White Paper: The Value of Grid-Connected Photovoltaics in Michigan

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Purpose/Background

This report is a deliverable of the U.S. Department of Energy's (DOE) Solar Energy Technologies Program Public Utilities Commission Technical Assistance Program. This program provides technical assistance to state policymakers and public utilities commissions in support of overcoming market barriers to the broad deployment of solar technologies.

Acknowledgments

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Major Findings

- Photovoltaic (PV) value is consistently higher than average electricity prices due to favorable correlation with peak prices.
- Over 75% of PV value in Michigan is realized in energy and generation capacity benefits and environmental benefits.
- On an annual basis, PV production in Michigan is valued at $0.138/kWh.

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1 Introduction

In recent years, Michigan has seen an increase in grid-connected photovoltaics (PV), with 1.9 MW installed in 2010, bringing the total grid-connected PV capacity to 2.6 MW (Sherwood 2011). As solar technologies become more prominent in Michigan's electric generation portfolio, it is increasingly important to understand the value it provides to the state's electric utilities and citizens. This study estimates the value of PV generation in Michigan by comparing hourly solar generation with hourly electricity prices from specific years. This study also considers other value components that have been quantified in previous PV valuation studies and uses these to estimate similar value components for PV installed in Michigan.

2 Data and Methodology

2.1 PV Value Components

PV installations can provide value across several categories. These value components are often difficult to quantify because they are either external benefits (such as environmental benefits) or indirect benefits (such as future transmission or distribution capacity deferrals). Several studies have explored the value that PV installations can provide. A literature review was conducted to explore the range of values estimated by these studies. Over 30 unique categories have been identified where PV systems can provide value to a variety of stakeholders (Hoff and Margolis 2005). This study consolidates the various categories into seven main components:

- **Energy and Generation** – The electricity generated by a PV system helps reduce the need to generate electricity from other sources, thus saving operating and fuel costs. This category is typically quantified using marginal wholesale electricity prices [locational marginal pricing (LMP)] and the fuel and operation and maintenance (O&M) costs of natural gas plants.
- **Capacity** – PV systems help to reduce the need for construction of future generation capacity and also reduce the need to run certain power plants during peak load. This category is typically quantified using the price of new natural gas peaking plants and the effective load carrying capacity[1] (ELCC) of solar plants.
- **Transmission and Distribution** – As electricity consumption increases, additional transmission and distribution (T&D) infrastructure is needed to facilitate the movement of electricity from the power plants to consumers. Since distributed PV is placed at or near where electricity is consumed, it can help offset the need to build or upgrade future T&D infrastructure. T&D deferrals are typically quantified using the ELCC of power plants and the cost of new T&D capacity.
- **Loss Savings** – Some energy is lost when transmitting electricity over long distances and through multiple transformers. Because distributed PV is placed near where

[1] The ELCC is the portion of the PV plant's rated capacity that can be relied upon to reduce the power grid's peak load. For a complete discussion of ELCC, see Perez et al. (2006).

electricity is consumed, it avoids much of these losses.[2] The value of avoiding these losses is typically quantified on a marginal basis.

- **Reactive Power Support** – PV inverters have the ability to provide reactive power for utilities. This helps avoid installing additional power quality equipment, such as capacitors.
- **Environmental Benefits** – PV systems help offset pollutant emissions and greenhouse gas emissions. Greenhouse benefits are typically quantified using renewable energy certificates (RECs), other premiums paid for green power, and estimates on possible carbon tax enactments.
- **Other** – PV benefits, such as hedge value, disaster recovery benefits, and other ancillary services help support a secure and reliable electric power system.

Data was collected from four studies: the Austin Energy study (Hoff et al. 2006), the WE Energies study (Norris et al. 2009), the Navigant study (Contreras et al. 2008), and the Arizona Public Service study (R.W. Beck 2009). The data collected expressed PV value in terms of dollars per kilowatt-hour, allowing for the analysis to abstract from system size and relative solar resource. Table 1 lists the four studies that were reviewed. In each of the studies, a range of values were typically given for each benefit component (high-end estimate and low-end estimate). The median value of the range was used in this analysis and is represented in Table 1.

Table 1. Summary of Select PV Valuation Studies

Study	Location	Energy/Generation Value Only ($/kWh)	Total PV Value ($/kWh)
Austin Energy	Austin, Texas	$0.070	$0.11
WE Energies	Milwaukee, Wisconsin	$0.063	$0.12
Navigant	Madison, Wisconsin[3]	$0.068	$0.23
Arizona Public Service	Phoenix, Arizona	$0.097	$0.11

Variations in the studies' values exist because of methodology differences. For example, the WE Energies study (Norris et al. 2009) does not quantify any capacity benefits and states: "Capacity benefits are considered to be small and were not included in the study even though PV also provides generation capacity benefits." (page ES-6)

For contrast, the Navigant study (Contreras et al. 2008) (having the highest quantified capacity benefit) provides a high-end estimate for capacity value at $0.108/kWh. Variations between values can also occur because of local considerations. For instance, some locations may have a

[2] Distributed PV systems not only offset the energy that conventional power plants produce but also the losses associated with delivering that energy. It is these offset losses that are attributed as "loss savings."

[3] The Navigant study was a national study but included PV value estimates for select locations around the United States. This analysis used data from the Wisconsin location due to its proximity to Michigan.

greater T&D value than other locations due to severe congestion in the power lines. Some locations may have a greater energy and generation value component due to a greater use of expensive fuels for power plants in that region.

The estimate for PV value in Michigan was obtained by averaging the various value components from these four PV valuation studies with exception to the energy value component. This value component was quantified by evaluating the market value of PV generation. Quantifying the market value of PV energy is the most direct way to measure the value of a PV system's generation. The market value is determined by overlaying the hourly PV energy output with the hourly wholesale electricity prices from the same time period. The PV energy output is valued and compensated at the market price. The wholesale electricity price data used was LMP data from the Midwest Independent System Operator (MISO 2011). Data was collected for the Michigan Hub. Hourly price data was collected for 2006–2009.

The PV production data used in this analysis were simulated using hourly meteorological data from SolarAnywhere (CPR 2011). Meteorological data for 2006–2009 was collected for the Michigan Hub, located near Grand Rapids, Michigan (MISO 2011). The data were used as an input for the System Advisor Model (SAM) (NREL 2011), which simulated hourly PV production. The PV system simulated had a fixed tilt of 25 degrees and faced due-south (180-degree azimuth). The PV production data was aligned and evaluated with the corresponding LMP data from the same year in order to determine the market value of PV generation in Michigan. This is illustrated in Figure 1, where the 2006–2009 average hourly PV production is compared with the 2006–2009 average LMP data for the first week in August.

As seen in Figure 1, Michigan's summer electricity market prices are well correlated with the solar resource. The PV system's peak generation typically occurs within 3 hours of when prices are at their peak. Figure 2 illustrates the PV production and wholesale electricity price comparison during the week of December 10. In December, electricity prices typically peak during the evening hours when there is little or no PV output.

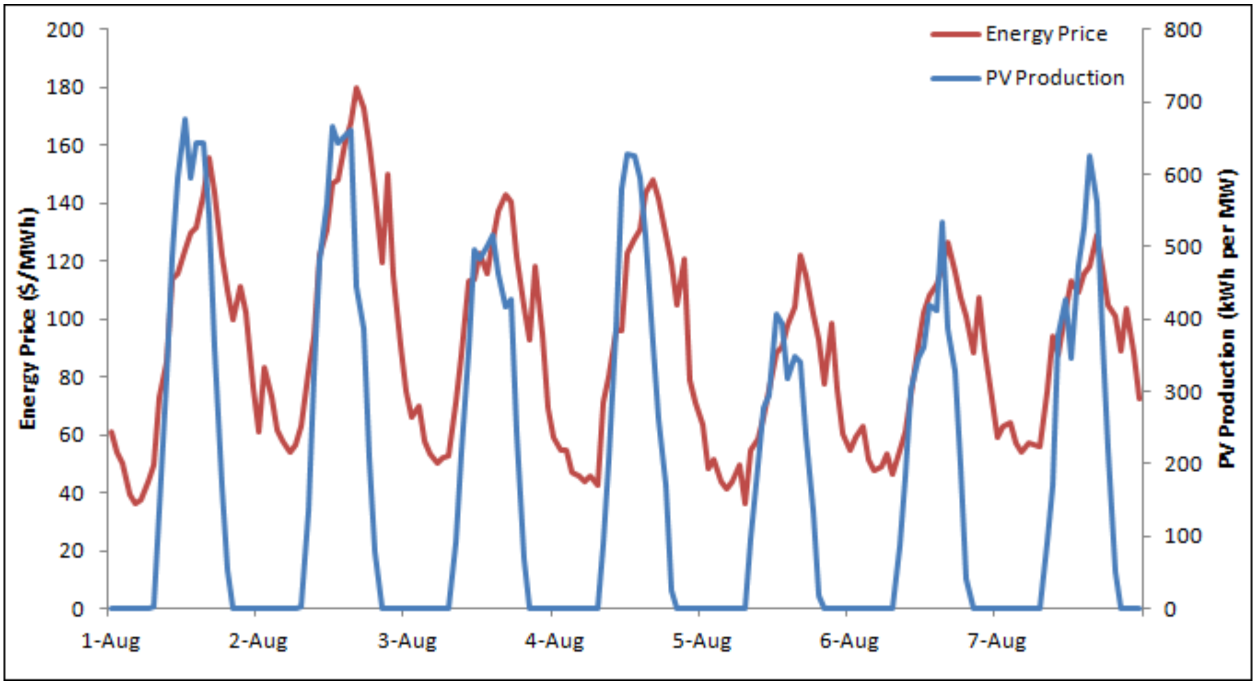

Figure 1. Average hourly PV production and wholesale electricity prices during the first week of August, 2006–2009

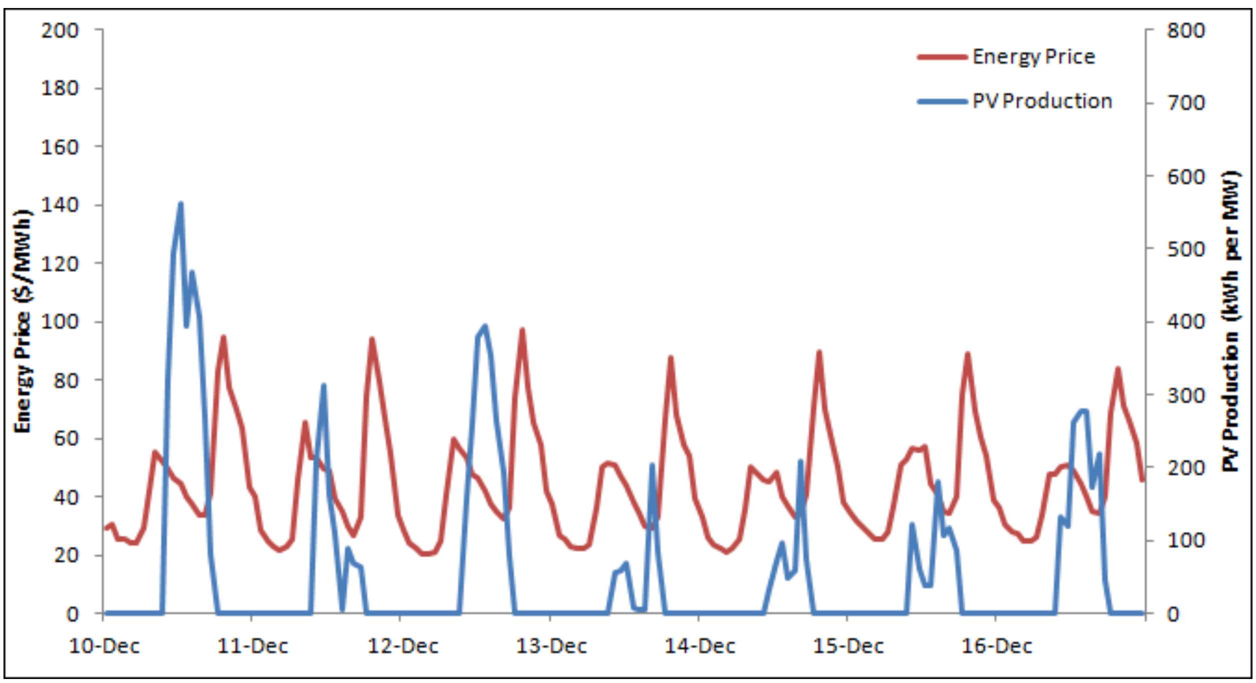

Figure 2. Average hourly PV production and wholesale electricity prices during the week of December 10, 2006–2009

The value of PV generation was evaluated on an hourly basis. The monthly and annual weighted average values (in $/MWh) was determined by dividing the total revenue of the PV generation by the total energy output of the PV system during the time period in question. Figure 3 shows the calculated energy value component stacked alongside the other values estimated for

Michigan. The other PV value components for Michigan were determined by taking the average of each value component from the four studies evaluated.

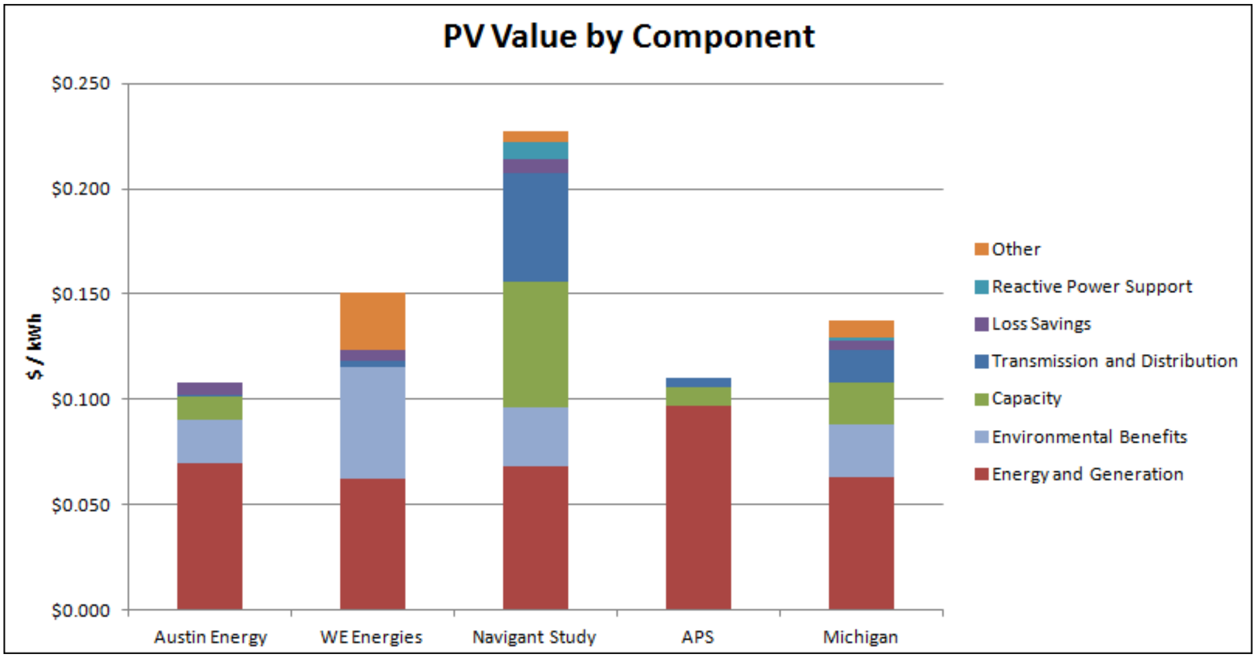

Figure 3. Value components quantified in various PV valuation studies

3 Results

PV production in Michigan coincides well with hourly wholesale electricity prices. Figure 4 illustrates the average PV value in Michigan by month. PV value remains above $70/MWh from June through August and peaks in August at $93/MWh. PV value is at a minimum from November through January, not only because grid prices are lower during this time but because the PV output is less correlated with peak prices than other months of the year. As a result, December is the only month when the average PV value is less than the average electricity price. The top 20% of electricity prices are also shown for comparison. Although PV value is consistently higher than average electricity prices, it is still less than the highest grid prices due to the time difference (2–4 hours) between peak solar production and peak grid prices. On an annual basis, PV production in Michigan is valued at $63/MWh ($0.063/kWh) on the wholesale electricity market.

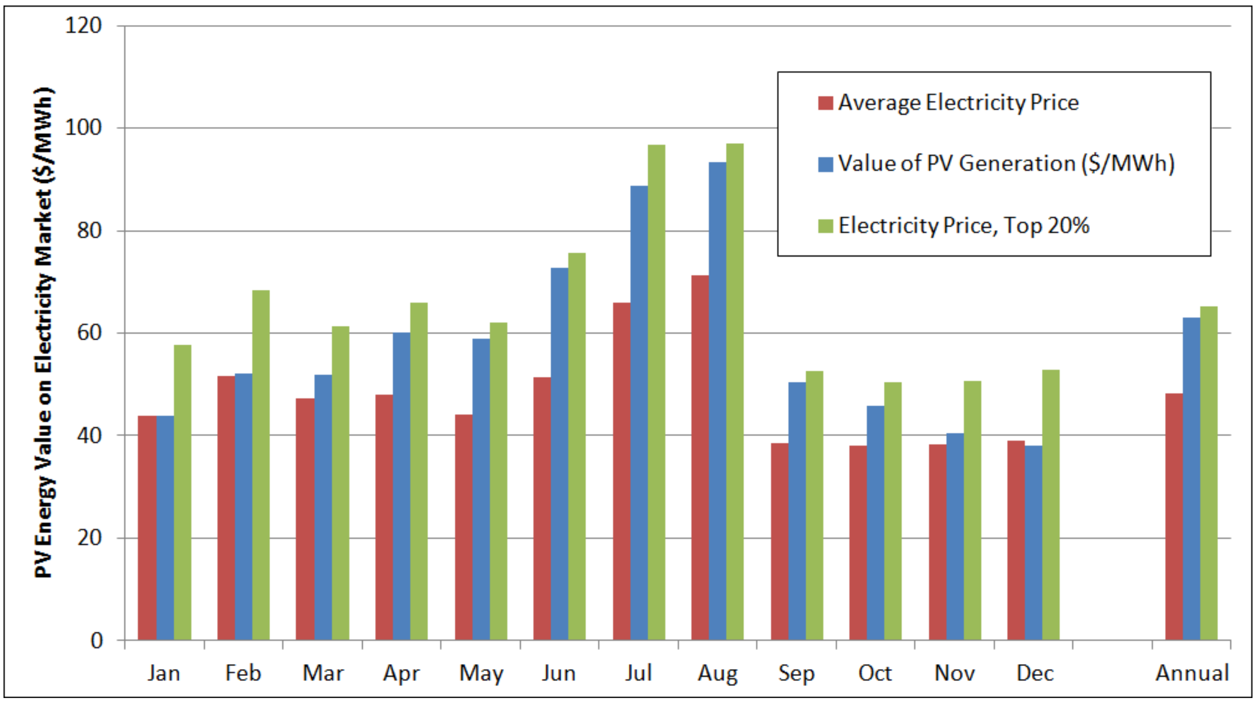

Figure 4. Average value of PV generation and electricity prices on Michigan wholesale electricity market

Figure 5 shows the estimated value of each component for PV in Michigan. The energy and generation value represents the largest component at $0.063/kWh, or 46% of the total value. The second largest component is the environmental benefits value at $0.025/kWh. Since Michigan is under a renewable portfolio standard, requiring a certain amount of its electricity to come from renewable resources, this value represents the price that utilities can avoid paying for RECs from other sources. Infrastructure support and deferrals make up the next $0.04/kWh, comprising T&D benefits, capacity benefits, and reactive power support. The combined value of all components is $0.138/kWh.

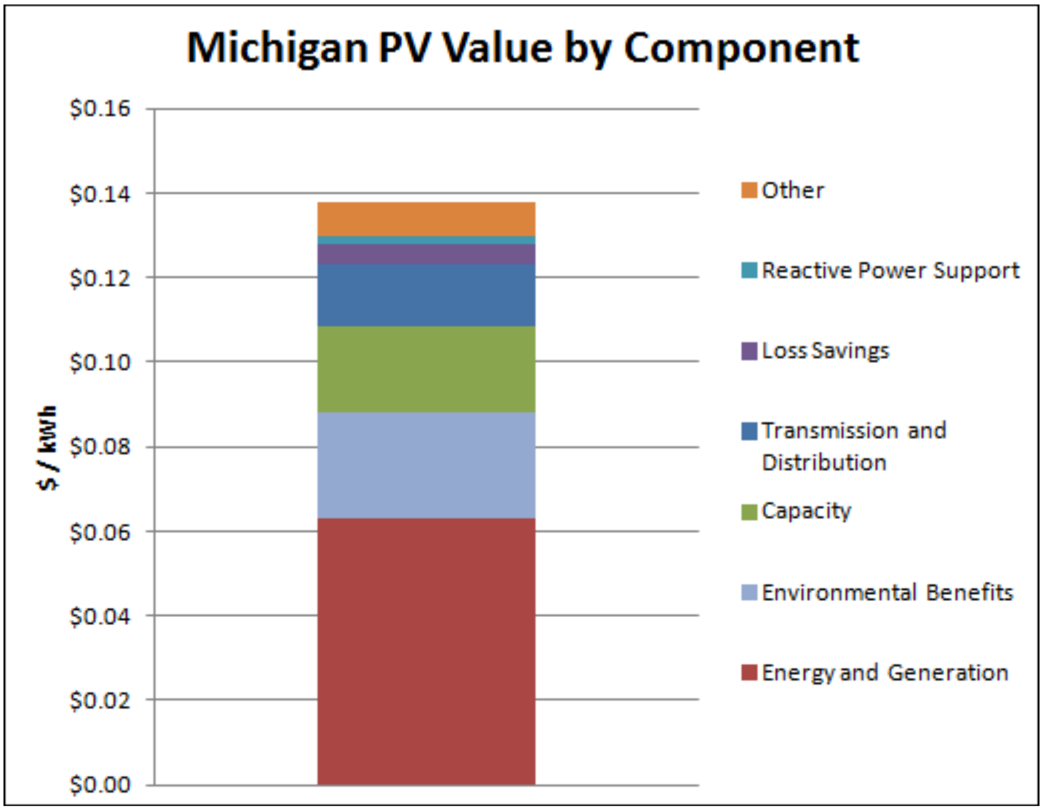

Figure 5. Estimated value of PV in Michigan

4 Conclusions

This study explores the value of PV generation in Michigan's wholesale electricity market and finds that PV value is consistently higher than average electricity prices due to favorable correlation with peak prices. Additional value components were also estimated, bringing the total value of PV in Michigan to four times that of its generation on the wholesale market. Over 75% of the PV value is realized in the energy and generation capacity benefits and the environmental benefits.

Suggestions for further analysis include a thorough investigation of PV value in Michigan, taking into account the various system constraints and infrastructure considerations for the state's local utilities.

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