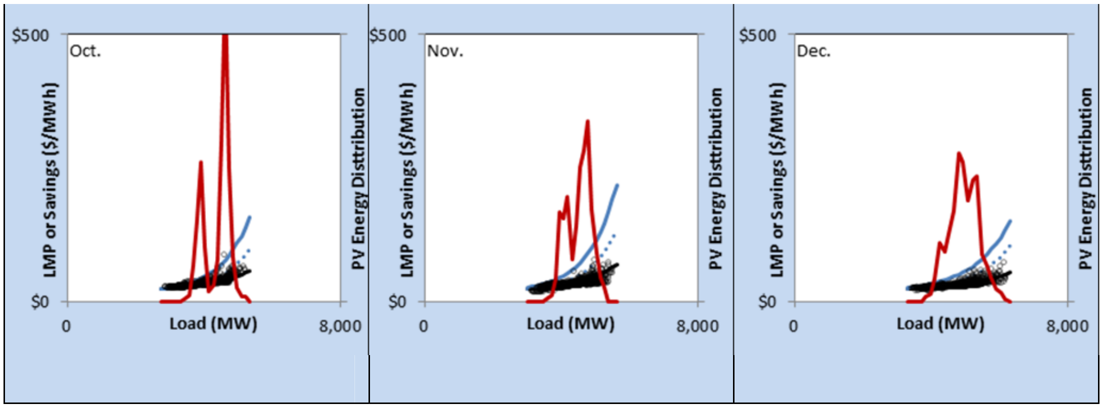


Figure 10 presents the results for the three steps for each month in 2011.

Figure 10. Measured and modeled LMPs (black circles and lines), price suppression benefit (solid blue for small output and dashed blue for 1,000 MW of output) and PV output distribution (PPL 2011).





Results

As illustrated in Table 7 the price reduction benefits are more than double the direct savings for a 100 MW of PV and slightly exceed the direct saving for 1,000 MW PV, for a combined value ranging from $127/MWh to $180/MWh.

Table 7. Market savings illustration.

	100 MW	1,000 MW
Direct Savings	$58	$58
Market Price Reduction	$122	$69
Total	$180	$127

A comparison of direct market savings and energy savings as calculated in this study is shown in Table 8. Fuel cost savings and O&M cost savings are combined because they represent the same costs that are included in market price. Direct savings were calculated for each hour as $P \cdot \Delta L$, summed for the year, and escalated at the same rate each year as natural gas futures beyond the 12 year limit.

Table 8. Direct market savings comparison (Newark, South-30).

	Value ($/kW)	Value ($/MWh)
Fuel Cost Savings	$709	38.8
O&M Cost Savings	$345	18.9
Total Energy Savings	**$1,054**	**57.7**
Direct Market Savings	**$1,470**	**80.4**

The results show that direct market savings are 39% above the energy savings. This discrepancy reflects the fact that the two quantities, while representing the same value components, use entirely different approaches. Fuel cost savings are derived from natural gas futures, discounted at the utility discount rate, and applied against an assumed CCGT heat rate. Direct market savings are based on hourly PJM zonal prices for 2011.

The energy savings achieved by the utility is based on avoided market purchases. However, historical market prices are not necessarily an indicator of future years, especially for 30 years into the future. For this reason, the energy savings methodology used in this analysis is more closely tied to the fundamentals of the cost: fuel and O&M costs that must be recovered by the marketplace for generation to be sustainable in the long run.

Zonal Price Model

To calculate the market price reduction in equation (4), a zonal price model was developed as follows. A function F() may be defined whose value is proportional to market clearing price using the form:

$$F(Load) = Ae^{BxLoad^{C}+D}$$

where coefficients A, B, C, and D are evaluated for each utility and for each month using hourly PJM zonal market price data, amounting to a total of 84 individual models.

P is the zonal wholesale clearing price, and P* is given by:

$$\frac{P^*}{P} = \frac{F(Load - FleetPower - LossSavings)}{F(Load)}$$

The market price reduction (in $/MWh) is calculated using the relevant term in Equation (4) and multiplying by the change in load, including loss savings.

Environmental Value

Introduction

It is well established that the environmental impact of PV is considerably smaller than that of fossil-based generation since PV is able to displace pollution associated with drilling/mining, and power plant emissions [15].

Methodology

There are two general approaches to quantifying the Environmental Value of PV: a regulatory cost-based approach and an environmental/health cost-based approach.

The regulatory cost-based approach values the Environmental Value of PV based on the price of Renewable Energy Credits (RECs) or Solar Renewable Energy Credits (SRECs) that would otherwise have to be purchased to satisfy state Renewable Portfolio Standards (RPS). These costs are a preliminary legislative attempt to quantify external costs. They represent actual business costs faced by utilities in certain states.

An environmental/health cost-based approach quantifies the societal costs resulting from fossil generation. Each solar kWh displaces an otherwise dirty kWh and commensurately mitigates several of the following factors: greenhouse gases, SOx/NOx emissions, mining degradations, ground water contamination, toxic releases and wastes, etc., that are all present or postponed costs to society. Several exhaustive studies have estimated the environmental/health cost of energy generated by fossil-based generation [16], [17]. The results from environmental/health cost-based approach often vary widely and can be controversial.

The environmental/health cost-based approach was used for this study.

The environmental footprint of solar generation is considerably smaller than that of the fossil fuel technologies generating most of our electricity (e.g., [19]). Utilities have to account for this environmental impact to some degree today, but this is still only largely a potential cost to them. Rate-based Solar Renewable Energy Credits (SRECs) markets in New Jersey and Pennsylvania as a means to meet Renewable Portfolio Standards (RPS) are a preliminary embodiment of including external costs, but they are largely driven more by politically-negotiated processes than by a reflection of inherent physical realities. The intrinsic physical value of displacing pollution is real and quantifiable however: depending on the current generation mix, each solar kWh displaces an otherwise dirty kWh and commensurately mitigates several of the following factors: greenhouse gases, SOx/NOx emissions, mining degradations, ground water contamination, toxic releases and wastes, etc., which are all present or postponed costs to society (i.e., the taxpayers).

The environmental value, EV, of each kWh produced by PV (i.e., not produced by another conventional source) is given by:

$$EV = \sum_{i=0}^{n} x_i \, EC_i$$

Where EC_i is the environmental cost of the displaced conventional generation technology and x_i is the proportion of this technology in the current energy mix.

Several exhaustive studies emanating from such diverse sources as the nuclear industry or the medical community ([20], [21]) estimate the environmental/health cost of 1 MWh generated by coal at $90-250, while a [non-shale[14]] natural gas MWh has an environmental cost of $30-60.

Considering New Jersey and Pennsylvania's electrical generation mixes (Table 9) and assuming that (1) nuclear energy is not displaced by PV at the assumed penetration level[15] and (2) that all natural gas is conventional, the environmental value of each MWh displaced by PV, hence the taxpayer benefit, is estimated at $48 to $129 in Pennsylvania and $20 to $48 in New Jersey.

We retained a value near the lower range of these estimates for the present analysis.

[14] Shale gas environmental footprint is likely higher both in terms of environment degradation and GHG emissions.

[15] The study therefore ascribes no environmental value related to nuclear generation. Scenarios can certainly be designed in which nuclear generation would be displaced, in which case the environmental cost of nuclear generation would have to be considered. This is a complex and controversial subject that reflects the probability of catastrophic accidents and the environmental footprint of the existing uranium cycle. The fact that the environmental liability is assumed to be zero under the present study may therefore be considered a conservative case.

Table 9. Environmental input calculation.

	Generation Mix		Prorated Environmental Cost ($/MWh)		
Pennsylvania	48%	Coal	43.2	to	120.0
	15%	Natural Gas	4.5	to	9.0
	34%	Nuclear	0.0	to	0.0
	3%	Other	0.0	to	0.0
	Environmental Value for PA		47.7	to	129.0
New Jersey	10%	Coal	9.0	to	25.0
	38%	Natural Gas	11.4	to	22.8
	50%	Nuclear	0.0	to	0.0
	2%	Other	0.0	to	0.0
	Environmental Value for NJ		20.4	to	47.8

Economic Development Value

The German and Ontario experiences as well as the experience in New Jersey, where fast PV growth is occurring, show that solar energy sustains more jobs per unit of energy generated than conventional energy ([21], [22]). Job creation implies value to society in many ways, including increased tax revenues, reduced unemployment, and an increase in general confidence conducive to business development.

In this report, only tax revenue enhancement from the jobs created as a measure of PV-induced economic development value is considered. This metric provides a tangible low estimate of solar energy's likely larger multifaceted economic development value. In Pennsylvania and New Jersey, this low estimate amounts to respectively $39 and $40 per MWh, even under the very conservative, but thus far realistic, assumption that 80% of the PV manufacturing jobs would be either out-of-state or foreign (see methodology section, below).

Methodology

In a previous (New York) study [24], net PV-related job creation numbers were used directly based upon Ontario and Germany's historical numbers. However this assumption does not reflects the rapid changes of the PV industry towards lower prices. In this study a first principle approach is applied based upon the difference between the installed cost of PV and conventional generation: in essence this approach quantifies the fact that part of the price premium paid for PV vs. conventional generation returns to the local economy in the form of jobs hence tax.

Therefore, assuming that:

- Turnkey PV costs $3,000 per kW vs. $1,000 per kW for combine cycle gas turbines (CCGT)
- Turnkey PV cost is composed of 1/3 technology (modules & inverter/controls) and 2/3 structure and installation and soft costs.
- 20% of the turnkey PV technology cost and 90% of the other costs are traceable to local jobs, while 50% of the CCGT are assumed to be local jobs, thus:
    - The local jobs-traceable amount spent on PV is equal to: $\left(\frac{0.2}{3}+\frac{0.9\times2}{3}\right)\times 3000 = \$1{,}990/kW$
    - And the local jobs-traceable amount spent on CCGT is equal to: $0.5\times 1000 = \$500/kW$
- PV systems in NJ and PA have a capacity factor of ~ 16%, producing ~ 1,400 kWh per year per kW_{AC} and CCGT have an assumed capacity factor of 50%, producing 4,380 kWh per year, therefore
    - The local jobs-traceable amount spent per PV kWh in year one is: 1,900/1,400 = $1.42
    - The local jobs-traceable amount spent per CCGT kWh in year one is: 500/4,380 = $0.114
- The net local jobs-traceable between PV and CCGT is thus equal to 1.42-0.11 = $1.30
- Assuming that the life span of both PV and CCGT is 30 years, and using a levelizing factor of 8%, the net local jobs-traceable amount per generated PV kWh over its lifetime amounts to: $1.30\times\frac{0.08\times1.08^{30}}{1.08^{29}} = \$0.116/\text{kWh}$
- Assuming that locally-traceable O&M costs per kWh for PV are equal to the locally-traceable O&M costs for CCGT, [16] but also assuming that because PV-related T&D benefits displace a commensurate amount of utility jobs assumed to be equal to this benefit (~0.5 cents per kWh), the net lifetime locally-traceable PV-CCGT difference is equal to 0.116-0.005 = $0.111/kWh
- Finally assuming that each PV job is worth $75K/year after standard deductions – hence has a combined State and Federal income tax rate of 22.29% in PA and 22.67% in NJ[17] -- and that each

[16] This includes only a fraction of the fuel costs – the other fraction being imported from out-of-state.

[17] For the considered solar job income level, the effective state rate = 3.07% in PA and 3.54% in NJ and the effective federal rate = 19.83%. The increased federal tax collection is counted as an increase for New Jersey's

new job has an indirect job multiplier of 1.6,[18] it can be argued that each PV MWh represents a net new-job related tax collection increase for NJ equal to a levelized value of $\$111/\mathrm{MWh} \times 0.2267 \times 1.6 = \$40/\mathrm{MWh}$, and a tax collection increase for PA equal to $\$111/\mathrm{MWh} \times 0.2229 \times 1.6 = \$39/\mathrm{MWh}$.

Solar Penetration Cost

It is important to recognize that there is also a cost associated with the deployment of solar generation on the power grid which accrues to the utility and to its ratepayers. This cost represents the infrastructural and operational expense that will be necessary to manage the flow of non-controllable solar energy generation while continuing to reliably meet demand. A recent study by Perez et al. [31] showed that in much of the US, this cost is negligible at low penetration and remains manageable for a solar capacity penetration of 30%. For utilities representative of the demand pattern and solar load synergies found in Pennsylvania, this penetration cost has been found to range from 0 to 5 cents per kWh when PV penetration ranges from 0% to 30% in capacity. Up to this level of penetration, the infrastructural and operational expense would consist of localized load management, [user-sited] storage and/or backup.[19] At the 15% level of penetration considered in this study, the cost of penetration can be estimated from the Perez et al. study[18] at $10-20/MWh.

taxpayer, because it can be reasonably argued that federal taxes are (1) redistributed fairly to the states and (2) that federal expense benefit all states equally.

[18]indirect base multipliers are used to estimate the local jobs not related to the considered job source (here solar energy) but created indirectly by the new revenues emanating from the new [solar] jobs

[19] At the higher penetration levels the two approaches to consider would be regional (or continental) interconnection upgrade and smart coupling with natural gas generation and wind power generation – the cost of these approaches has not been quantified as part of this study.

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Appendix 3: Detailed Results

Pittsburgh

Table A4- 1. Technical results, Pittsburgh.

	South-30	Horiz	West-30	1-Axis
Fleet Capacity (MWac)	475	475	475	475
Annual Energy Production (MWh)	716,621	631,434	595,373	892,905
Capacity Factor (%)	17%	15%	14%	21%
Generation Capacity (% of Fleet Capacity)	41%	43%	45%	48%
T&D Capacity (% of Fleet Capaccity)	31%	32%	32%	32%

Table A4- 2. Value ($/kW), Pittsburgh.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$813	$719	$678	$1,011
O&M Cost Savings	$396	$350	$331	$493
Total Energy Value	$1,209	$1,069	$1,009	$1,503
Strategic				
Security Enhancement Value	$446	$394	$372	$554
Long Term Societal Value	$557	$493	$465	$693
Total Strategic Value	$1,003	$887	$837	$1,247
Other				
Fuel Price Hedge Value	$613	$542	$512	$763
Generation Capacity Value	$432	$446	$468	$505
T&D Capacity Value	$127	$127	$130	$129
Market Price Reduction Value	$696	$718	$715	$740
Environmental Value	$1,064	$940	$888	$1,322
Economic Development Value	$870	$769	$726	$1,081
(Solar Penetration Cost)	($446)	($394)	($372)	($554)
Total Other Value	$3,355	$3,149	$3,067	$3,987
Total Value	**$5,568**	**$5,105**	**$4,913**	**$6,737**

Table A4- 3. Levelized Value ($/MWh), Pittsburgh.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$41	$41	$41	$41
O&M Cost Savings	$20	$20	$20	$20
Total Energy Value	$61	$61	$62	$61
Strategic				
Security Enhancement Value	$23	$23	$23	$23
Long Term Societal Value	$28	$28	$28	$28
Total Strategic Value	$51	$51	$51	$51
Other				
Fuel Price Hedge Value	$31	$31	$31	$31
Generation Capacity Value	$22	$26	$29	$21
T&D Capacity Value	$6	$7	$8	$5
Market Price Reduction Value	$35	$41	$44	$30
Environmental Value	$54	$54	$54	$54
Economic Development Value	$44	$44	$44	$44
(Solar Penetration Cost)	($23)	($23)	($23)	($23)
Total Other Value	$170	$181	$187	$162
Total Value	**$282**	**$293**	**$300**	**$274**

Figure A4- 1. Value ($/kW), Pittsburgh.

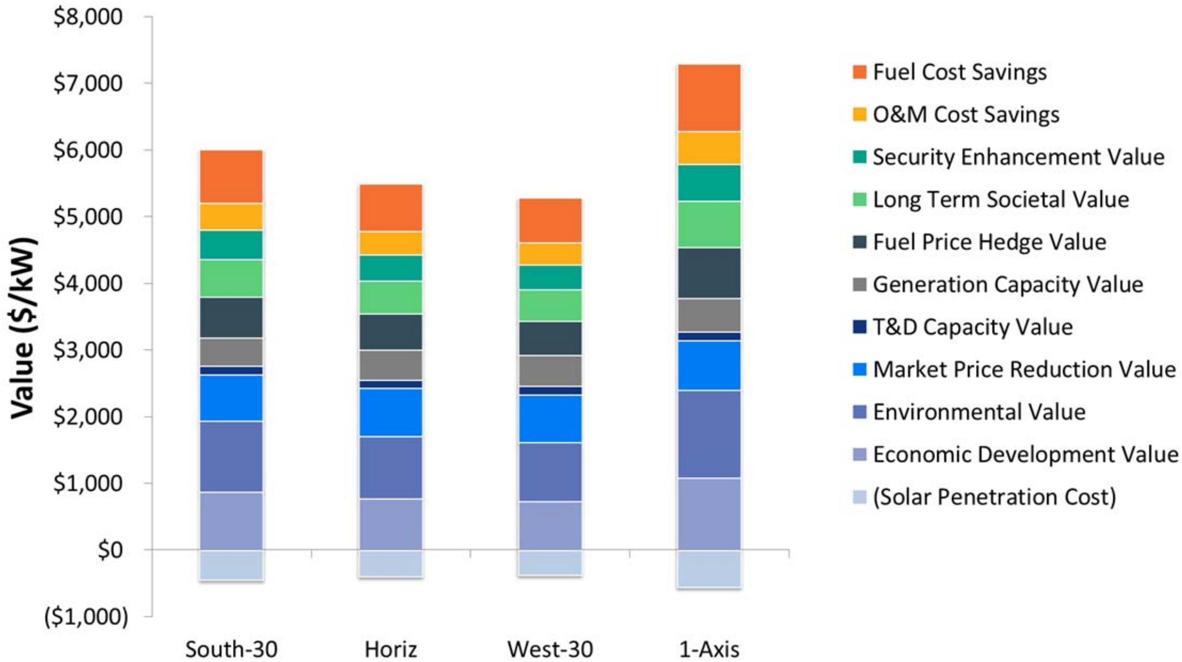
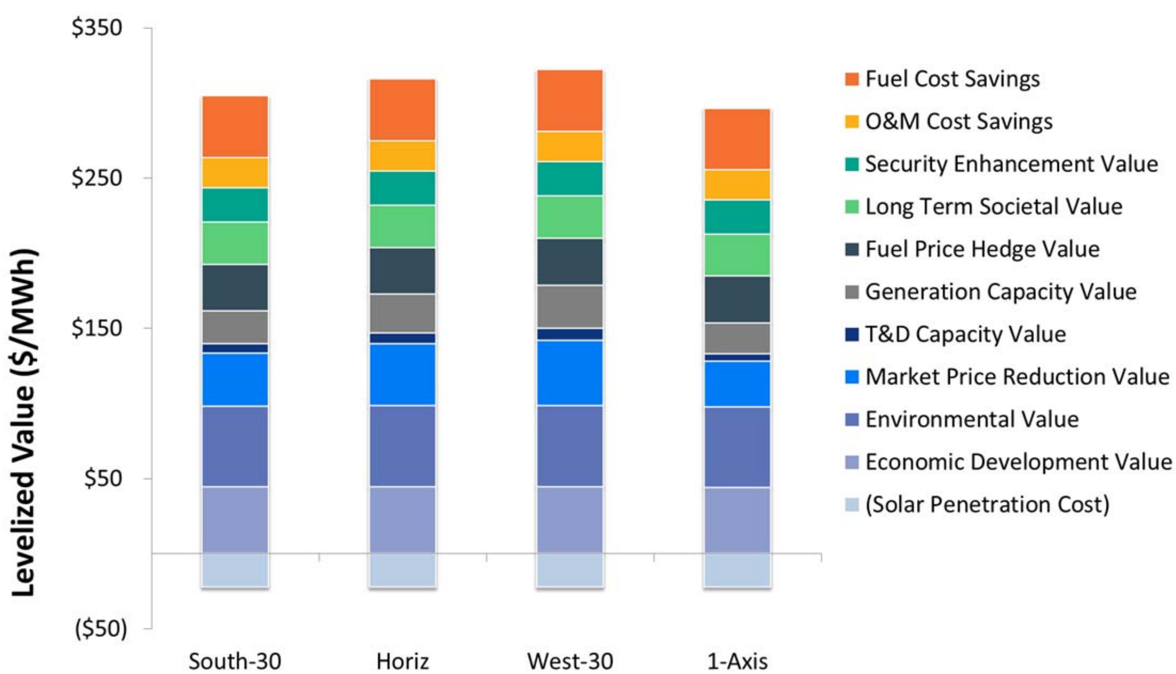


Figure A4- 2. Levelized Value ($/MWh), Pittsburgh.



Harrisburg[20]

Table A4- 4. Technical results, Harrisburg.

	South-30	Horiz	West-30	1-Axis
Fleet Capacity (MWac)	1129	1129	1129	1129
Annual Energy Production (MWh)	1,809,443	1,565,940	1,461,448	2,274,554
Capacity Factor (%)	18%	16%	15%	23%
Generation Capacity (% of Fleet Capacity)	28%	27%	26%	32%
T&D Capacity (% of Fleet Capaccity)	14%	14%	14%	14%

Table A4- 5. Value results ($/kW), Harrisburg.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$751	$652	$608	$942
O&M Cost Savings	$366	$318	$296	$459
Total Energy Value	$1,117	$969	$904	$1,401
Strategic				
Security Enhancement Value	$424	$368	$343	$532
Long Term Societal Value	$530	$460	$429	$665
Total Strategic Value	$954	$827	$772	$1,196
Other				
Fuel Price Hedge Value	$786	$682	$636	$985
Generation Capacity Value	$297	$287	$274	$336
T&D Capacity Value	$24	$24	$24	$24
Market Price Reduction Value	$1,241	$1,224	$1,171	$1,335
Environmental Value	$1,011	$877	$819	$1,268
Economic Development Value	$827	$717	$669	$1,037
(Solar Penetration Cost)	($424)	($368)	($343)	($532)
Total Other Value	$3,761	$3,444	$3,249	$4,454
Total Value	**$5,832**	**$5,240**	**$4,925**	**$7,051**

[20] Scranton and Harrisburg constitute two examples of a 15% penetration within PPL territory. Strictly speaking this does not amount to a 30% penetration, but two examples of 15% grid penetration where resource would be deployed in either location, illustrating how results are influenced by the location choice, everything else (utility and economic assumptions) being equal.

Table A4- 6. Levelized Value results ($/MWh), Harrisburg.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$41	$41	$41	$40
O&M Cost Savings	$20	$20	$20	$20
Total Energy Value	$60	$61	$60	$60
Strategic				
Security Enhancement Value	$23	$23	$23	$23
Long Term Societal Value	$29	$29	$29	$29
Total Strategic Value	$52	$52	$52	$51
Other				
Fuel Price Hedge Value	$42	$43	$43	$42
Generation Capacity Value	$16	$18	$18	$14
T&D Capacity Value	$1	$1	$2	$1
Market Price Reduction Value	$67	$76	$78	$57
Environmental Value	$55	$55	$55	$55
Economic Development Value	$45	$45	$45	$45
(Solar Penetration Cost)	($23)	($23)	($23)	($23)
Total Other Value	$203	$215	$217	$191
Total Value	**$315**	**$327**	**$330**	**$303**

Figure A4- 3. Value ($/kW), Harrisburg.

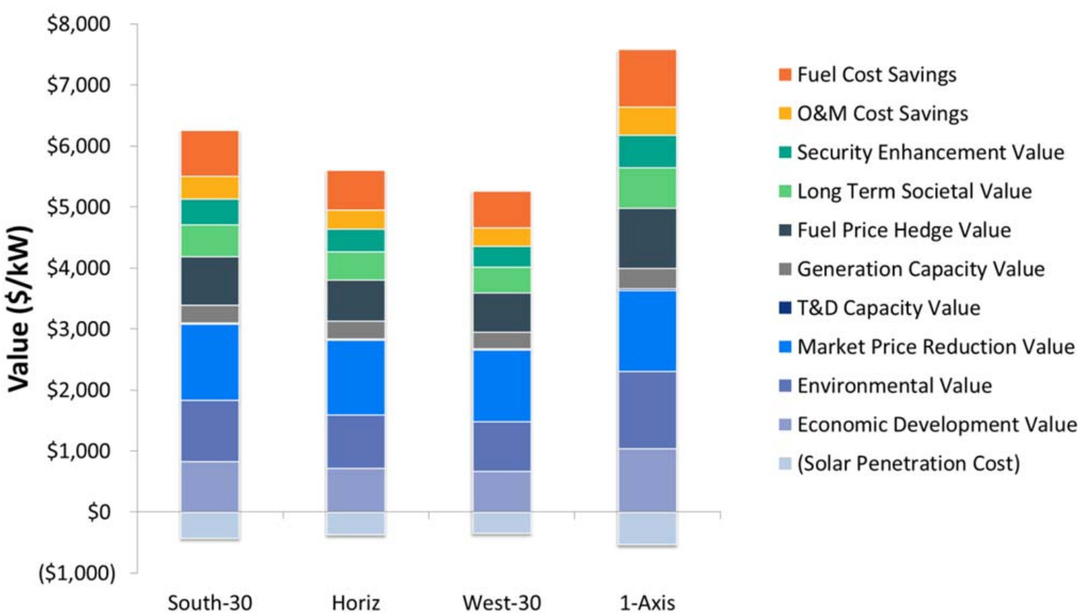
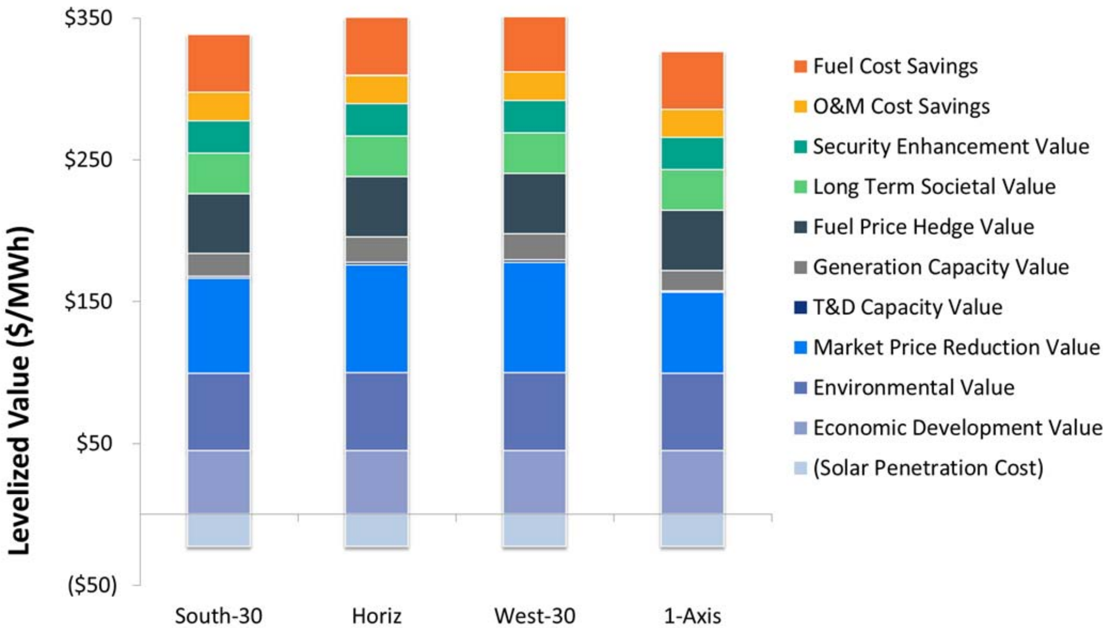


Figure A4- 4. Levelized Value ($/MWh), Harrisburg.



Scranton

Table A4- 7. Technical results, Scranton.

	South-30	Horiz	West-30	1-Axis
Fleet Capacity (MWac)	1129	1129	1129	1129
Annual Energy Production (MWh)	1,698,897	1,479,261	1,386,699	2,123,833
Capacity Factor (%)	17%	15%	14%	21%
Generation Capacity (% of Fleet Capacity)	28%	27%	26%	32%
T&D Capacity (% of Fleet Capaccity)	14%	14%	14%	14%

Table A4- 8. Value ($/kW), Scranton.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$706	$616	$577	$880
O&M Cost Savings	$344	$300	$281	$429
Total Energy Value	$1,050	$916	$859	$1,309
Strategic				
Security Enhancement Value	$398	$348	$326	$497
Long Term Societal Value	$498	$435	$407	$621
Total Strategic Value	$896	$782	$733	$1,118
Other				
Fuel Price Hedge Value	$738	$644	$604	$921
Generation Capacity Value	$290	$283	$276	$336
T&D Capacity Value	$24	$24	$24	$24
Market Price Reduction Value	$1,206	$1,193	$1,157	$1,311
Environmental Value	$950	$829	$777	$1,185
Economic Development Value	$777	$678	$636	$969
(Solar Penetration Cost)	($398)	($348)	($326)	($497)
Total Other Value	$3,586	$3,303	$3,148	$4,249
Total Value	**$5,532**	**$5,001**	**$4,740**	**$6,676**

Table A4- 9. Levelized Value ($/MWh), Scranton.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$41	$41	$41	$41
O&M Cost Savings	$20	$20	$20	$20
Total Energy Value	$60	$61	$61	$60
Strategic				
Security Enhancement Value	$23	$23	$23	$23
Long Term Societal Value	$29	$29	$29	$29
Total Strategic Value	$52	$52	$52	$51
Other				
Fuel Price Hedge Value	$42	$43	$43	$42
Generation Capacity Value	$17	$19	$19	$15
T&D Capacity Value	$1	$2	$2	$1
Market Price Reduction Value	$69	$79	$82	$60
Environmental Value	$55	$55	$55	$55
Economic Development Value	$45	$45	$45	$45
(Solar Penetration Cost)	($23)	($23)	($23)	($23)
Total Other Value	$206	$218	$222	$196
Total Value	**$318**	**$331**	**$334**	**$307**

Figure A4- 5. Value ($/kW), Scranton.

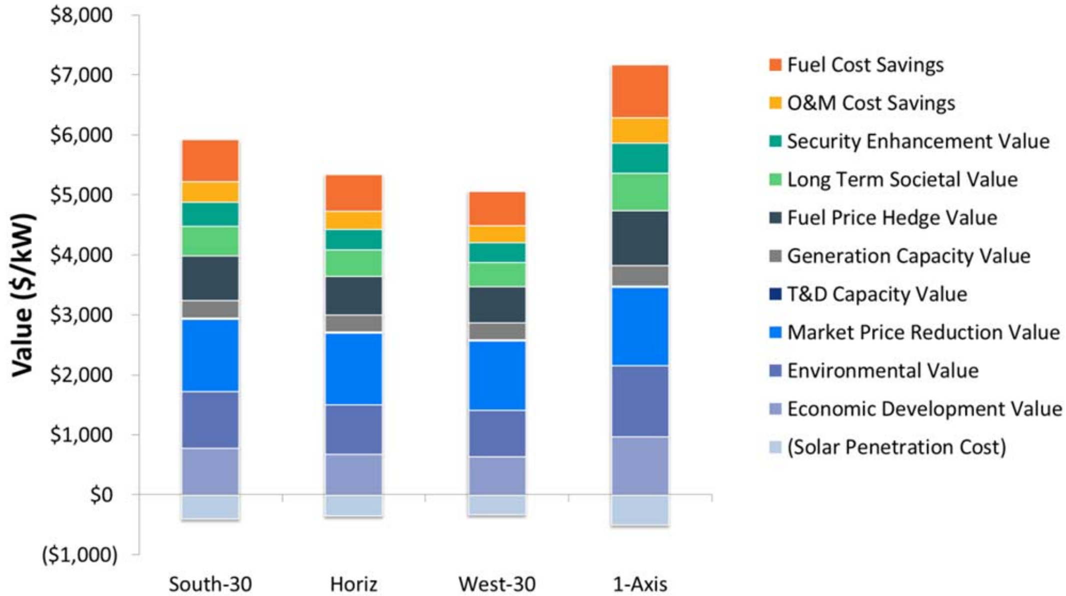
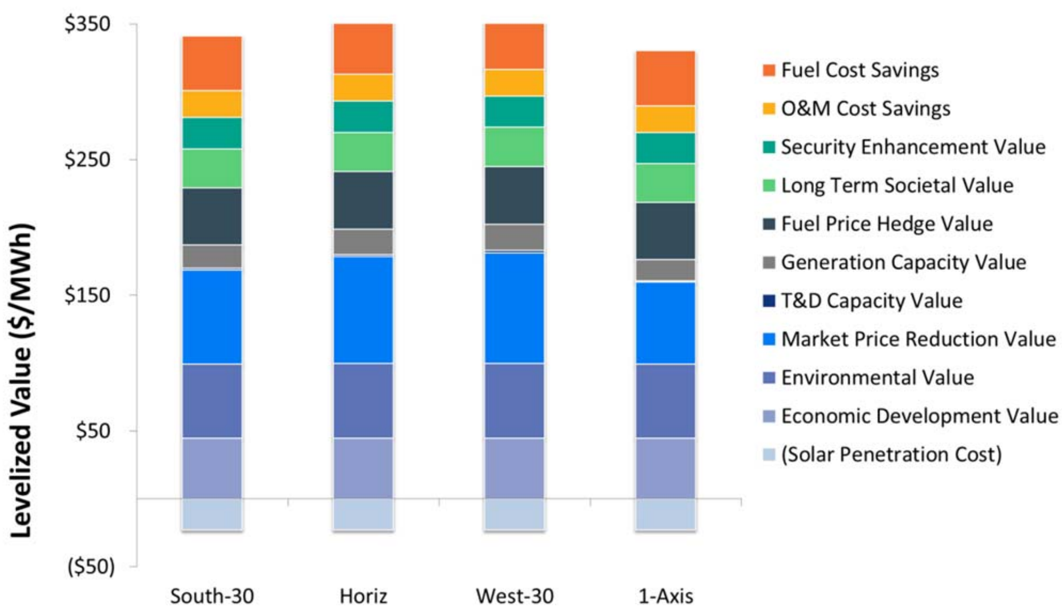


Figure A4- 6. Levelized Value ($/MWh), Scranton.



Philadelphia

Table A4- 10. Technical results, Philadelphia.

	South-30	Horiz	West-30	1-Axis
Fleet Capacity (MWac)	1348	1348	1348	1348
Annual Energy Production (MWh)	2,339,424	1,991,109	1,847,394	2,943,101
Capacity Factor (%)	20%	17%	16%	25%
Generation Capacity (% of Fleet Capacity)	38%	40%	43%	46%
T&D Capacity (% of Fleet Capaccity)	21%	21%	21%	21%

Table A4- 11. Value results ($/kW), Philadelphia.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$706	$602	$559	$886
O&M Cost Savings	$344	$294	$273	$432
Total Energy Value	$1,049	$896	$832	$1,318
Strategic				
Security Enhancement Value	$405	$346	$321	$509
Long Term Societal Value	$507	$432	$402	$636
Total Strategic Value	$912	$778	$723	$1,145
Other				
Fuel Price Hedge Value	$876	$747	$694	$1,100
Generation Capacity Value	$401	$418	$452	$483
T&D Capacity Value	$65	$65	$65	$65
Market Price Reduction Value	$1,013	$1,027	$1,018	$1,103
Environmental Value	$967	$825	$766	$1,214
Economic Development Value	$790	$675	$626	$993
(Solar Penetration Cost)	($405)	($346)	($321)	($509)
Total Other Value	$3,706	$3,412	$3,300	$4,449
Total Value	**$5,667**	**$5,086**	**$4,855**	**$6,912**

Table A4- 12. Levelized Value results ($/MWh), Philadelphia.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$38	$38	$38	$38
O&M Cost Savings	$18	$19	$19	$18
Total Energy Value	$56	$57	$57	$56
Strategic				
Security Enhancement Value	$22	$22	$22	$22
Long Term Societal Value	$27	$27	$27	$27
Total Strategic Value	$49	$49	$49	$49
Other				
Fuel Price Hedge Value	$47	$47	$47	$47
Generation Capacity Value	$22	$26	$31	$21
T&D Capacity Value	$3	$4	$4	$3
Market Price Reduction Value	$54	$65	$69	$47
Environmental Value	$52	$52	$52	$52
Economic Development Value	$42	$43	$43	$42
(Solar Penetration Cost)	($22)	($22)	($22)	($22)
Total Other Value	$199	$215	$224	$190
Total Value	**$304**	**$321**	**$330**	**$295**

Figure A4- 7. Value ($/kW), Philadelphia.

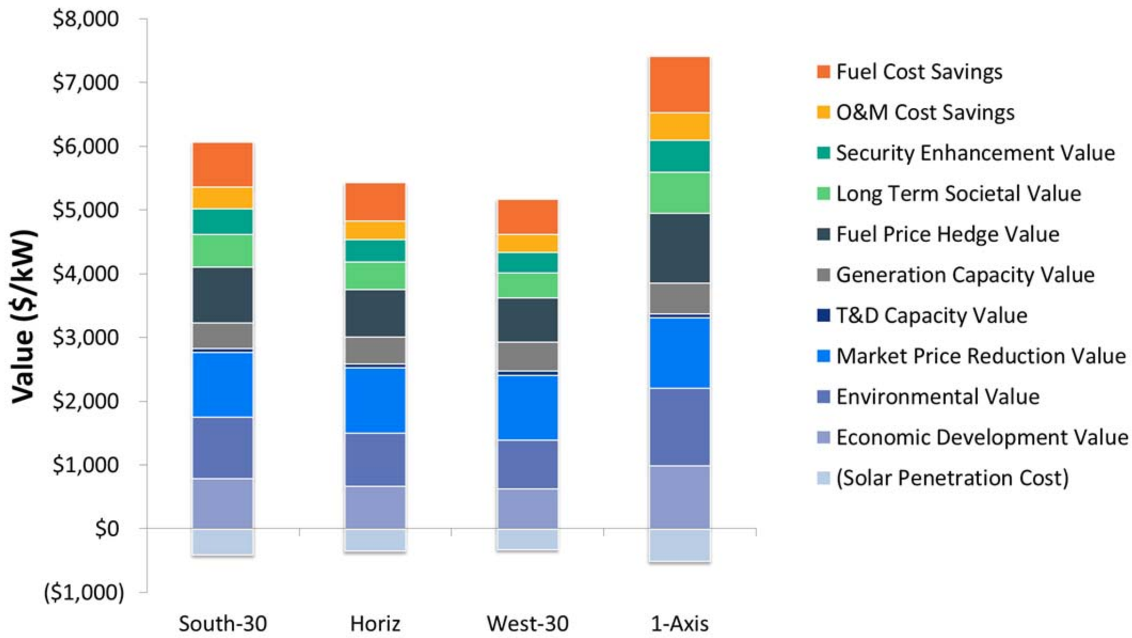
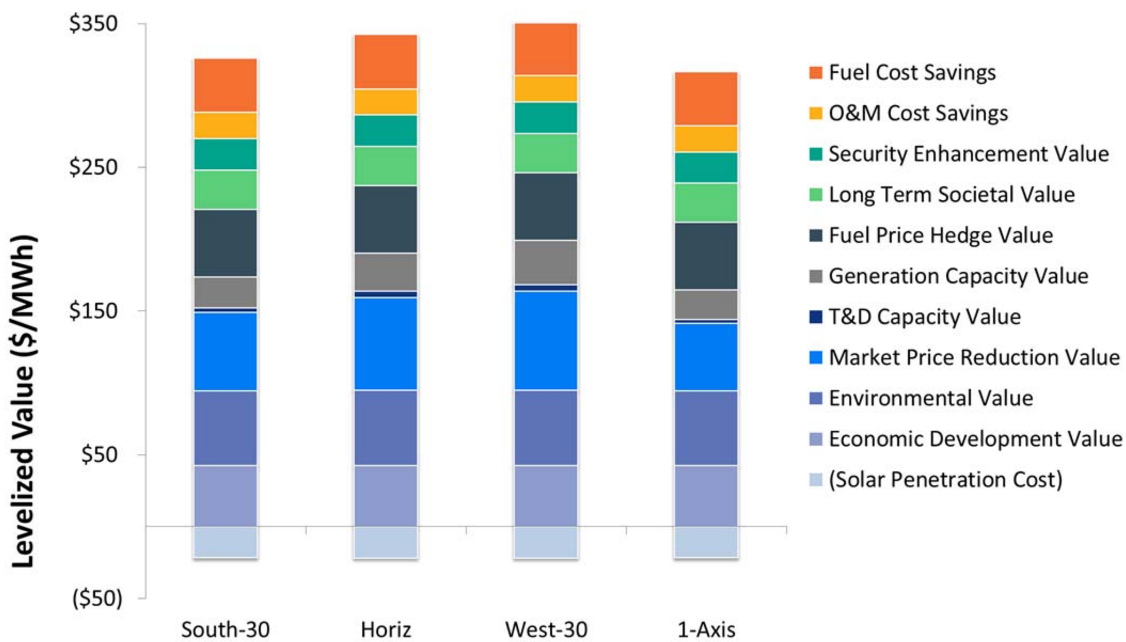


Figure A4- 8. Levelized Value ($/MWh), Philadelphia.



Jamesburg

Table A4- 13. Technical results, Jamesburg.

	South-30	Horiz	West-30	1-Axis
Fleet Capacity (MWac)	991	991	991	991
Annual Energy Production (MWh)	1,675,189	1,431,899	1,315,032	2,102,499
Capacity Factor (%)	19%	16%	15%	24%
Generation Capacity (% of Fleet Capacity)	45%	47%	51%	52%
T&D Capacity (% of Fleet Capaccity)	29%	31%	29%	26%

Table A4- 14. Value results ($/kW), Jamesburg.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$1,020	$878	$808	$1,276
O&M Cost Savings	$497	$428	$394	$622
Total Energy Value	$1,517	$1,306	$1,203	$1,898
Strategic				
Security Enhancement Value	$549	$472	$435	$686
Long Term Societal Value	$686	$590	$544	$858
Total Strategic Value	$1,234	$1,062	$978	$1,544
Other				
Fuel Price Hedge Value	$586	$504	$465	$733
Generation Capacity Value	$468	$496	$531	$546
T&D Capacity Value	$23	$25	$23	$21
Market Price Reduction Value	$1,266	$1,306	$1,315	$1,363
Environmental Value	$560	$482	$444	$700
Economic Development Value	$1,097	$944	$870	$1,373
(Solar Penetration Cost)	($549)	($472)	($435)	($686)
Total Other Value	$3,451	$3,285	$3,212	$4,050
Total Value	**$6,202**	**$5,653**	**$5,393**	**$7,492**

Table A4- 15. Levelized Value results ($/MWh), Jamesburg.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$42	$42	$43	$42
O&M Cost Savings	$21	$21	$21	$21
Total Energy Value	$63	$63	$63	$63
Strategic				
Security Enhancement Value	$23	$23	$23	$23
Long Term Societal Value	$28	$29	$29	$28
Total Strategic Value	$51	$51	$52	$51
Other				
Fuel Price Hedge Value	$24	$24	$24	$24
Generation Capacity Value	$19	$24	$28	$18
T&D Capacity Value	$1	$1	$1	$1
Market Price Reduction Value	$52	$63	$69	$45
Environmental Value	$23	$23	$23	$23
Economic Development Value	$45	$46	$46	$45
(Solar Penetration Cost)	($23)	($23)	($23)	($23)
Total Other Value	$143	$159	$169	$134
Total Value	**$257**	**$274**	**$284**	**$247**

Figure A4- 9. Value ($/kW), Jamesburg.

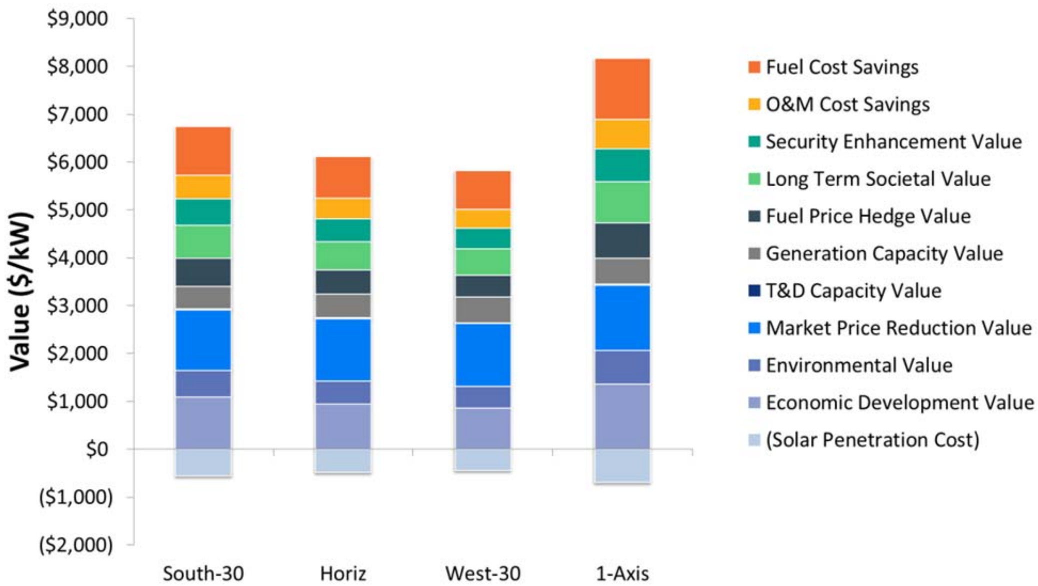
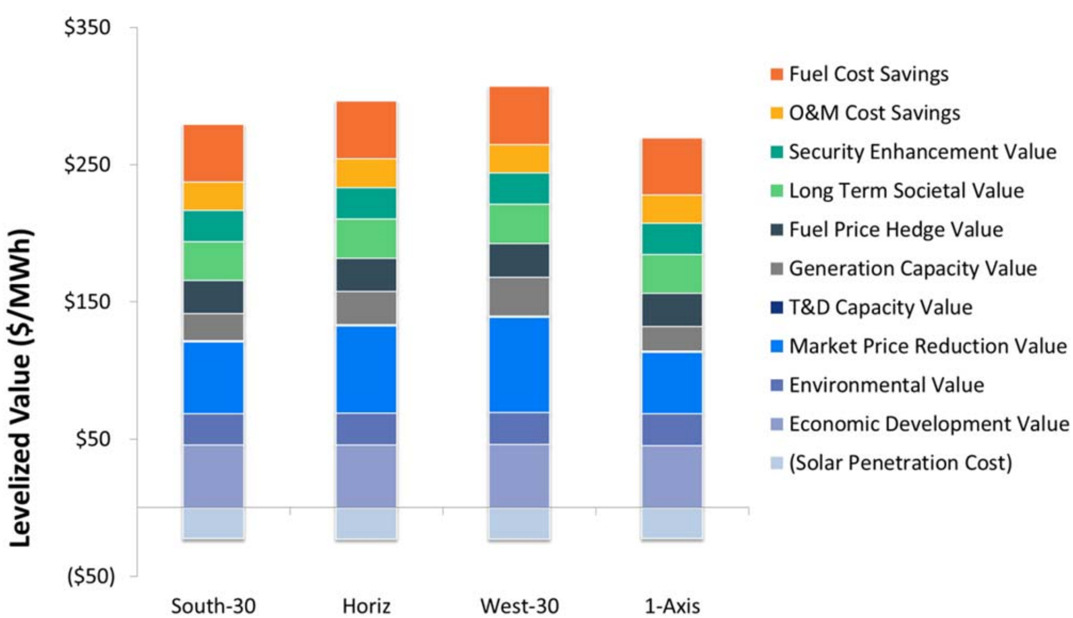


Figure A4- 10. Levelized Value ($/MWh), Jamesburg.



Newark

Table A4- 16. Technical results, Newark.

	South-30	Horiz	West-30	1-Axis
Fleet Capacity (MWac)	1640	1640	1640	1640
Annual Energy Production (MWh)	2,677,626	2,303,173	2,118,149	3,350,313
Capacity Factor (%)	19%	16%	15%	23%
Generation Capacity (% of Fleet Capacity)	45%	47%	51%	54%
T&D Capacity (% of Fleet Capaccity)	56%	57%	57%	57%

Table A4- 17. Value results ($/kW), Newark.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$709	$612	$564	$885
O&M Cost Savings	$345	$298	$275	$431
Total Energy Value	$1,054	$911	$839	$1,317
Strategic				
Security Enhancement Value	$403	$348	$321	$503
Long Term Societal Value	$504	$435	$401	$629
Total Strategic Value	$907	$783	$721	$1,132
Other				
Fuel Price Hedge Value	$798	$689	$635	$996
Generation Capacity Value	$470	$489	$534	$568
T&D Capacity Value	$147	$151	$151	$151
Market Price Reduction Value	$927	$959	$958	$989
Environmental Value	$411	$355	$327	$513
Economic Development Value	$806	$696	$641	$1,007
(Solar Penetration Cost)	($403)	($348)	($321)	($503)
Total Other Value	$3,156	$2,991	$2,926	$3,721
Total Value	**$5,117**	**$4,685**	**$4,486**	**$6,170**

Table A4- 18. Levelized Value results ($/MWh), Newark.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$39	$39	$39	$39
O&M Cost Savings	$19	$19	$19	$19
Total Energy Value	$58	$58	$58	$58
Strategic				
Security Enhancement Value	$22	$22	$22	$22
Long Term Societal Value	$28	$28	$28	$28
Total Strategic Value	$50	$50	$50	$50
Other				
Fuel Price Hedge Value	$44	$44	$44	$44
Generation Capacity Value	$26	$31	$37	$25
T&D Capacity Value	$8	$10	$10	$7
Market Price Reduction Value	$51	$61	$66	$43
Environmental Value	$22	$23	$23	$22
Economic Development Value	$44	$44	$44	$44
(Solar Penetration Cost)	($22)	($22)	($22)	($22)
Total Other Value	$173	$190	$202	$163
Total Value	**$280**	**$298**	**$310**	**$270**

Figure A4- 11. Value ($/kW), Newark.

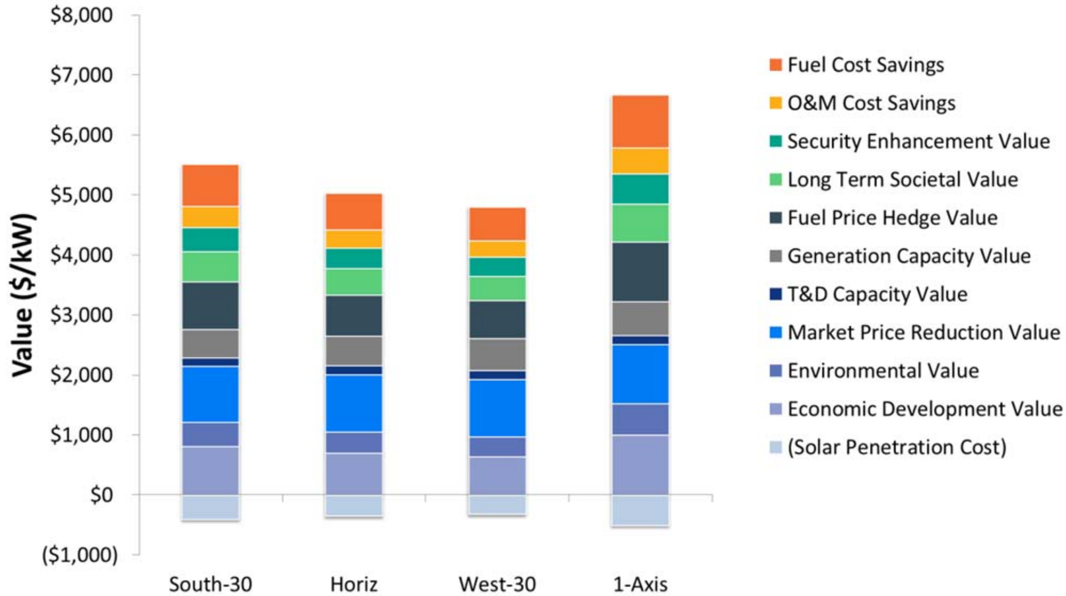
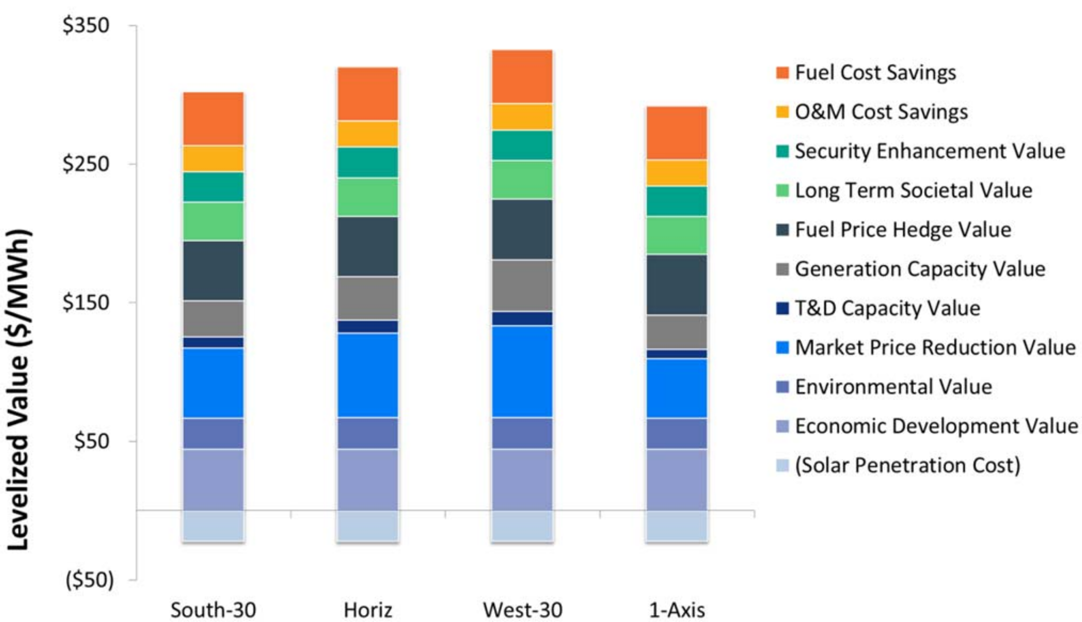


Figure A4- 12. Levelized Value ($/MWh), Newark.



Atlantic City

Table A4- 19. Technical results, Atlantic City.

	South-30	Horiz	West-30	1-Axis
Fleet Capacity (MWac)	443	443	443	443
Annual Energy Production (MWh)	827,924	705,374	654,811	1,039,217
Capacity Factor (%)	21%	18%	17%	27%
Generation Capacity (% of Fleet Capacity)	46%	48%	54%	57%
T&D Capacity (% of Fleet Capaccity)	36%	37%	38%	36%

Table A4- 20. Value results ($/kW), Atlantic City.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$1,081	$927	$863	$1,354
O&M Cost Savings	$527	$452	$421	$660
Total Energy Value	$1,609	$1,380	$1,283	$2,015
Strategic				
Security Enhancement Value	$584	$501	$466	$732
Long Term Societal Value	$730	$626	$582	$914
Total Strategic Value	$1,314	$1,127	$1,048	$1,646
Other				
Fuel Price Hedge Value	$662	$567	$528	$828
Generation Capacity Value	$478	$503	$569	$600
T&D Capacity Value	$49	$51	$52	$49
Market Price Reduction Value	$1,412	$1,485	$1,508	$1,503
Environmental Value	$596	$511	$475	$746
Economic Development Value	$1,168	$1,002	$932	$1,463
(Solar Penetration Cost)	($584)	($501)	($466)	($732)
Total Other Value	$3,781	$3,618	$3,598	$4,458
Total Value	**$6,704**	**$6,125**	**$5,929**	**$8,119**

Table A4- 21. Levelized Value results ($/MWh), Atlantic City.

	South-30	Horiz	West-30	1-Axis
Energy				
Fuel Cost Savings	$41	$42	$42	$41
O&M Cost Savings	$20	$20	$20	$20
Total Energy Value	$61	$62	$62	$61
Strategic				
Security Enhancement Value	$22	$22	$22	$22
Long Term Societal Value	$28	$28	$28	$28
Total Strategic Value	$50	$50	$51	$50
Other				
Fuel Price Hedge Value	$25	$25	$25	$25
Generation Capacity Value	$18	$23	$27	$18
T&D Capacity Value	$2	$2	$2	$1
Market Price Reduction Value	$54	$66	$73	$46
Environmental Value	$23	$23	$23	$23
Economic Development Value	$45	$45	$45	$44
(Solar Penetration Cost)	($22)	($22)	($22)	($22)
Total Other Value	$144	$162	$174	$135
Total Value	**$256**	**$274**	**$286**	**$247**

Figure A4- 13. Value ($/kW), Atlantic City.

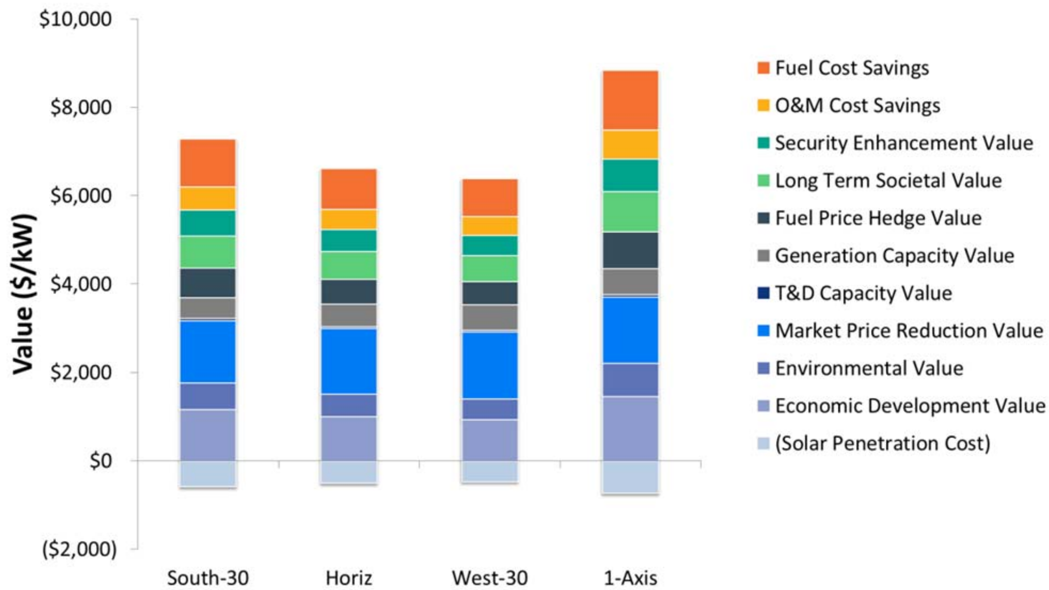


Figure A4- 14. Levelized Value ($/MWh), Atlantic City.