Xcel Energy®

414 Nicollet Mall
Minneapolis, MN 55401

May 1, 2013

—Via Electronic Filing—

Burl W. Haar
Executive Secretary
Minnesota Public Utilities Commission
121 7th Place East, Suite 350
St. Paul, MN 55101

RE: SOLAR EFFECTIVE LOAD CARRYING CAPABILITY (ELCC) STUDY
DOCKET NO. E002/CI-13-315

Dear Dr. Haar:

Northern States Power Company, doing business as Xcel Energy, submits the attached preliminary Effective Load Carrying Capability (ELCC) study as proposed in our January 18, 2013 Reply Comments in Docket No. E002/GR-10-971 and ordered by the Minnesota Public Utilities Commission at their April 25, 2013 meeting.

Because all customers pay for the costs of power obtained from solar resources, it is important to closely align the price paid for solar power with the value provided by solar resources. The attached study analyzes the contribution of distributed solar electric generation to electric system reliability and the capacity value of solar on the NSP System. The Company also estimated accredited capacity for large solar systems using the methodology for intermittent resources prescribed by the Midwest Independent System Operator (MISO). We believe ELCC analysis and the MISO accreditation methodology are valuable tools to establish a sound basis for the value of solar that could be recognized in rates, regardless of the specific rate mechanism. For example, the analysis can be used to inform an appropriate solar capacity credit in the Standby Service Tariff or the buy rate under a Buy-all/Sell-all framework.

The Company will organize a meeting to review and discuss the preliminary study with interested parties, including the modeling assumptions and methodologies, and modify the analysis as necessary in response to parties' feedback. As ordered by the Commission, we will submit a solar rate proposal on October 1, 2013 that reflects the final analysis and any regulatory or policy changes that occur as part of the current legislative session. We will provide an update on July 1, 2013 that reports on our progress in working with stakeholders on the rate proposal.

We have electronically filed this document with the Minnesota Public Utilities Commission, and copies have been served on the parties on the attached service list.

Please contact me at amy.a.liberkowski@xcelenergy.com or 612-330-6613 if you have any questions regarding this filing.

Sincerely,

/s/

AMY LIBERKOWSKI
MANAGER
REGULATORY ANALYSIS

Enclosures
c: Service Lists

Effective Load Carrying Capability (ELCC) Study for Solar Generation Resources

Preliminary Results

Xcel Energy
Docket No. E002/CI-13-315

May 1, 2013

Table of Contents

I. Executive Summary

The goal of studying the value of solar resources in meeting peak electric demand is to develop a rate that appropriately reflects the value provided by solar resources, while protecting the interests of other customers who ultimately pay the costs of electricity purchased from these resources.

The analysis presented in this study expands on the work done in the Company's 2012 Solar Load Profile Study. Using a detailed simulation model, the Company calculated the effective load carrying capability (ELCC) of solar PV systems on the NSP System, which measures the contribution of solar to meeting peak electric demand. The Company also estimated accredited capacity using the methodology for intermittent resources prescribed in the Resource Adequacy Business Practices Manual developed by the Midwest Independent System Operator (MISO). The MISO methodology offers some advantages over the ELCC method, since it has received a thorough review process and can be easily replicated for individual projects.

The ELCC simulations used typical meteorological year (TMY) solar shapes that correlate well with the TMY load shapes used in the Company's simulation model. The MISO methodology was applied to the TMY data, as well as the actual data from three customer sites as presented in the 2012 Solar Load Profile Study. The analysis results show that, due to its variable nature, solar contributes less than its maximum rating to system reliability at peak periods.

ELCC & MISO Accreditation Summary Results*

Typical Meteorological Year	MISO Accreditation	ELCC	Average
TMY – Fixed Panel	45.4%	42.9%	44.2%
TMY – 1-Axis Tracking	52.3%	48.1%	50.2%

Customer Sites	MISO Accreditation
Customer Site 1 – Fixed Panel	60.7%
Customer Site 2 – Fixed Panel	58.6%
Customer Site 3 – 1-Axis Tracking	57.2%

* Percent of AC nameplate value

It is important to note that the data used in this analysis is limited. Currently, the NSP System has approximately 10 MW of solar resources in its entire footprint and MISO has yet to accredit any large solar installations.

II. Background

The Company currently has five customers with grid-connected solar PV systems that exceed the 60 kW_{AC} threshold requiring service under our Standby Service Tariff. The first system came online in April 2010. The most recent system came online in March 2013. Effective June 1, 2013, customers on the Standby Service Tariff will receive an interim solar capacity credit of $5.15 per kW per month.[1] This amount is halfway between the midpoint of the range identified by the Department and the Solar Rate Reform Group, $8.35, and the value suggested by the Company in its 2012 Solar Load Profile Study, $2.00. As ordered by the Commission, the Company will submit a new solar rate proposal on October 1, 2013 with a target implementation date of January 1, 2014.

The Company completed a solar load profile study in response to the Settlement Agreement in the Company's 2011 Test Year general electric rate case (Docket No. E002/GR-10-971). Specifically, the Settlement Agreement states:

> **F.2. Large Solar Facilities.** The Chamber proposed development of a new DG Solar rate that: a) would not have standby requirements; b) would not have demand charge penalties; and c) would reflect the Special MISO Mod E accrediting rating for solar installations. At this time, the Company lacks the information needed to determine the reasonableness of the Chamber's request. *The Company agrees to study the load profile of larger Solar facilities to determine the applicability of a solar facility's unique load characteristics to the standby and supplemental rate tariff and share those results with the Chamber by August 15, 2012.* (Italics added)

The Commission's May 14, 2012 FINDINGS OF FACT, CONCLUSIONS AND ORDER in the same docket required the study results to be filed with the Commission and shared with the Department of Commerce. The Company complied with the requirements, sharing the results with the Chamber on August 15, 2012 and filing public and non-public versions of the study on August 24, 2012. On September 14, 2012, the Company re-filed the study with the previously redacted information made public.

The 2012 Solar Load Profile Study provided an analysis of the production profiles of PV facilities greater than 60 kW_{AC} located at three customer sites using metering data. The customer-based analysis was also applied to solar data

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[1] As ordered by the Commission at the April 25, 2013 hearing in Docket Nos. E002/GR-10-971 and E002/M-10-1278.

sets based on a typical meteorological year[2] (TMY) for locations at the Minneapolis-St. Paul International Airport (MSP) and the St. Cloud Regional Airport (StC). The results showed that the average solar generation during the summer peak demand hours of 1 p.m. to 7 p.m. ranged from 37% to 50% of maximum rated AC output.[3] Table 1 provides the availability factor results from the Solar Load Profile Study.

Table 1: Solar Facility Availability Factor Summary

	1 p.m. - 7 p.m. On-Peak						
	Customer Sites			**Modeled Sites**			
Tracking:	Fixed	Fixed	1-Axis	Fixed	Fixed	1-Axis	1-Axis
Site	1	2	3	MSP	StC	MSP	StC
Summer	47%	43%	46%	37%	37%	50%	50%
Winter	25%	27%	24%	23%	23%	28%	29%
Annual	32%	33%	30%	25%	25%	33%	32%

* Percent of AC nameplate value

The study concluded that solar contributes to meeting the Company's peak demand, but the contribution is highly variable by time of day, month, and customer load requirement. Due to the limited data available, the Company advised that further analysis would be needed to support decision-making. The ELCC study provides the preliminary results of this additional analysis.

III. Effective Load Carrying Capability (ELCC) of Solar

This preliminary analysis calculates the effective load carrying capability (ELCC) of solar PV systems on the NSP System, which measures the contribution of solar to meeting peak electric demand. The results should be regarded as generalizations, as the actual contribution of any one specific PV installation will depend on site location, panel orientation, and type of equipment used. As discussed below, the Company used a detailed simulation model of system reliability to calculate the ELCC based on TMY solar patterns for the Minneapolis airport location from the National Renewable Energy Laboratory's (NREL) PVWatts[4] database.

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[2] A typical meteorological year is an 8,760 hourly pattern that represents typical atmospheric conditions at a specific location.

[3] The summer peak demand period is defined as 1 p.m. to 7 p.m. during the months of June through September.

[4] http://www.nrel.gov/rredc/pvwatts/

A. Methodology

The calculation of ELCC incorporates the use of a measure of electric system reliability called loss of load expectation (LOLE). LOLE is calculated by taking the average of the hourly loss of load probabilities (LOLP) over an entire year. LOLPs are in turn calculated using computer models that simulate a utility's hourly loads, generation capacity, and forced outage rates. For this study, the Company set its reliability target as an LOLE of one day in 10 years (or 2.4 hours per year), which is an industry standard typically used when evaluating system reliability.

The ELCC attributed to solar generation can be calculated by analyzing two generation portfolios: one with incremental solar generation and another with an incremental, generic capacity resource such as a gas-fired combustion turbine. Once the system without either incremental solar generation profile or the incremental generic capacity resource has obtained the target LOLE of one day in 10 years, the incremental solar resource is added to the system and the resulting LOLE becomes the target for the incremental, generic capacity resource profile. The total capacity of the incremental, generic capacity resource portfolio is adjusted until the annual average of the portfolio's hourly LOLPs is equal to the target LOLE value obtained with the solar generation profile. Then, the ELCC of the solar generation is obtained by dividing the incremental generic capacity resource MW_{AC} by the incremental solar MW_{AC}. For example, an ELCC measure of 45% indicates that 45 MW of combustion turbine capacity would supply the same peak capacity requirements as 100 MW of installed solar capacity. It can be considered the percent of a PV system's maximum AC output that is available, on average, to meet system peak demand.

The Company conducted this ELCC analysis utilizing a ProSym[5] production cost simulation model. ProSym uses a TMY pattern to represent the hourly energy demand from our customers. As such, it was appropriate to use solar patterns that were also based on a TMY. If actual solar generation patterns from metered installations had been used, there would potentially have been a misalignment between solar generation and customer demand, which could have skewed the result of the LOLE calculation. Additionally, at this time, the number of actual customer sites and duration of metering data is insufficient to develop a representative sample.

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[5] ProSym is a Ventyx product used in resource planning.

ProSym was run using two different TMY shapes from NREL's PVWatts[6] database. One was based on a fixed panel installation with a 45 degree tilt and a 180 degree azimuth (due south); the other was a single-axis tracking design with the same orientation that has the ability to track the sun as it moves across the sky. The orientations of these panels are typical for the Minnesota region, as they maximize the total annual capacity factor of solar arrays. As illustrated in Table 2, designing solar installations for maximum annual generation does not result in production at maximum capacity during the summer months when customer demand is highest. Instead, maximum output is achieved in February and March when the sun's position in the sky most closely matches the 45 degree tilt that was assumed in the TMY solar shapes.

Table 2: TMY Solar Shape Summary

	Fixed Panel		**1-Axis Tracking**	
	Average Capacity Factor	Maximum Generation	Average Capacity Factor	Maximum Generation
Jan	14%	96%	17%	95%
Feb	17%	100%	20%	100%
Mar	17%	100%	20%	100%
Apr	16%	89%	21%	91%
May	19%	88%	25%	89%
Jun	19%	78%	25%	78%
Jul	18%	76%	26%	78%
Aug	17%	76%	23%	78%
Sep	17%	81%	21%	81%
Oct	15%	84%	18%	84%
Nov	10%	79%	11%	79%
Dec	10%	86%	12%	86%
Annual	16%	100%	20%	100%

The specific procedure used in ProSym to calculate the ELCC of solar is as follows:

1) Set up ProSym model for reliability run analyses and convert all scheduled maintenance days to maintenance rates.
2) Adjust the firm generic resource capacity in ProSym until the system's LOLE is equal to one day in 10 years.
3) Add 100 MW_{AC} solar profile to the NSP System and run ProSym to record the resulting (lower) LOLE.
4) Remove the 100 MW_{AC} solar profile from ProSym and incrementally add small amounts of firm generic resource capacity (natural gas

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[6] http://www.nrel.gov/rredc/pvwatts/

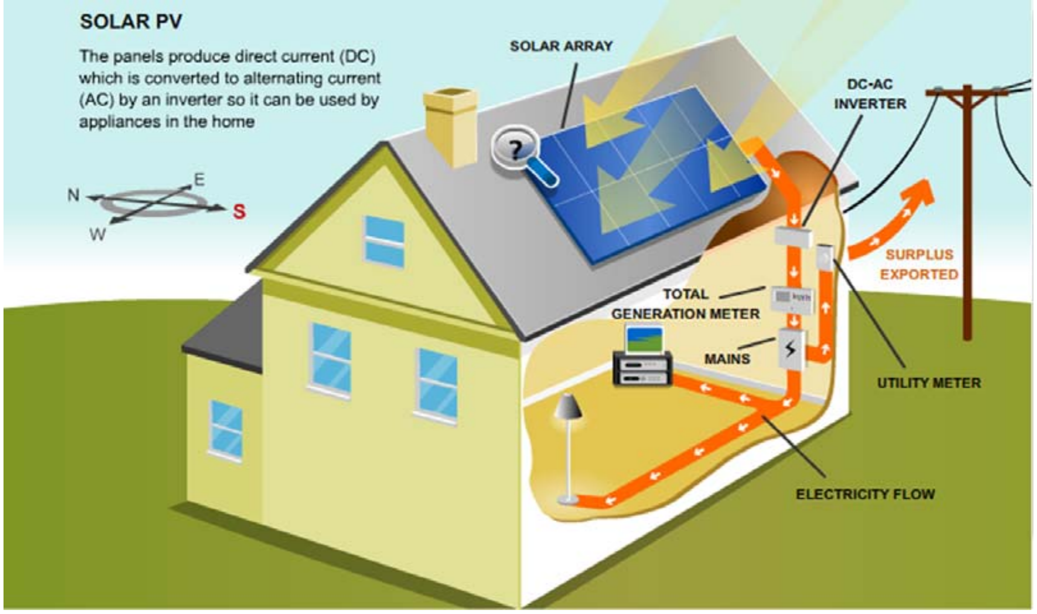
combustion turbine) until the LOLE returns to the lower LOLE observed in the previous step.

5) Calculate ELCC as (Firm Resource Capacity)/100 MW_{AC} Solar

The analysis used 100 MW increments of solar because, after testing, it was determined that the actual 10 MW level of solar on the NSP System was too small to produce reliable model results. Because the ELCC of solar is approximately 50% of the maximum rating, the amount of firm capacity in the ProSym model using the actual 10 MW on our system was only about 5 MW. In the context of the 10,000 MW NSP System, such a small increment of firm capacity was essentially "lost in the noise" of the rest of the model simulations. Testing with 100 MW provided much more stable results, allowing the ELCC values to be generalized to the smaller MW levels currently on the system.

We present the results as both a percent of AC capacity and DC capacity. As shown in Figure 1 below, solar panels create DC electricity that is passed through an inverter for conversion to AC electricity that can be used by end users or exported to the distribution grid. Some electricity is lost through the conversion process. This analysis assumed an inverter efficiency rating of 85%, which means that the maximum generation capacity of the PV system is 15% less than the DC nameplate capacity.

Figure 1: Solar PV System Diagram



Accompanying this study on compact disk is a comprehensive data package to assist in stakeholder review. The data is contained in two spreadsheets. The first spreadsheet titled "ELCC Data" contains the hourly inputs for load and solar profiles used in the analysis and the hourly LOLP results produced by ProSym. The second spreadsheet titled "MISO Method and Charts" provides the data and calculation for estimating the capacity credit values under the MISO methodology and the supporting data for the charts presented in the study. Attachment A provides an index to the data included in the spreadsheets.

B. Results

ProSym modeling results indicated that fixed panel installations have an ELCC of 42.9**%,** while single-axis tracking systems have an ELCC of 48.1**%**. That is, 42.9% of the maximum AC rating of a fixed panel PV installation and 48.1% of the maximum AC rating of a single-axis tracking system can be counted as firm capacity that contributes to total system reliability. Assuming an inverter efficiency rating of 85%, the corresponding DC ratings would be 36.5% and 40.9% for fixed panel and single-axis tracking, respectively. As previously noted, these results are based on TMY patterns with a 45% tilt and a 180 degree azimuth. The actual ELCC of any specific solar installation will vary year to year depending on the amount of solar insolation received and the orientation of the panel. Table 3 summarizes the ELCC values for fixed panel and single-axis tracking PV installations.

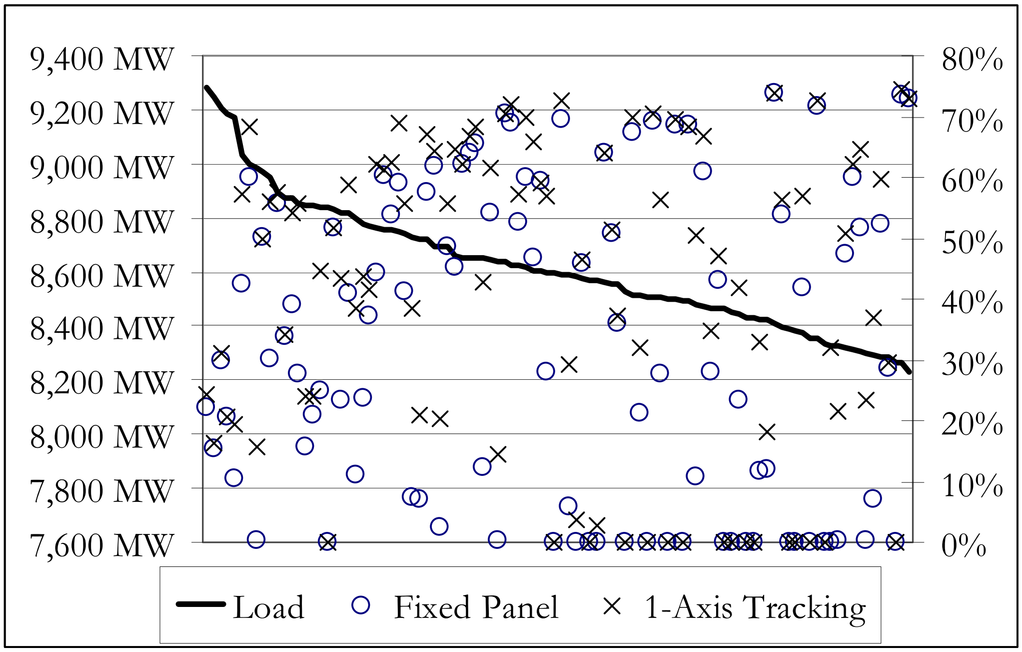
Table 3: ELCC Results

	ELCC Relative to Maximum AC Output	ELCC Relative to Maximum DC Output*
Fixed Panel PV	42.9%	36.5%
1-Axis Tracking PV	48.1%	40.9%

* Assumes an inverter efficiency of 85%.

While calculation of solar's ELCC involves summing its contribution to system reliability in every hour of the year, the greatest contribution occurs during periods of the highest customer demands. Figure 2 illustrates the 100 highest customer demand hours, as modeled in ProSym, and the solar generation in each of those hours based on the PVWatts TMY. The secondary y-axis on the right measures the solar generation as a percent of maximum AC capacity. These results are specific to this ELCC study. Analysis of data from a specific year and specific site may produce different results, including greater (or lesser) correlation between peak demand and solar output.

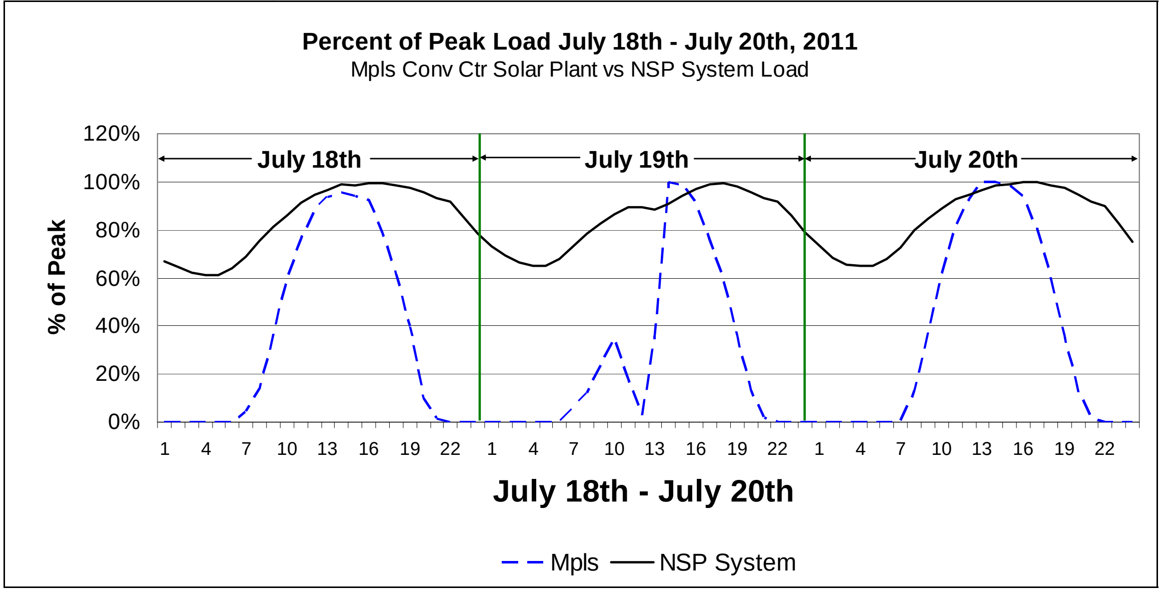
Figure 2: Solar Generation During Highest 100 Demand Hours



As shown above, during the 100 highest customer demand hours modeled in ProSym, fixed panel PV generates no energy in 18 hours, while single-axis tracking systems generate no energy in 14 hours. Inspection of the data reveals that these hours are between 6 p.m. and 10 p.m. in July and August. There are instances in the solar data where tracking systems generate power as late as 8 p.m. and fixed panel configurations generate as late as 7 p.m. However, these instances do not coincide with the highest customer demand hours.

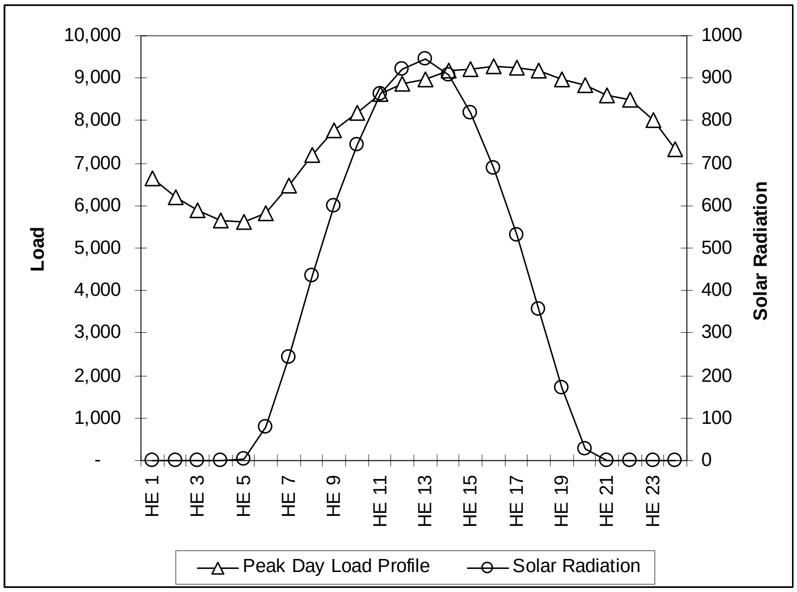
Figure 2 also highlights the variability of solar's contribution to meeting peak demand. There could be several reasons why solar output is not more closely correlated with periods of high demand. For example, it is possible that during periods of peak demand there may be atmospheric interferences (clouds or haze) that limit peak generation from solar panels. Figure 3 illustrates the impact of a storm's disturbance of solar output using actual solar output and system load data over a period of three days in July 2011. The solar output as a percentage of peak drops significantly on July 19 from 10 a.m. to 2 p.m. (hours 10-14), as the cloud interference related to a storm passes between the sun and the PV installation. Since the ELCC is measurement of reliability, the possibility of this type of weather event explains a portion of the difference between the ELCC finding and peak output of the PV system over a period of time.

Figure 3: Impact of Storm Activity on Solar Output



Additionally, peak load hours tend to occur later in the day when solar radiation is not at its peak. Figure 4 illustrates the typical hourly load pattern for a peak demand summer day on the NSP System and corresponding measured solar radiation. A similar pattern is present in Figure 3.

Figure 4: Peak Day Load Profile and Solar Radiation[7]



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[7] Solar radiation source: National Solar Radiation Database - http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2010/

C. Analysis Limitations

The Company believes it has produced a sound analysis of the ELCC for solar generation. As with any model, however, there are limitations to our analysis. For example, it was not possible to perfectly align the solar patterns with the load shape used in ProSym. While both solar and load patterns represent typical meteorological years, the vintages are different. The PVWatts database used years ranging from 1963 to 1990 to develop the TMY for solar. The load shape in ProSym is a TMY developed using data from the years 1990 to 1996. Thus, the weather patterns represented in the solar shape are not identical to the patterns in the load shape; both represent typical or average weather patterns, but they are not identical. Due to limited data, it does not seem possible to either fit actual solar data to ProSym's current load TMY, nor is it possible to find hourly load data from 1963 to 1990 that would fit the TMY that is used by PVWatts. One recommendation for future improvement in the assessment of solar's contribution to system reliability is to develop new TMY patterns for solar and load. The Company welcomes suggestions on how to improve the fit of the data.

IV. MISO Accreditation of Intermittent Resources

The Company also evaluated solar's contribution to peak demand using a methodology established by MISO. Any solar resource that connects directly to the transmission system and seeks to be accredited as a network resource must register with MISO and calculate a capacity credit. Currently, there are no large solar generation facilities that have received capacity credit in MISO.

The Resource Adequacy Business Practices Manual (BPM) specifies a methodology for establishing an accredited capacity value of non-wind intermittent generation. Section 4.2.2.3 of the BPM states:

> All other Intermittent Generation and Dispatchable Intermittent Resources will have their annual UCAP value determined based on the 3 year historical average output of the resource for hours 1500-1700 EST for the most recent Summer months (June, July, and August).[8]

For systems that are new, upgraded or returning from extended outages, where data does not exist for some or all of the previous 36 months, MISO instructs applicants to submit all operating data for June, July, or August with a

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[8] https://www.midwestiso.org/Library/BusinessPracticesManuals/Pages/BusinessPracticesManuals.aspx

minimum of 30 consecutive days, in order to have their new or upgraded capacity registered with MISO.

The Company does not have three full years of hourly data that can be used to calculate the MISO UCAP value for solar. As a substitute, we applied the methodology to the single year of TMY data used in the ELCC analysis and the three sets of customer data presented in our 2012 Solar Load Profile Study. The results are summarized in Table 4.

Table 4: Solar Accreditation – MISO Methodology

	MISO Accreditation Relative to Maximum AC Output	**MISO Accreditation Relative to Maximum DC Output***
TMY – Fixed Panel	45.4%	38.6%
TMY – 1-Axis Tracking	52.3%	44.5%
Customer Site 1 – Fixed Panel	60.7%	56.5%
Customer Site 2 – Fixed Panel	58.6%	49.8%
Customer Site 3 – 1-Axis Tracking	57.2%	51.0%

* TMY values assume 85% inverter efficiency

Using the MISO methodology, the accredited values for the customer sites is slightly higher than for the TMY data used in the ELCC analysis. It is possible that these sites have oriented their panels to capture more solar energy during peak periods, either by tilting panels to be flatter than the 45 degrees assumed in the TMY data or by pointing panels in a more westerly direction.

Figure 5 illustrates that the TMY shapes have more consistent year-round generation, while the generation at customer sites is more focused on the summer months.[9] Additionally, Attachment B provides charts of average generation by hour for June, July, and August for the customer sites and TMY shapes. These charts show that the generation in the TMY shapes is higher in the morning hours and lower in the afternoon in comparison to the customer data. This indicates that the azimuth of the customer sites might be oriented more towards the west than the due south orientation assumed by the TMY data. Without a larger sample of customer sites and a longer interval of metering data, it is not known if these customer site results are representative of the overall solar population or just particular to the three sample data set the Company was able to obtain.

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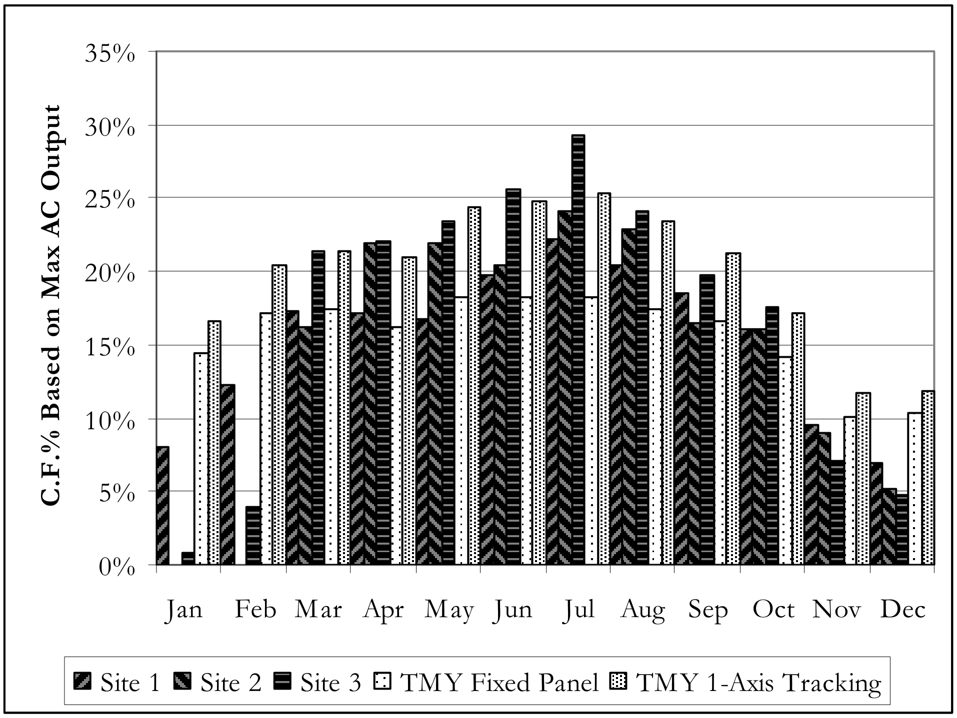
[9] The data for site 2 in January and February was unavailable.

Figure 5: Monthly Solar Capacity Factor Values



V. Rate Implications

A capacity credit should adequately reflect the contribution of solar to meeting peak demand, but not be excessive since all other customers pay for the credit. We used the results of the ELCC study and MISO methodology to estimate capacity credits by applying the solar capacity contribution percents to the generation ($4.99 per kW) and transmission ($2.52 per kW) cost components of the present average monthly demand charge. Although we have included transmission capacity cost credits in the table, transmission cost savings are not fully related to system peak loads and have not been clearly established. As shown in the table below, we estimate a generation capacity credit range of $2.14 per kW to $2.61 per kW, and if transmission capacity cost is included in the credit, the solar capacity credit range is $3.22 per kW to $3.93 per kW.

Table 5: Estimated Solar Capacity Credits

	Avg. Monthly Demand Charge	Fixed Panel		1-Axis	
		ELCC	MISO	ELCC	MISO
		42.9%	45.4%	48.1%	52.3%
Generation	$4.99	$2.14	$2.26	$2.40	$2.61
Gen. + Trans.	$7.51	$3.22	$3.41	$3.61	$3.93

The estimated solar capacity credits are derived from seasonal demand charges for firm service to maintain a consistent embedded cost basis for both rates and rate credits. The direct application of a solar capacity contribution percent to a current avoided cost could produce a credit that is inconsistent and out of proportion to the present rate that is credited.

VI. Conclusion

The analysis presented in this preliminary study confirms that solar generation contributes to system reliability, but at far less than its maximum rating. Based on the TMY analysis and the ELCC and MISO methodologies, fixed panel PV contributes, on average, 44% of its maximum rating to meeting system peak. The single-axis tracking systems average 50% of maximum rating. The results also show that the ELCC methodology for calculating accredited capacity results in lower but generally consistent values compared to the method prescribed by MISO.

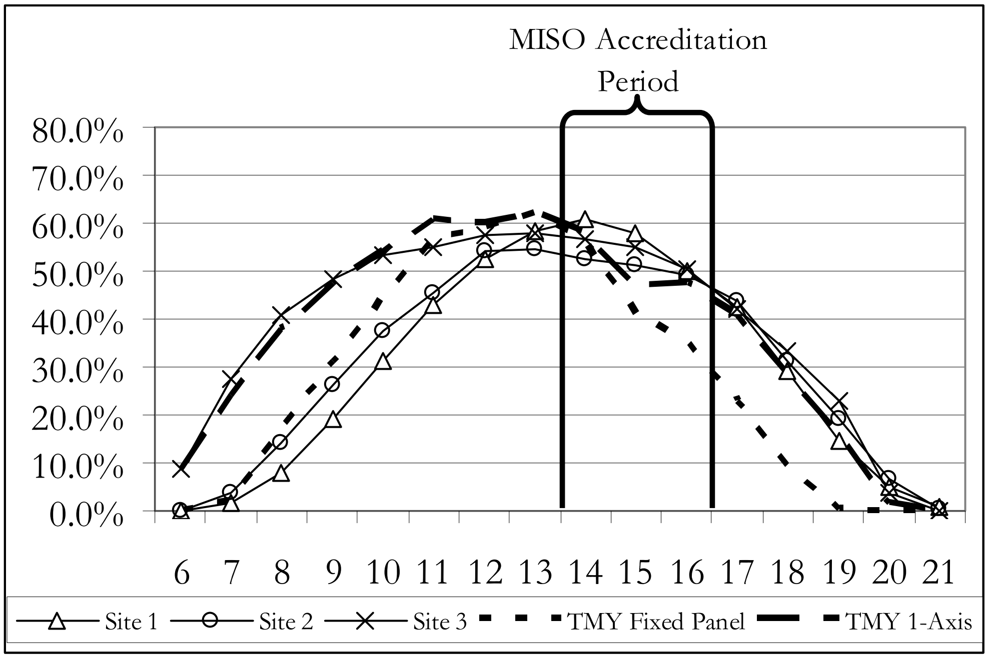
Index for Data Package

- Attachment A.1 – ELCC Data.xls
    - Tab 1 – Solar & Load Inputs
    - Tab 2 – Hourly LOLP Results
    - Tab 3 – Figure 2 Data (Solar Generation During Highest 100 Demand Hours)

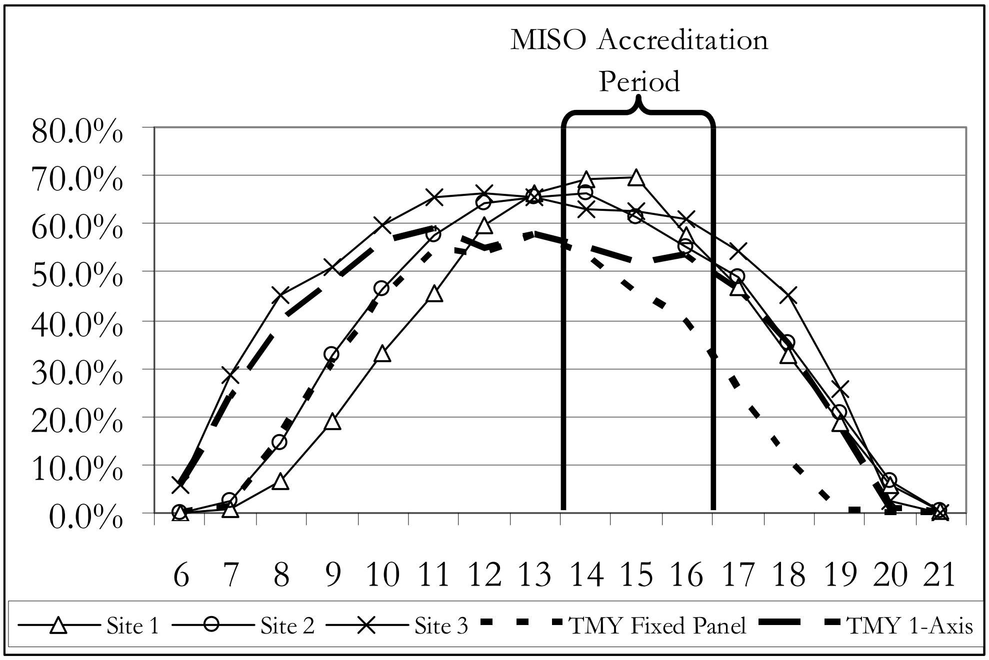
- Attachment A.2 – MISO Method & Charts.xls
    - Tab 1 – Figure 2 (Peak Day Load Profile and Solar Radiation)
    - Tab 2 – Average Solar Shapes (as presented in Attachment A)
    - Tab 3 – Figure 4 (Monthly Solar Capacity Factor Values)
    - Tab 4 – Summary Data (Including MISO accreditation calculations)
    - Tab 5 – Site Data (Hourly data and summary calculations)
    - Tab 6 – TMY Data (Hourly data for TMY shapes)

Average Generation by Hour for June, July, and August

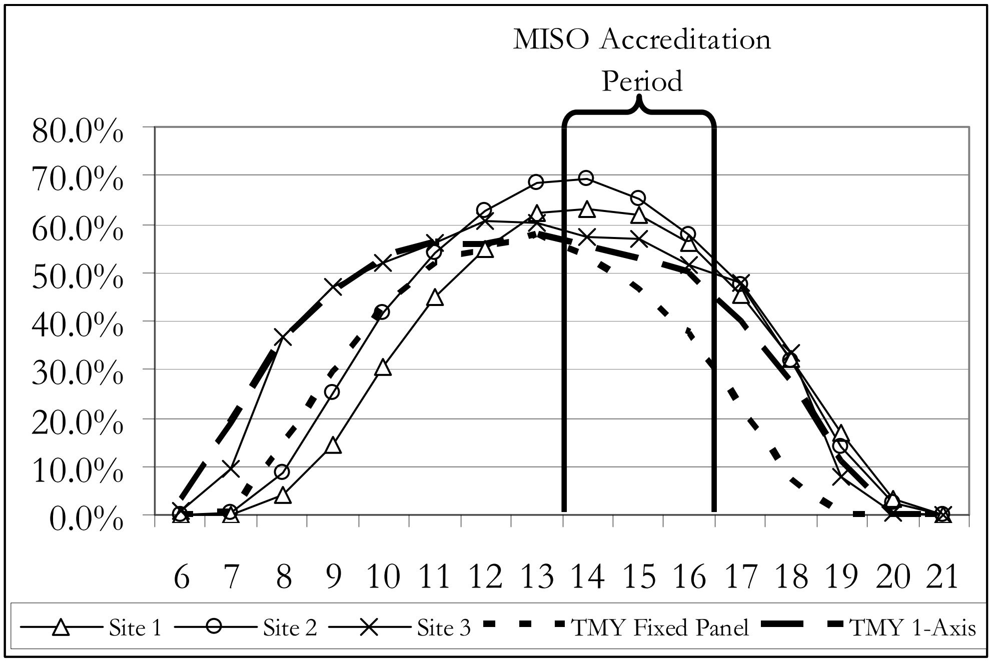
Average Hourly Generation - June



Average Hourly Generation - July



Average Hourly Generation - August



CERTIFICATE OF SERVICE

I, SaGonna Thompson, hereby certify that I have this day served copies of the foregoing document on the attached list of persons.

xx by depositing a true and correct copy thereof, properly enveloped with postage paid in the United States mail at Minneapolis, Minnesota

xx electronic filing

Docket Nos. E002/GR-10-971 and E-002/M-10-1278

Dated this 1st day of May 2013

/s/

SaGonna Thompson
Records Analyst

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