BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of KCP&L Greater Missouri Operations Company for Permission and Approval of a Certificate of Public Convenience and Necessity Authorizing It to Construct, Install, Own, Operate, Maintain and Otherwise Control and Manage Solar Generation Facilities in Western Missouri.	)))))))	Case No. EA-2015-0256

EVERGY MISSOURI WEST'S COMPLIANCE FILING

COMES NOW, Evergy Missouri West, Inc. d/b/a Evergy Missouri West ("Evergy Missouri West" or the "Company")[1] and states as follows:

1. On March 2, 2016, the Missouri Public Service Commission ("Commission") issued its Report and Order ("Report and Order") in the above-captioned proceeding, to be effective on March 12, 2016, which stated in part:

> 2(e) Develop and file with the Commission a plan outlining its learning objectives for the Greenwood Solar Facility and a description of how the company will evaluate those objectives before commencing construction.
>
> **2(f) File with the Commission an evaluation of the Plan required by (e) after the Greenwood Solar Facility has operated for a period of five years before the company's application for a certificate of convenience and necessity for its next utility-scale solar facility.**[2]

2. The information requested by the Commission is contained in the attached **CONFIDENTIAL Exhibit A**.

3. Due to an oversight the Company is filing the required compliance information outside of the five year operation deadline.

[1] Effective October 7, 2019, Evergy Missouri West adopted the service territory and tariffs of KCP&L Greater Missouri Operations Company ("GMO").
[2] Report and Order, p. 19, Ordering ¶ 2(f).

Respectfully submitted,

/s/ Roger W. Steiner

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CERTIFICATE OF SERVICE

I do hereby certify that a true and correct copy of the foregoing document has been hand delivered, emailed or mailed, postage prepaid, to all counsel of record in this case on this 18th day of February 2022.

/s/ Roger W. Steiner

Counsel for and Evergy Missouri West

Final report: Evergy Integrated Grid – Utility Scale Solar Pilot Project

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI) PREPARED THIS REPORT.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

The Electric Power Research Institute (EPRI) prepared this report.

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This report describes research sponsored by EPRI.

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2 ABSTRACT

This is the final report for a multi-year supplemental project undertaken by Evergy (née KCP&L) and EPRI entitled **"KCPL Integrated Grid Pilot – Utility Scale Solar Pilot Project"** (contract ID **20006745**). This report covers research for assessing PV plant performance and evaluating grid impacts and economics on distribution feeders. Data from plant operation was collected, transferred from Evergy to EPRI in two segments. One from beginning of January 2018 to June of 2019, the other from June 2019 to June 2020. Both data sets reached the same conclusion. The Greenwood plant appears to be operating as expected. The actual power output is slightly better (2.5%) than expected. This suggests the actual system loss is lower than expected in the model. Additionally, modules could have received higher irradiance than the sensor measurement. The expected power output is lower than predicted. This is caused by the lower insolation at the plant comparing to a typical meteorological year, at 4.09 vs. 4.45 kWh/m^2/day, respectively. The site was impacted by many snow events, which contributed to ~4.9% energy loss. The snow induced losses are difficult to predict. Nevertheless, they should be estimated and accounted for when designing future plants.

Evaluation of impacts on distribution feeders will be addressed in additional reports.

3 EXECUTIVE SUMMARY

3.1 KEY RESEARCH QUESTIONS

Generation question

- How well are PV plants performing relative to upfront design predictions? To actual, local weather conditions?
- How accurate are PV plant modeling tools in predicting real-world energy performance?
- How dependable (and variable) is solar power capacity at specific times of day across different seasons?

Distribution question

- Where (and to what extent) is the power system impacted when siting distribution-connected PV plants?
- How well does localized solar power align with overall distribution feeder load?
- What are benefits/cost implications to distribution systems when integrating PV plants at different locations along a feeder?

3.2 RESEARCH OVERVIEW

This project seeks to answer strategic research questions about renewable generation and integration of utility-scale plants on the power system. Specifically, this project intends to support the Evergy Utility Scale Greenwood Solar Facility by utilizing planned deployments to accomplish the following tasks:

1. Assess PV Plant Performance: and
2. Evaluate Grid Impacts and Economics on Distribution Feeders

Results are expected to be applicable within Evergy's service territory, and generalized learnings may provide public benefit. The objectives are to provide new learnings and help KCP&L accomplish several goals:

- Assess strategies and decision points for locating and designing utility scale solar facilities.
- Understand links between design and construction of the solar facility to solar generation performance.
- Communicate the performance of solar from an energy and capacity perspective.
- Determine grid impacts of PV plants on distribution feeders and how modelling can be used dependably for planning; and
- Inform operations and maintenance activities (including personnel training), their frequency, associated cost, and link to energy production.

Research results are not generally available. Thus, it may be of interest to many utilities engaged in deployment of PV plants.

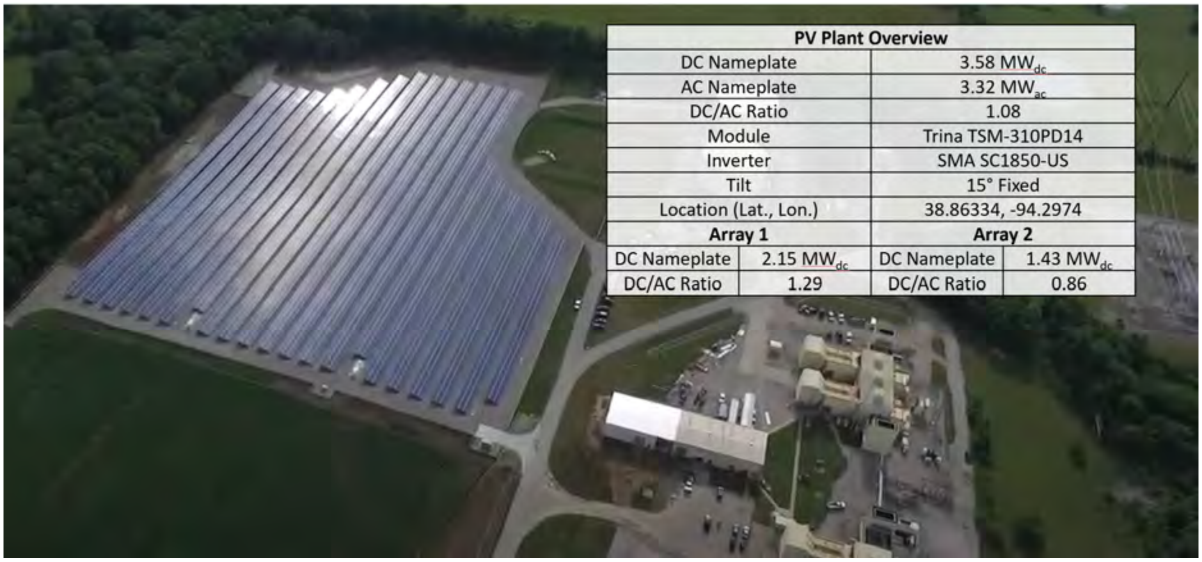
3.3 KEY FINDINGS

EPRI's work to date has yielded multiple insights:

- The monitoring and data collection quality is high, as seen by the little amount of missing and erroneous data.
- The occurrence and significance of power outages are relatively small. Only 0.7% of the plant's potential energy is lost due to outages. The default input in the modeling tool is 2%. It is early in the life of the plant, so there is potential for outages to increase in time if proper preventative maintenance is not taken.
- The site was impacted by many snow events contributing to 4.9% energy loss from potential. Snow loss is difficult to predict. Nevertheless, it should be estimated and accounted for in future plant designs.
- An artificial clipping limit placed on Inverter 2 limited the plant output to 3 MW_{ac} as opposed to a possible 3.3 MW_{ac}. This had negligible effect on the energy generated over the course of the analysis period.
- Solar insolation for the period was lower than typical. Daily insolation (global horizontal) was 4.09 $kWh/m^2/day$ compared to 4.45 $kWh/m^2/day$ for a typical meteorological year.
- During times of full capability (no snow or outages), plant performance is better than expected with the assumed losses given. This indicates a good design, quality construction, and low accumulation of faults, failures, and degradation.
- The capacity factor is ~0.15 when including outage and potential snow cover events. The capacity factor of the fully capable system (no snow or outages) is 0.167 compared to an expected capacity factor of 0.166. Despite this, the capacity factor is lower than the predicted one of 0.186 due to lower than typical insolation.
- When the system is not compromised by snow, the performance ratio shows that it performs at around 88.5% of its nameplate rating. A value that is relatively good for PV plants.
- The fully capable system performs about 2.5% higher than the modeled system with the assumed losses described in Table 1. This suggests the system loss is lower than expected. It is also possible that modules have received higher irradiance than measured by the sensor.
- Variable production, primarily due to variable irradiance from passing clouds, was measured. The inner quantile variations are >20% of nameplate capacity for all seasons. This is mainly due to the small number of clear sky days and high variability of cloud coverage at the plant.
- PV output each day is generally in line with the mid-day load peak. However, the overall shape of PV production is much steeper than load demand due to no power generation at night. PV output is also in line with peak load demand in summer throughout the year, but they quickly diverge in winter.
- Collocating a PV plant with thermal power plant appears beneficial, mainly from operations, maintenance, and training perspectives. The cost of operating and maintaining the Greenwood PV plant seems to be at the lower end of the cost distribution in the industry.

4 PROJECT OVERVIEW

For the last decade, solar energy has been growing at a rapid speed. This is mainly driven by technology advancement, capital cost reduction, and industrial goal to achieve carbon neutrality. Despite this, solar power still needs to overcome several challenges before it becomes a mainstream energy source. One challenge is the understanding of energy production, this includes the understanding of the actual energy production when comparing to the projected energy production. Another challenge is the optimizing of operation and maintenance cost over the life span of the project.



PV Plant Overview			
DC Nameplate		3.58 MW_{dc}	
AC Nameplate		3.32 MW_{ac}	
DC/AC Ratio		1.08	
Module		Trina TSM-310PD14	
Inverter		SMA SC1850-US	
Tilt		15° Fixed	
Location (Lat., Lon.)		38.86334, -94.2974	
Array 1		**Array 2**	
DC Nameplate	2.15 MW_{dc}	DC Nameplate	1.43 MW_{dc}
DC/AC Ratio	1.29	DC/AC Ratio	0.86

Figure 1. Evergy Greenwood PV pilot plant overview

Figure 1 is a brief overview of the Evergy Greenwood pilot PV plant. The Inset table shows the details of the plant design with two different arrays. Polycrystalline silicon modules were used for the project. Array 1 was designed with a DC/AC ratio of 1.29, while Array 2 was designed with a DC/AC ratio of 0.86. The Array differences were intended to understand the DC/AC ratio impact to plant performance.

5 INTRODUCTION

PV power plants do not use consumable material comparing to coal and gas power plants. Nonetheless, PV plant is a system of many components. As shown in Figure 2, the performance of a PV plant starts with choosing and designing the site, to selecting the appropriate PV module, mounting structure and inverter, to establishing the balance of system (BOS) and digital infrastructures.

PV plant power output is affected by many elements:

- The irradiance level at the site, which can vary drastically between locations and seasons.
- The irradiance received by the module. This is affected by the module tilt angle, cloud, soil and snow cover etc.
- Module efficiency and degradation rate throughout its lifetime. Higher efficiency modules can covert light into electricity more efficiently. Also, we must consider the module degradation

rate over time, which can have a significant impact on energy output over the lifetime of a PV plant.

- Module temperature response. Module efficiency can decrease when module temperature arises. The typical power output impact is between 0.4-0.6%/°C.
- Resistance power loss through wires and interconnections.
- DC to AC conversion losses at inverter.
- DC : AC ratio of the plant design, where clipping of DC power can occure when output DC power exceeds the AC rating of the inverter
- Curtailment of the PV power plant. This happens when the PV power plant can generate more power than the grid demand or transmission capacity. The excess power is purposely reduced to meet the demand.

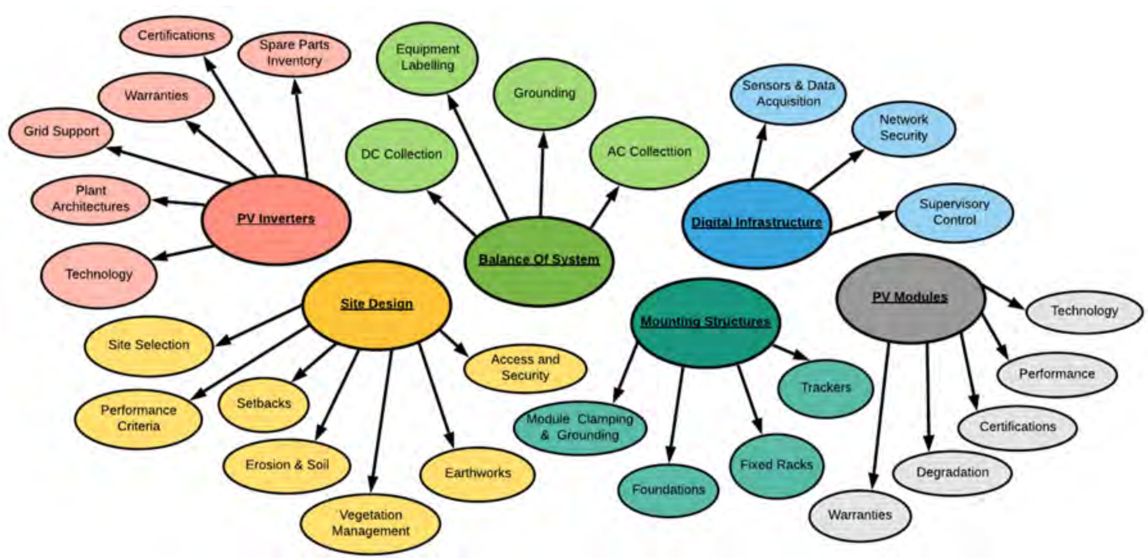


Figure 2. Large scale PV power plant performance assessment

As a result, critical parameters at PV power plants are measured from component to system level. This is to monitor PV plant performance and to assist in the diagnosis of problems. Figure 3 shows the commonly measured parameters at PV plant. Typically, pyranometers will be used to measure irradiance. This includes in-plane irradiance or power of array (POA), and global horizontal irradiance (GHI). The ambient temperature and wind speed is measured by weather station. The irradiance, ambient temperature and wind speed can all affect module temperature, thus influence module power output. The AC/DC voltage, current and powers are typically recorded at inverter. There are many other factors that can affect plant performance, such as soiling, precipitation, snow, and shading. Those factors will need special sensors combined with additional data analysis to quantify the impact, thus is not considered in this report. One exception is the snow impact, which is estimated using customized analytical method.

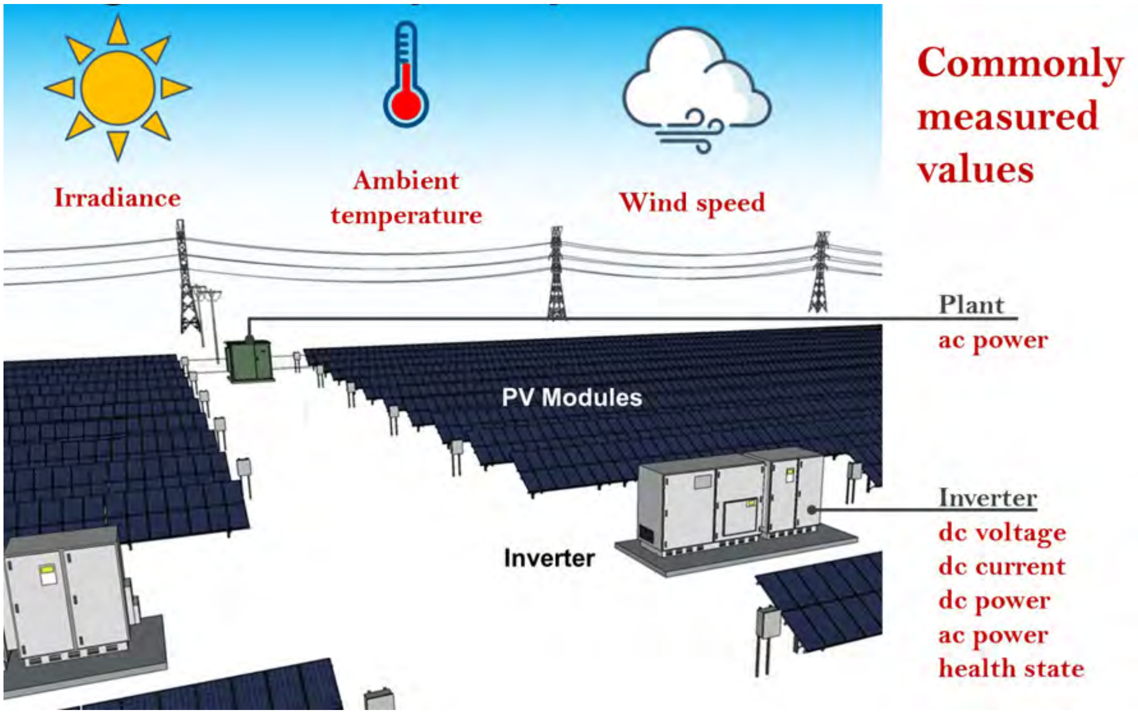


Figure 3. parameters measured to monitor PV plant heath

6 PERFORMANCE ASSESSMENT METHOD

6.1 PERFORMANCE MODELING

Assessing PV performance is quite complex due to the many factors involved. There are numerous models available for evaluating PV plant performance. Examples are PVSyst [1], System Advisor Model (SAM) and Plant Predict. Before the PV plant is constructed, power output can be predicted by modeling the PV plant using historical weather data. For example, the typical meteorological year (TMY) file can be obtained from the National Solar Radiation Database. The PV plant design information will need to be provided, such as module type, inverter type, racking system (e.g., fixed tilt, single axis, or dual axis tracker). Also, the model can be adjusted by assuming some system losses, such as soiling and wiring losses. the "predicted" energy output is very useful because the data can be used to calculate the business case for the project before it is built. Once the PV plant is constructed, the "expected" energy output is modeled using the same software with inputs from the actual measured data. Instrumentation will be deployed to collect real time weather data, such as irradiance, temperature, and wind speed. The "expected" output is typically used to compare to the "actual" output measured at inverter to understand the PV plant performance. Figure 4 illustrates how the "predicted", "expected" and "actual" output were obtained.

[1] PVSyst is mostly commonly used PV modeling software available for Silicon modules. SAM is an open-source software created by National Renewable Energy Laboratory (NREL), Plant Predict is developed for CdTe thin film modules. There are many more modeling software available on the market.

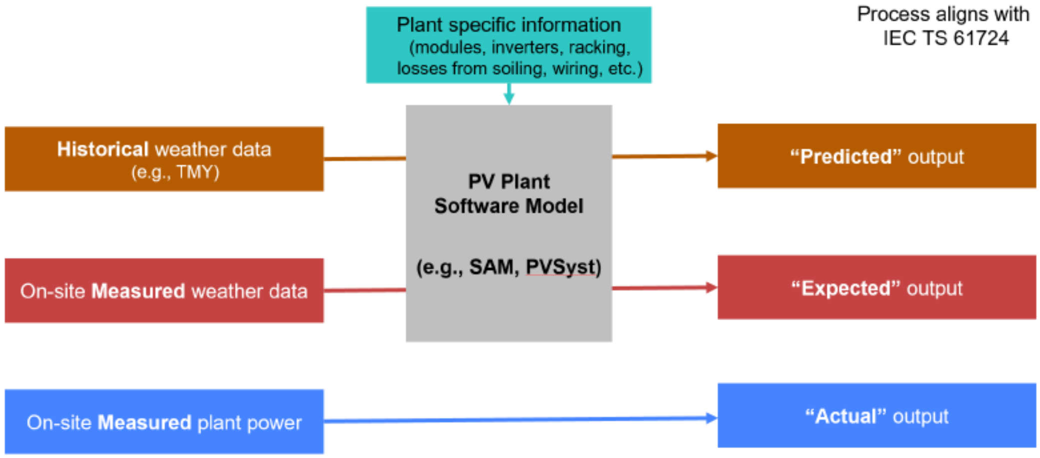


Figure 4. Explanation of how Predicted, Expected, and Actual plant performance outputs are created.

In this work, the SAM software was used to calculate the expected power output from the Greenwood PV plant. It is worth noting that modeling is inherently limited by the assumptions built into the model. The parameters included in the model and the accuracy of inputs will greatly affect results. For PV energy output modeling, the simulated energy output is usually within +/-5% error due to instrumentation errors and other factors presumed in the model. Some important parameters are not measured because they are difficult or expensive to measure, can be estimated, or are thought to be insignificant. Parameters included but not directly measured are soling, module mismatches, wiring, connections, diodes, and inverter efficiency. Their actual used values are shown in Table 1. Parameters not included in the model are shading, snow, plant availability, nameplate, degradation, module efficiency at different light condition, inverter efficiency at different DC input etc. Furthermore, errors can come from the difference between real and intended design, such as plant construction and maintenance.

Table 1. Loss Parameters used in Modeling

Losses Included (SAM Default Values)	
Soiling	5%
Mismatch	2%
Wiring	2%
Connections and Diodes	0.5%
Inverter Efficiency	98% (CEC Weighted Efficiency)
Losses Not Included	
Shading, Degradation, Snow, Availability, Nameplate	

It is worth mentioning that unique models need to be created for each array in the Greenwood PV plant due to the different DC:AC ratio.

6.2 Data Quality Processing

Instrumentation data received usually requires some further processing. Some faulty data can significantly change the results of analysis. Faulty data can be caused by sensor malfunction, errors in data, communication issues, or any environmental noises. Typically, some data filtering technique can be used to improve data quality. In this work, the International Electrotechnical Commission (IEC) guidelines [2] for data filtering was applied before further analysis. The recommended criteria are shown in Table 2.The standard also recommend that certain values and criteria should be adjusted to the local condition.

Table 2. Example of data filtering criteria, to be adjusted according to local conditions

Flag type	Description	Irradiance W/m^2	Temperature °C	Wind speed m/s	Power (AC power rating)
		Suggested criteria for flag (15 min data)			
Range	Value outside of reasonable bounds	< –6 or > 1 500	> 50 or < –30	>32 or < 0	> 1,02 × rating or < –0,01 × rating
Missing	Values are missing or duplicates	n/a	n/a	n/a	n/a
Dead	Values stuck at a single value over time. Detected using derivative.	< 0,0001 while value is > 5	< 0,0001	?	?
Abrupt change	Values change unreasonably between data points. Detected using derivative.	> 800	> 4	> 10	> 80 % rating
May be adjusted depending on the tilt of the system and the season of data acquisition.					

There were two segments of data provided by Greenwood PV plant. One from beginning of January 2018 to June of 2019, the other from June 2019 to June 2020. There were no significant differences in data quality between the two sets of data.

Figure 5 depicts an overview of the first set of data filtered using Table 2 criteria. This is a period after the site being switched over to Emerson Ovation system. Overall, the abnormal data being filtered in each category is < 1%. This indicates that the instruments are well-maintained, and the data quality is excellent for further analysis. When comparing actual vs. expected output, all four channels: output power, power of array irradiance, ambient temperature and wind speed must be available. Furthermore, IEC suggest > 90% data availability to ensure proper representation when aggregating. Although interpolation of data is acceptable during the analysis, interpolation was not used in this work. The missing values and timestamps were simply removed, and remaining values were proportionally scaled when aggregating by week or month for analysis.

Following the applied filtering criteria, the power of array irradiance (Figure 6), wind speed (Figure 7), and ambient temperature (Figure 8) all appear reasonable.

[2] Photovoltaic system performance –Part 3: Energy evaluation method. International Electrotechnical Commission, Geneva, Switzerland. IEC 61724-3:2016

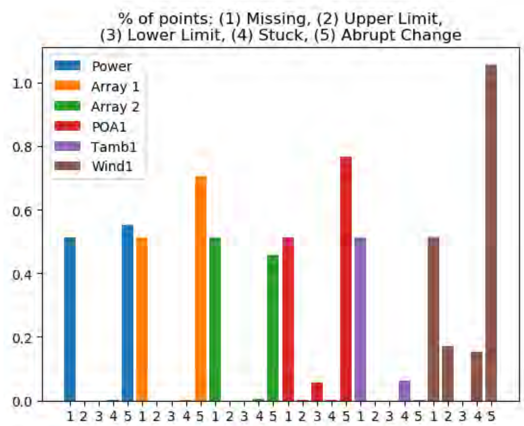


Figure 5. filtered data based on IEC-61724-3 criteria.

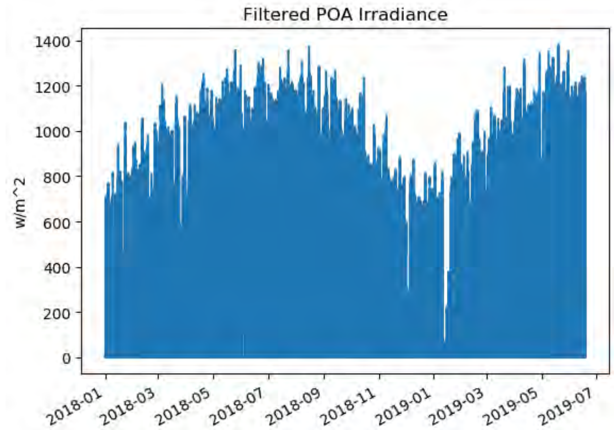


Figure 6. Filtered power of array (POA) irradiance at site

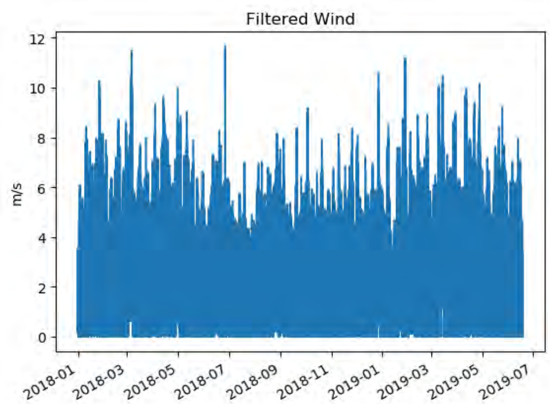


Figure 7. Filtered wind speed measured at site

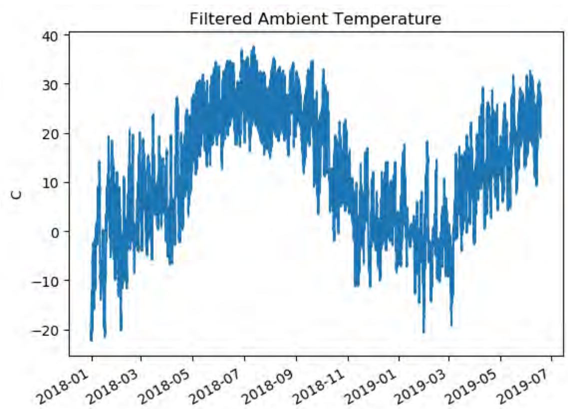


Figure 8. Filtered ambient temperature of the site

6.3 Outage and Reduced Capability

6.3.1 Classification of events

Special events such as outage and maintenance can significantly impact power output. Regarding special events, IEC has guidelines to categorize plant availability [3]:

- **Non-operative:** System is not capable of performing the intended functions due to scheduled maintenance, planned corrective action, forced outage or suspended circumstances. The forced outage is obtained when damage, fault or failure has disabled component or systems, such as inverter failure, cable fault, control failure, and circuit breaker trip, etc. The suspended category encompasses all situations in which scheduled maintenance, planned corrective action, and forced outage activities must be interrupted due to safety or equipment integrity concerns.
- **Forced majeure:** This refers to any situation in which the parties are unable to fulfill their obligations due to an extraordinary incident or circumstance beyond their control.

[3] *Information model for availability of photovoltaic (PV) power systems.* International Electrotechnical Commission. IEC 63019:2018

- **Operative but Out-of-service:** System is capable to operate, but not producing power in cases of out of environmental specification, requested shutdown or out of electrical specification. This includes solar irradiance below specified threshold, snow or ice build-up on PV modules beyond operational limits, ambient temperature above or below specification for operation, O&M requested shutdown, external or grid operator requested curtailment, grid failure, poor power quality, and phase imbalance, etc.
- **Operative and In-service:** System is producing power at full capacity, partial capability, or service set points. Partial capacity can be caused by faults, string level failures, difference in modelled inverter clipping, unexpected inverter defects, degradation and derating, etc. Service set points are when the power system is ready to respond to a predefined event, such as automatic generation control, constrained operation, sourcing/sinking energy form/to storage, and partial curtailment order, etc.

The analyses in this report classified three distinct categories:

- **Outage**: When power is reported to be zero or nearly zero while irradiance is reasonable. Outages occur when the grid is down, the system has scheduled maintenance, or the inverter is malfunctioning, etc.
- **Snow cover**: This is when the system experiences dramatically reduction in power vs. expected output. The expected power is calculated using sensor-measured irradiance, which can differ significantly from module-received irradiance during snow events.
- **Clipping**: Array 2 power output was found to be clipped at a ceiling at high irradiance times. The ceiling was less than the maximum power rating of the array.

6.3.2 Outage and snow cover

In the data analysis, the outage and snow events were identified by comparing expected vs. actual power. The events will be flagged when actual output is < 30% of expected output over a two-hour period. The threshold was decided to detect obvious excursions. As a result, it could miss the partial outage or snow cover situation when the output power was reduced for less than 70%. In addition, ambient temperature was used to distinguish outage vs. snow occurrences. This method is useful to estimate the impact of different type of events. However, this method tends to mislabel when an outage occurs at a low temperature.

In cases when a portion of day was flagged as outage or snow cover, the entire day was replaced with expected power. The power was then scaled to match adjacent days to represent a fully capable system. The full capable system was used to estimate the power loss and other important metrics due to the outage or snow events.

During the reported period from January 2018 to June 2019, it was found that 42/533 days were flagged as snow days and 5 of those were flagged as outage. The overall energy loss due to snow cover and outage were 4.9% and 0.7%, respectively. Although the overall impact seems small, this can be quite significant for specific months. For example, the largest energy output impact from snow cover was 35% in February 2019. It is worth noting that snow cover losses are highly unpredictable, varying month to month and year to year, whereas outage losses are far more predictable.

6.3.3 Clipping power loss

During analysis, it was found that Array 2 output power was clipped at 1350kW although the inverter could deliver 1660kW. Further investigation found out that the plant was designed to be capped at 3 MW_{ac} rather than the 3.3 MW_{ac}, what the system was capable of. As a result, the excess power was clipped from Array 2. Although this seems significant, the total energy loss due to clipping was negligible, accounting for only 0.34% of Array 2 output. This was due to the short duration of the high power at some sunny summer days. The DC:AC ratio of Array 2 was changed from 0.86 to 1.06 due to the artificial setpoints at the inverter for clipping.

7 PERFORMANCE ANALYSIS AND DISCUSSION

7.1 KEY METRICS AND DEFINITION

Several key metrics were used in this work to understand Greenwood PV plant performance.

- **Solar Insolation:** This records the daily amount of solar energy received at the plant. The main factors affect insolation are location, weather, and season.
- **Daily clearness index (CI):** This is the ratio of solar energy measured on a given surface to the theoretical maximum energy on the same surface during a clear sky day. It is calculated using equation 1 on a daily basis:

$$Daily\ Clearness\ Index\ (CI) = \frac{Actual\ solar\ insolation}{Predicted\ clear\ sky\ insolation} \tag{1}$$

- **Daily variability index (VI):** It measures variability by comparing the strength of irradiance changes against a clear sky day. When irradiance is variable, the length of line plotted in the measured irradiance will be greater and thus higher variability corresponds to greater index values. VI is calculated daily using equation 2:

$$Daily\ Variability\ Index\ (VI) = \frac{Line\ length\ of\ measured\ irradiance}{Line\ length\ of\ predicted\ clear\ sky\ irradiance} \tag{2}$$

The use of both CI and VI metrics on a daily basis allows for the classification of variability into five types: clear, overcast, mild, moderate, and high. Figure 9 gives examples of measured irradiance (blue lines) vs. predicted clear sky irradiance (red lines) for the five variability types.

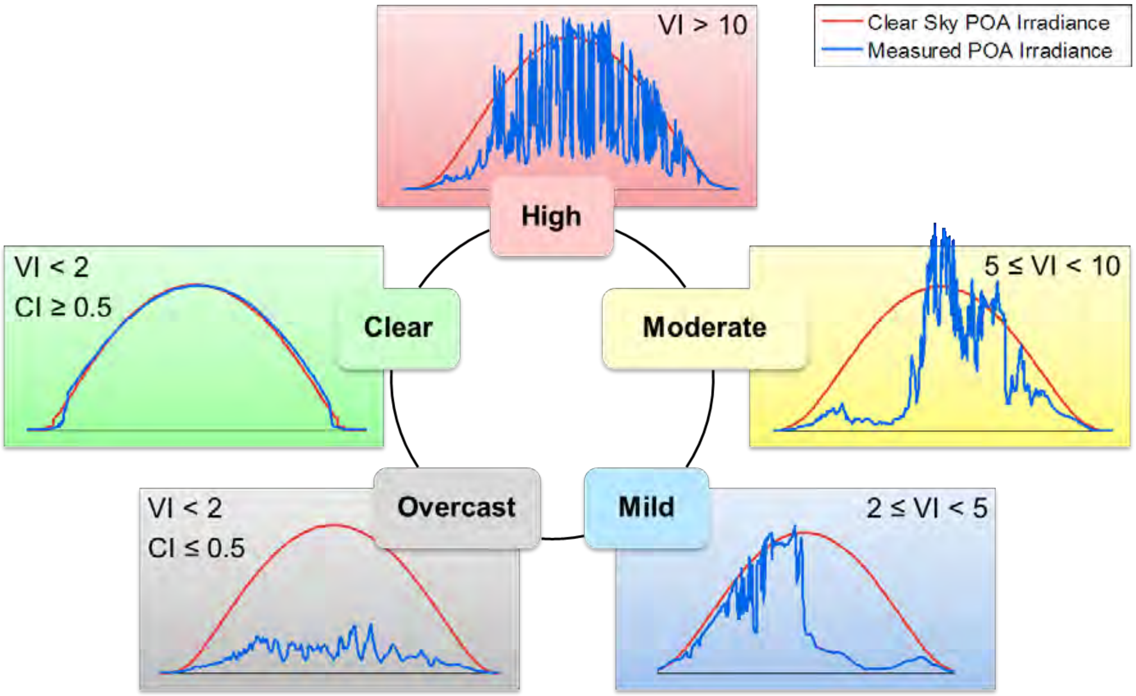


Figure 9. Variability categories based on clearness index (CI) and Variability index (VI) [4]

- **Ramp Rate (RR):** Ramp rate is defined as the change in power or irradiance over time. Ramp rate equals power/irradiance at one time interval minus power/irradiance at prior time interval. Calculating RR is easy, e.g., Power RR is calculated using the following equation 3:

$$RR = |P_t - P_{t-1}| \tag{3}$$

- **Capacity Factor (CP):** This is the ratio of total energy output to nameplate rating of the power plant. As shown in equation 4, the nameplate rating used in denominator can be DC output of the PV array or AC rating of the inverter, whichever is smaller. CP typically ranges from 0.15 to 0.22 for fixed tilt design to as high as 0.35 for tracker design. CP is also dependent on location, weather, and season. Furthermore, design variables such as tilt angle, tracker design, module technology, and inverter can all have a significant impact on this metric.

$$\begin{cases} \frac{\sum_i P_{AC}[kWh_{AC}]}{P_{array}\,[kW_{DC}]} \cdot \frac{1}{Test\ period}, when\ P_{array} < P_{system} \\ \frac{\sum_i P_{AC}[kWh_{AC}]}{P_{system}\,[kW_{AC}]} \cdot \frac{1}{Test\ period}, when\ P_{system} < P_{array} \end{cases} \tag{4}$$

Where, P_{AC} is the AC power of the array. P_{array} is the DC power rating of the array. P_{system} is the system power rating of the array.

- **Performance Ratio (PR):** PR is defined as the fraction of nameplate capacity after correcting for insolation and temperature. It is correlated to the efficiency of the plant in converting irradiance into output power. The result is a ratio, typically range from 0.7-0.9. Two types of PR are usually

[4] *Multi-Year Variability Analysis and Production Impact of PV Plants*. EPRI, Palo Alto, CA: 2019. 3002009936

in the industry. Basic PR (shown in equation 5) only normalizes for irradiance, while temperature corrected PR (equation 6) normalizes for both irradiance and temperature effect.[5]

$$PR_{basic} = \frac{\sum_i P_{AC}[kWh_{AC}]}{\sum_i \left(P_{array} \cdot \left(\frac{G_{POA,i}}{G_{ref}} \right) \right) [kWh_{DC}]} \tag{5}$$

$$PR_{temp} = \frac{\sum_i P_{AC}[kWh_{AC}]}{\sum_i \left(P_{array} \cdot \left(\frac{G_{POA,i}}{G_{ref}} \right) \cdot \left(1 + C_t \cdot \left(T_{m,i} - T_{ref} \right) \right) \right) [kWh_{DC}]} \tag{6}$$

Where, $G_{POA,i}$ is the measured POA irradiance in time interval i. G_{ref} and T_{ref} are the reference irradiance and temperature conditions in the module datasheet for which the specified nameplate is given. C_t is the module temperature coefficient. $T_{m.i}$ is the module temperature in time interval i.

PR is a useful metric in analyzing the trend within a plant but not as useful in comparing plants with different designs. Because of the normalization, PR requires accurate irradiance data. It uses plane-of-array (POA) irradiance, where the pyranometers are positioned on the same tilt plane as the PV modules. As a result, any irradiance disparity between what the POA sensor reads vs. what the module receives will introduce error in the method. For example, irradiance can differ at sensor and module because of soling and snow cover. In addition, PR is affected by design elements such as module, wiring and inverter technologies, etc.

- **Actual vs. Predicted and Expected Energy**: Using performance modeling software, this metric normalizes predicted and expected energy production with respect to actual production. Predicted energy output uses historical meteorological data at the region, while expected energy output uses sensor measured data at the PV plant. The comparison of actual vs. expected output is a useful tool for estimating plant health. Equation 7 shows the formula for calculating the relative difference.

$$\text{Relative difference (\%)} = \frac{\text{Predicted or Expected energy-Actual Energy}}{\text{Actual Energy}} \cdot 100 \tag{7}$$

The relative disparities can be used at the start of the plant operation to determine if there are any major construction issues with the plant, and to adjust the economics of the project if needed. The relative difference can also be used to help detect problems throughout the plant's lifetime.

When analyzing the key metrics, the unavailable data were removed, then the metrics were computed on the remaining data. Regarding solar insolation and capacity factor, the remaining data was scaled to cover the missing times. This is because the metrics are sensitive to total solar

[5] *Photovoltaic system performance monitoring – Guidelines for measurement, data exchange, and analysis.* International Electrotechnical Commission, Geneva, Switzerland. IEC 61724-1:1998.

insolation and total energy. In the case of snow and outage, periods of snow and outage were replaced by expected energy. It was then scaled to match the actual energy output.

7.2 SOLAR INSOLATION

Figure 10 shows the average daily insolation at the site. The overall daily insolation is at ~4.33. This compares to the annual average daily insolation range from 4.25-4.50 at this location recorded in the National Solar Radiation Database from NREL (shown in Figure 11). One thing worth mentioning here is the big difference between Summer and Winter. This is mainly caused by the incident angle change of the sun light. The further we move away from the equator, the greater the difference in irradiance between summer and winter.

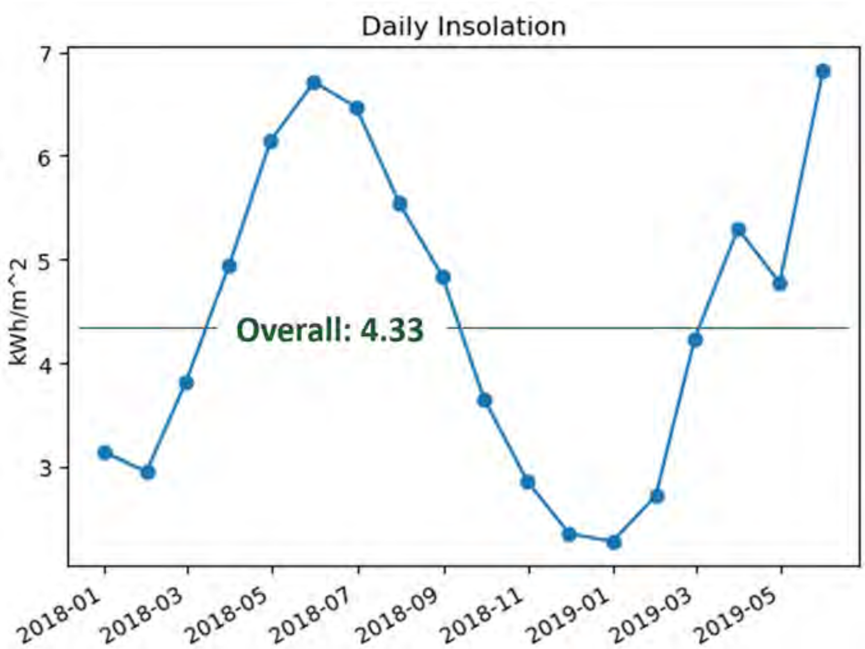


Figure 10. Daily insolation from 2018 to 2019 at Evergy Greenwood project site

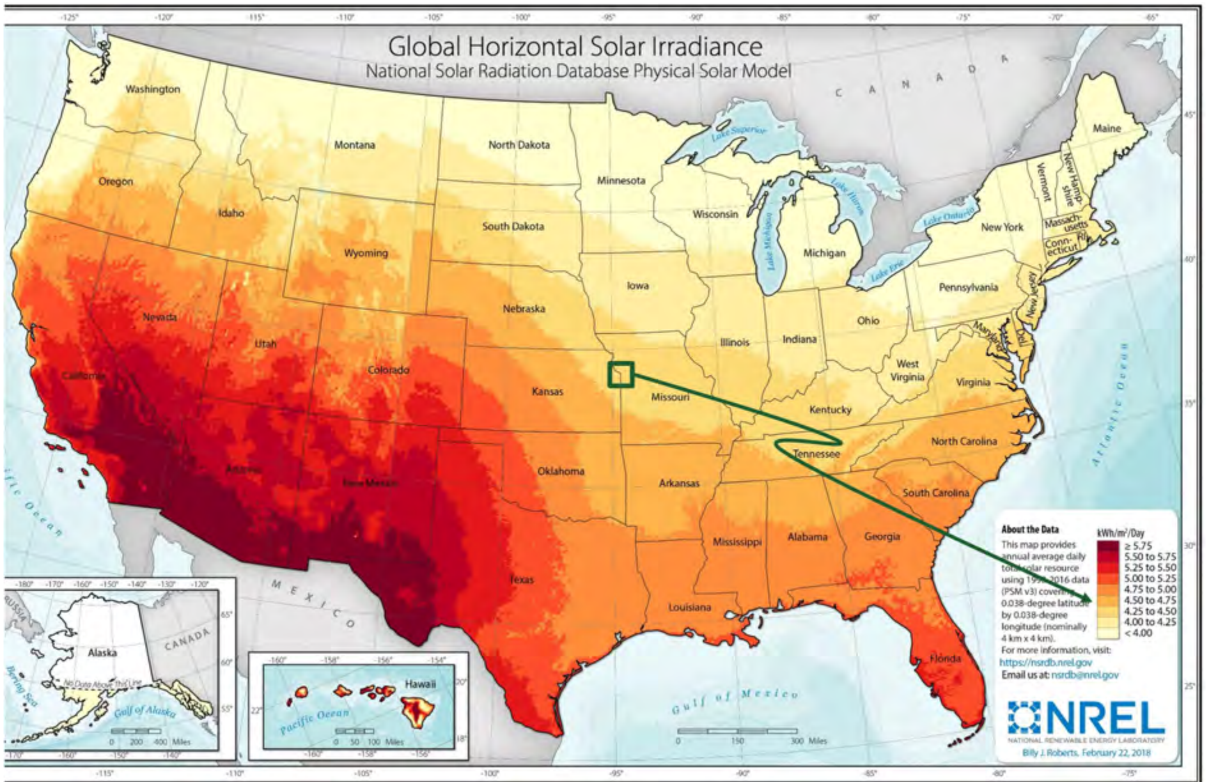


Figure 11. Annual average daily total solar resource using 1998-2016 data covering 0.038-degree latitude by 0.038-degree longitude (nominally an area of 4 km x 4 km)

7.3 IRRADIANCE VARIATION

PV power generation varies from day to day and throughout the day. Intermittent cloud cover exacerbates the variation. These intermittencies need to be quantified to properly estimate and plan transmission and/or distribution grid impacts. Daily variability of Greenwood PV plant was categorized in Figure 12 using CI and VI metrics. Data was averaged monthly for 2.5 years from January 2018 to June 2020. On average, only 14% of the days were clear. About 50% were either mild- or moderate-variability days. There was a large seasonable variation on overcast and high-variability days, causing the reverse bell curve to appear. High-variability days increased dramatically during the summer, while overcast days decreased dramatically. The greatest variation in overcasting occurred during the winter months. It is obvious that Greenwood PV plant has large variation in daily and seasonal irradiation. Thus, it is essential to understand the potential impact of 86% non-clear days.

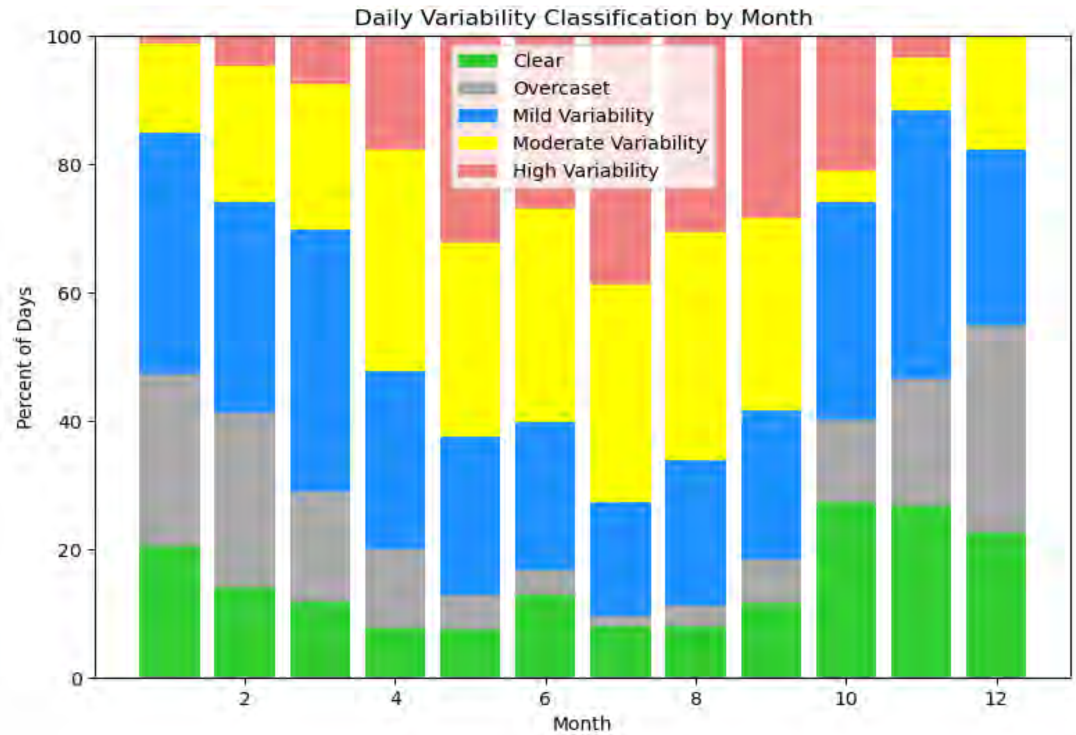


Figure 12. Irradiance variability averaged monthly at Evergy Greenwood PV plant between 2018 to 2020

7.4 Ramp Rate statistics

Ramp rate can be affected by the chosen time window. Averaging over longer time intervals can hide volatility apparent at shorter time intervals. On the contrary, using short time intervals can distribute a longer ramping event into multiple smaller ramping events. Figure 13 illustrates how ramp rate is affected by the time window selected. Hourly ramp rate is useful because it typically produces the highest RR. Thus, it can be used for worst case analysis. However, Short-term impacts such as passing clouds are usually missed by hourly time resolution. Shorter time windows will have lower ramp rates but can be more practical for assessing impact of near-term power fluctuations.

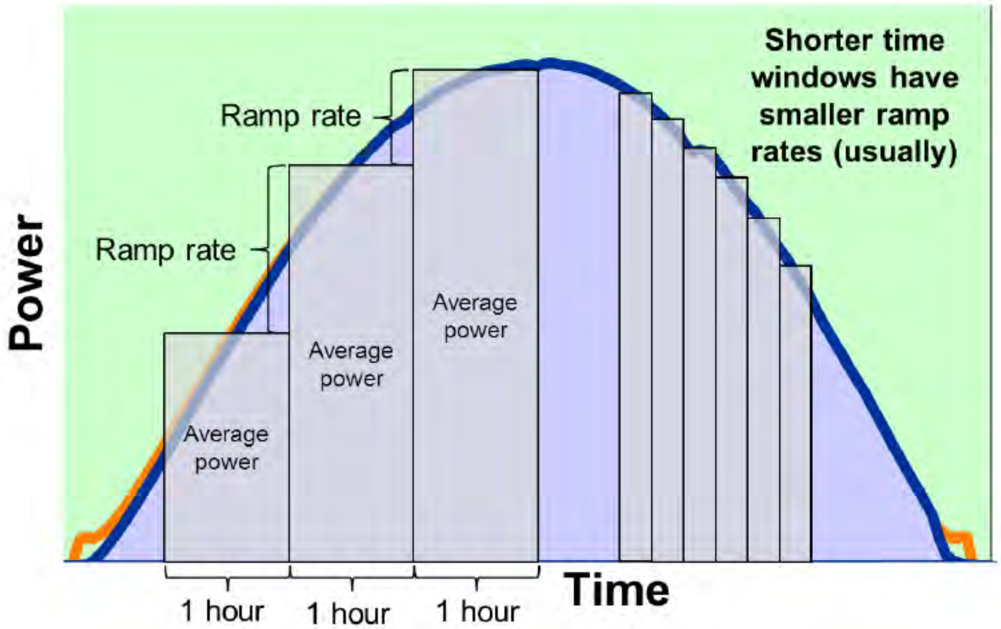


Figure 13. Illustrative example showing impact of time window on ramp rate

In this report, a cumulative distribution function (CDF)[6] was used to assess ramp rate statistics. CDF analysis is useful to visualize and compare large ramping events over long time periods. There are 4 steps to calculate and plot a CDF chart as shown in Figure 14 :

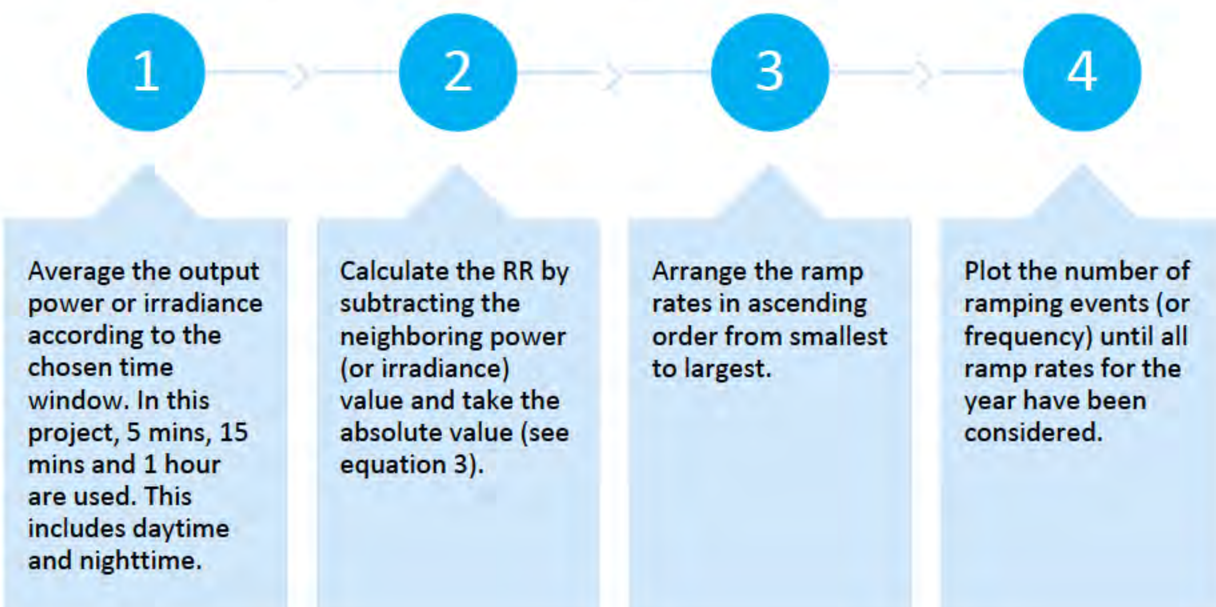


Figure 14. Steps to calculate and plot a cumulative distribution function (CDF) chart

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[6] *Multi-Year Variability Analysis and Production Impact of PV Plants*. EPRI, Palo Alto, CA: 2019. 3002009936.

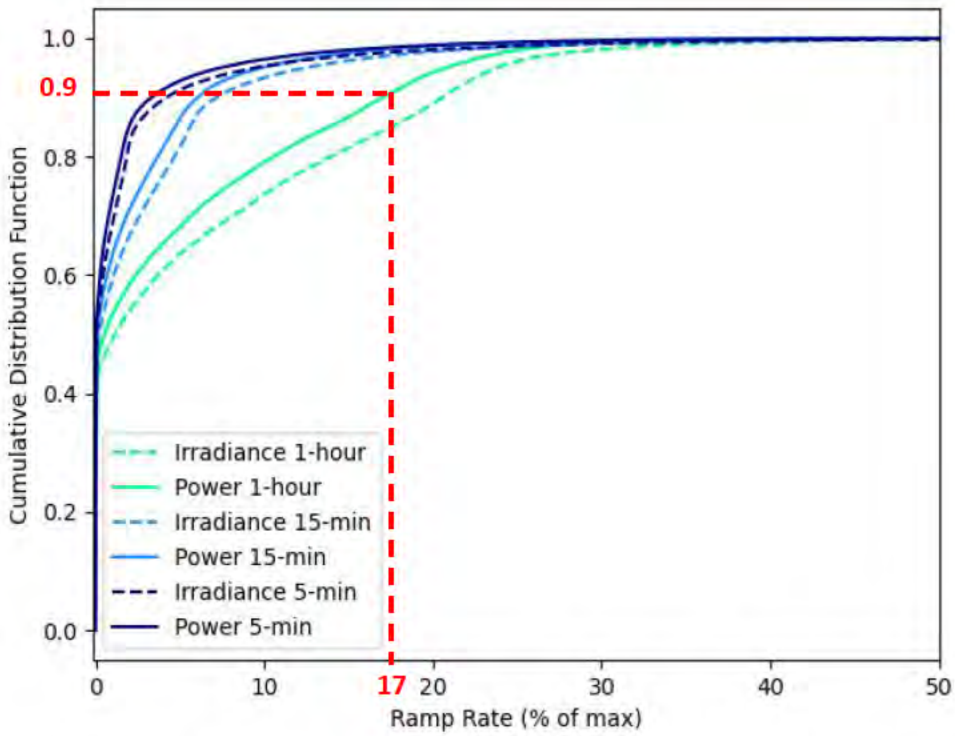

Figure 15 shows the results of the ramp rate at Greenwood PV plant. Each of the power curves (solid lines) represents the probability of ramping occurring during its respective time window. For example, there is a 10% chance that power output will vary by more than 17% of the DC nameplate of the plant over a one-hour window. The nameplate of the plant is 3.58 MW_{dc}. Therefore, 17% represents a ramp rate of 0.61 MW_{dc}. Also, there are nearly no ramping events larger than 30% of DC nameplate over a 5-minute and 15-minute interval. This establishes an upper limit for how much ramping may be expected in these short intervals.

Since the frequency is calculated using both daytime and nighttime power output. The nighttime output causes a spike of 0% ramping (no power ramping). This represents as much as 50% of all observed ramping events.

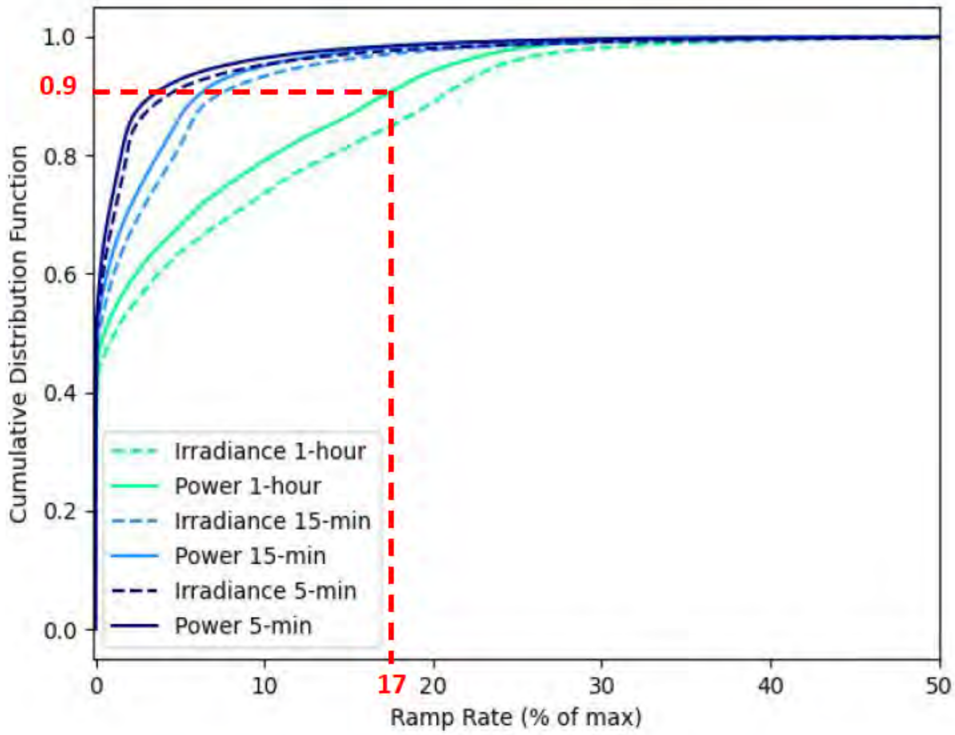

Figure 15. Power output and irradiance ramping based on different time window.

A few important insights derived from the CDF graph:

- There is more ramping of irradiance than power (i.e., the irradiance curves are to the right of the power curves). This is partly due to the geographic smoothing effect of having PV modules spread over a larger array than a single point sensor. A passing cloud's shadow may obscure the point sensor. The cloud's shadow, on the other hand, may only fall on a section of the array, causing less of an impact on power output.
- The DC:AC ratio of the power plant will impact the shape of the CDF curves. Generally, PV plant uses DC:AC ratios over one will have flatter power outputs and are more buffered from irradiance variability. However, the extra DC power that exceeds the inverter's AC nameplate are discarded. It nis important to note that, although Array 2 was designed with a DC:AC ratio of less than one, both Arrays at the Greenwood PV plant have a DC:AC ratio greater than one due to the artificial clipping of Array 2 output to 1.35MW_{ac}.
- The slight "double-knee" shape of the power/irradiance ramp curve is a natural phenomenon caused by sun rises/sets. This occurs when the direct normal irradiance (DNI) increases suddenly when the sun comes into direct view of the array and irradiance sensors. Greenwood PV plant has limited clear sky days, so this is less noticeable when compared to projects with more clear sky days.

7.5 Capacity Factor (CF)

The monthly capacity factor (CF) of the overall Greenwood PV plant is shown in Figure 16. The average CF of the plant is at ~0.15, which peaks in summer at ~0.24 and reaches the bottom in winter at ~0.07.

This compares to a typical capacity factor at ~0.14-0.16 in the region, as shown in Figure 17 for fixed tilt arrays. The peaks and valleys are mainly associated with the irradiance differences in summer and winter as demonstrated in solar insolation. Furthermore, because CF is related to PV plant designs, the seasonal difference can increase or decrease depending on other factors such as module technology, tilt angle, tracker design, and inverter selection, etc.

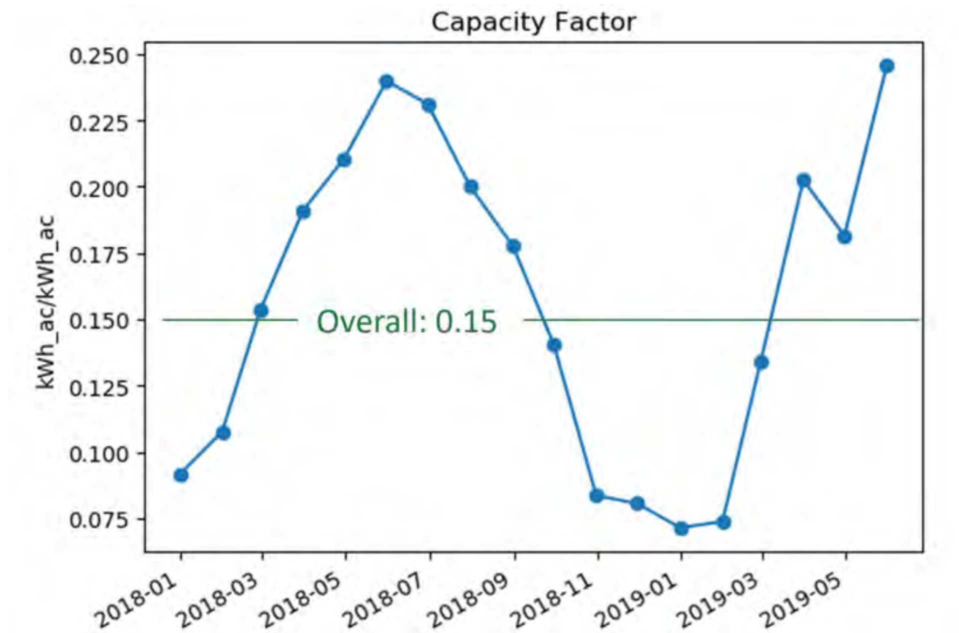

Figure 16. Capacity factor of the arrays at Evergy Greenwood PV plant.

A few important insights regarding capacity factor at Greenwood PV plant:

- PV module efficiencies are measured at standard testing condition, 1000 W/m^2 at 25 ^oC. Modules are usually more efficient at high irradiance than low irradiance, which can further increase the seasonal difference. On the contrary, modules typically produce 0.3-0.5% less power for every one-degree census increase in module temperature. The temperature difference summer vs. winter could reduce seasonal differences ~8-12% [7].

[7] Module temperature are usually 30 ^oC higher than ambient temperature. If we assume a module has a temperature coefficient of 0.4%/^oC, and it operates at 55^oC in summer and 25 ^oC in winter with same irradiance, then its expected power output difference will be around (55^oC – 25^oC) *0.4%/^oC = 12%. It will be slightly different in reality because the temperature coefficient was calculated at 1000W/m^2, and it is not always linear especially at low temperature.

Figure 17. Typical Capacity Factor for fixed-tilt arrays [8]

- Module tilt angle can greatly affect irradiance level that was directed onto module. The Evergy Greenwood PV plant was designed with 15-degree fixed tilt angle. This compares to an optimal tilt angle of ~30 degree based on the latitude of the site. The tilt angel design will increase the POA irradiance of the plant in summer, while sacrificing the POA irradiance in winter. This will increase the seasonal difference in CF.
- Inverter efficiency can also play a role in the low CF in winter. Most inverters are efficient above 30% of rated power. However, it could drop exponentially when input power is lower than ~30%. This would impact conversion efficiency at partial snow cover situation.
- A tracker design can increase the capacity factor. Tracker can increase the POA irradiance of the module and potentially help clear snow more efficiently.

7.6 Performance Ratio (PR)

Figure 18 Shows the basic performance ratio for both arrays. The basic performance ratio will normalize plant irradiance according to the POA sensor. It does not, however, consider the effects of module temperature or any weather-related energy losses, such as soling or snow cover difference between module and POA sensor. The overall PR of Greenwood PV plant is ~0.76, with Array 2 performed slightly higher than Array 1. This is mainly due to the lower DC:AC ratio of the Array design. The performance ratio peaks in the spring, around March or April, then falls slightly in the summer and recovers mostly in the fall. This is explained by the negative temperature coefficient effect of the module. Photovoltaic modules produce more power at low temperature than high temperature at same irradiance.

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[8] E. Drury et. al., *Relative performance of tracking vs. fixed tilt photovoltaic systems in the USA*. Prog. Photovolt: Res. Appl. (2013). DOI: 10.1002/pip.2373

Figure 18. Basic performance ratio from 2018 to 2019 at Evergy Greenwood PV plant

The temperature effect is apparent when we do a temperature correction to the performance ratio, as illustrated in Figure 19. After the correction, performance ratio is mostly flat from March to October, where irradiance is highest.

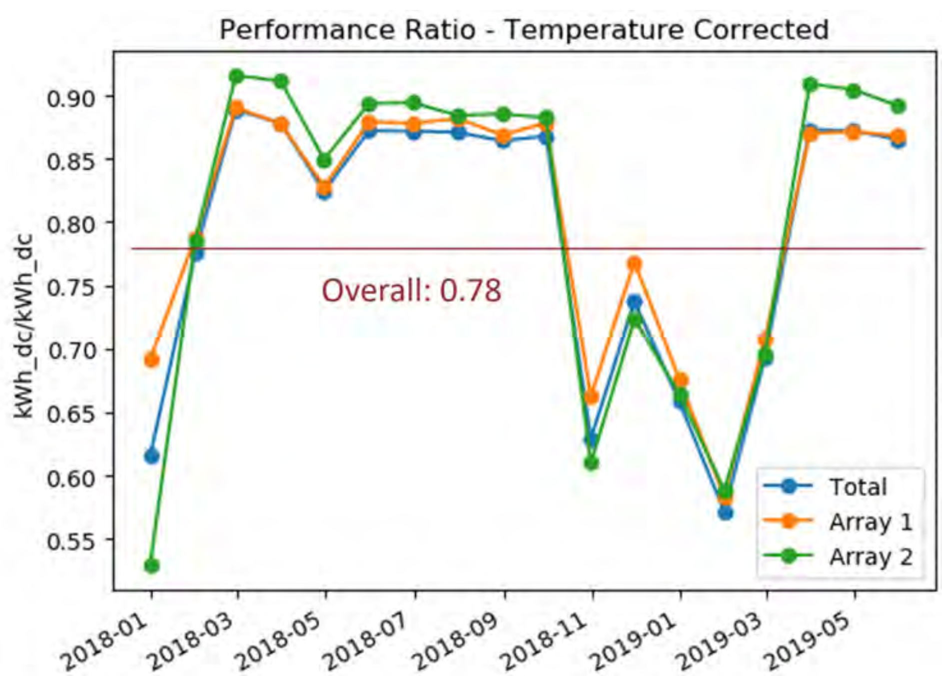

Figure 19. Temperature corrected performance ratio from 2018 to 2019 at Evergy Greenwood PV plant

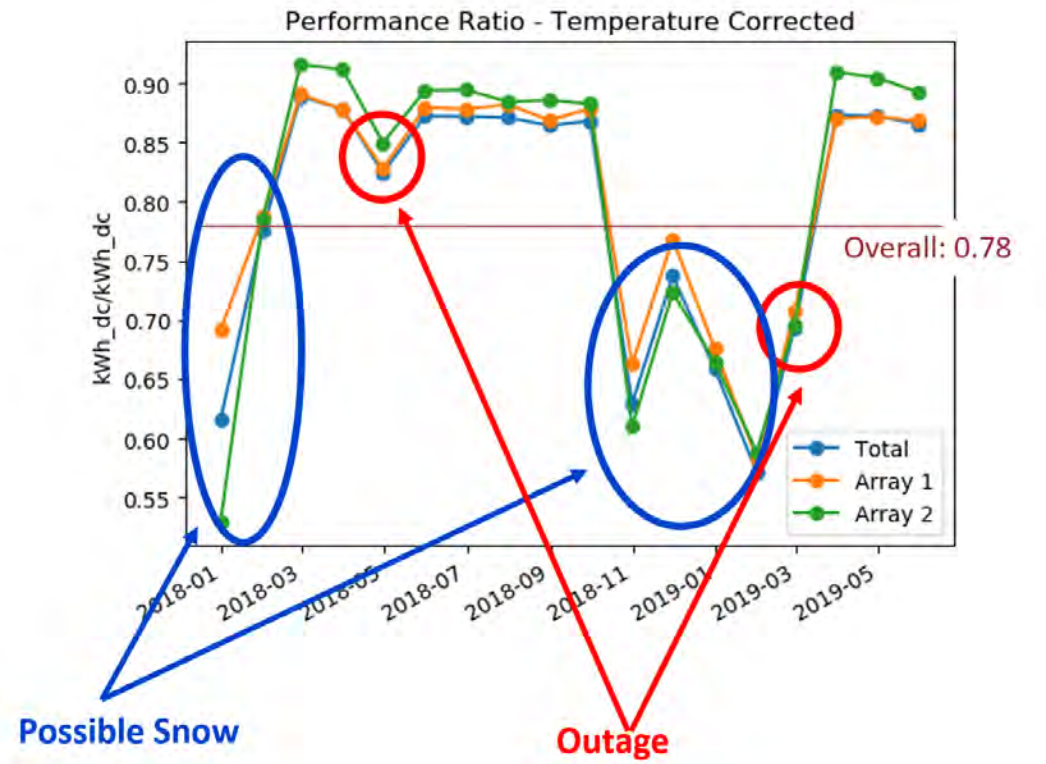

Figure 20. Performance excursion at Evergy Greenwood PV plant

It is apparent that the performance ratio of Greenwood PV plant is lower than expected during winter seasons. Although PR is corrected for irradiance and temperature, it uses POA sensors to measure irradiance, which could be different from module irradiance. The disparity comes from sensor maintenance and soiling/snow covering differences between sensor and module. Similar as CF, PR can be affected by lower module and inverter efficiency at low irradiance and low input power, respectively.

The low PRs in winter are likely associated with snow coverage on the panel, as illustrated in Figure 20. A few outages were also identified during the monitoring period. This explains the small dip of PR at ~ May 2018 and the slow recovery at ~March 2019. The average performance ratio is ~0.78 after temperature correction. This compares to the typical PR ratio range from 0.7 to 1 in the industry. Currently there are no standards regarding whether to include curtailment, maintenance, snow, and soiling coverage in PR. Thus, the PR of 0.78 from Greenwood PV plant appears reasonable.

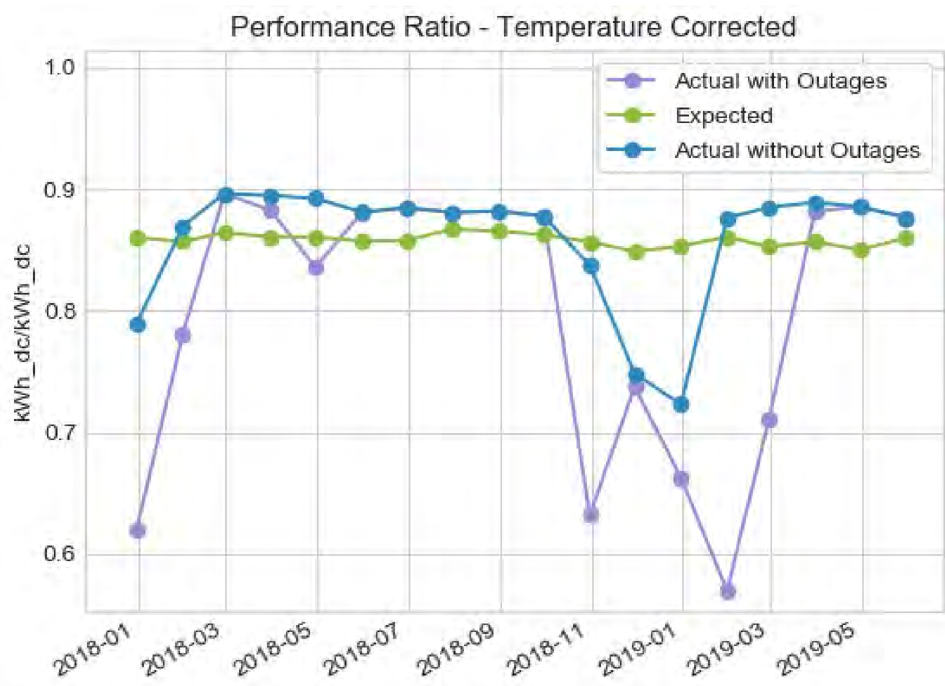

Figure 21. Monthly Temperature Corrected Performance Ratio

Using the outage and snow cover flagging approach, we can eliminate the effect of possible outage/snow cover effect on performance ratio. Figure 21 shows the actual performance ratio (blue line) after removing the outage and snow cover events. When compares to the expected PR (green line), the actual performance becomes much more aligned, except for a small dip in winter. This is likely due to the methodology used to flag snow events. Due to the point shape and small size of the sensor in comparison to the module, the sensor measured irradiance differs from what the module receives during snow covering events. In this report, snow events were flagged only when actual output was < 30% of expected over a two-hour period. As a result, some partial snow cover events were not flagged. Without further investigation, the fully capable system's performance ratio is around 88.5%. This means the system is ~ 88.5% efficient comparing to its nameplate rating. The 11.5% reduction vs. nameplate comes from system losses, such as wiring and inverter losses, non-flagged snow losses, soiling, clipping, and system malfunctions. The actual power output is higher than the expected system for most of the month. This indicates that the plant losses were lower than what was assumed in the performance model.

7.7 ACTUAL VS. PREDICTED VS. EXPECTED ENERGY PRODUCTION

The predicted and expected energy production was modeled using SAM. Some system losses were assumed in the model according to Table 1. Figure 22 shows the weekly aggregated results for expected vs. actual energy production. Apart from occasions when snow cover was not flagged using the filtering criteria, the expected output with assumed loss values was about 2.5% lower than actual production. This implies that the losses assumed in the model were higher than they were in reality.

Figure 22. Expected vs. Actual Energy (Weekly Aggregation)

The predicted output vs. actual is much noisier as shown in Figure 23. This demonstrates the importance of weather normalization. In most cases, the relative differences between predicted and actual output are greater than zero. This is due to the PV plant's higher predicted irradiance based on historical weather data.

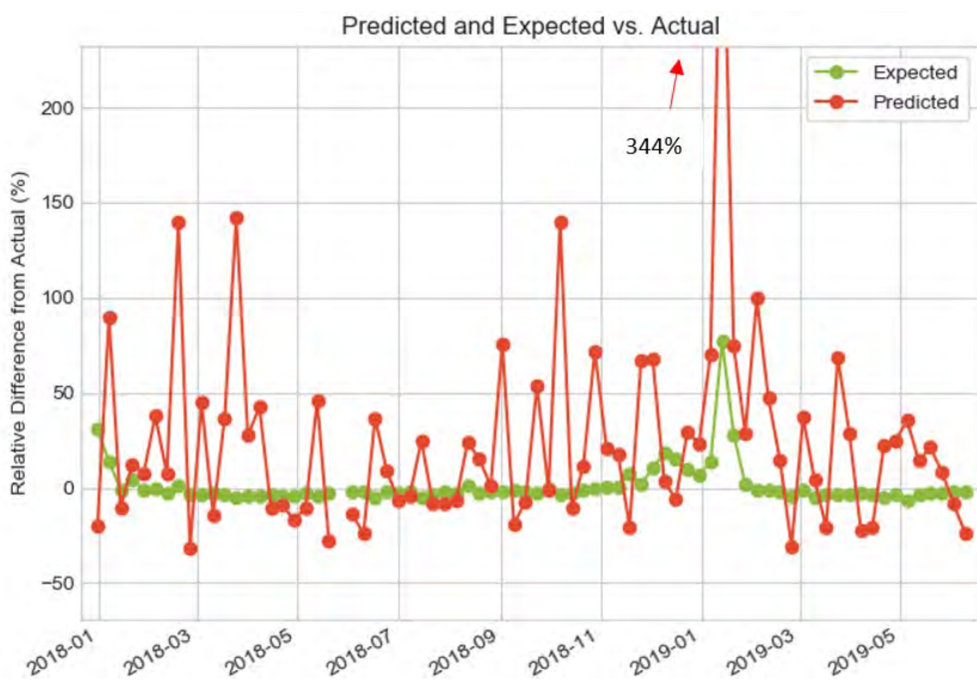

Figure 23. Predicted and Expected vs. Actual Energy (Weekly Aggregation)

It is also worth mentioning that there is some evidence of gradual system degradation when looking at the normalized power over time (depicted in Figure 24). However, more data over a longer timeframe is required to effectively quantify the rate.

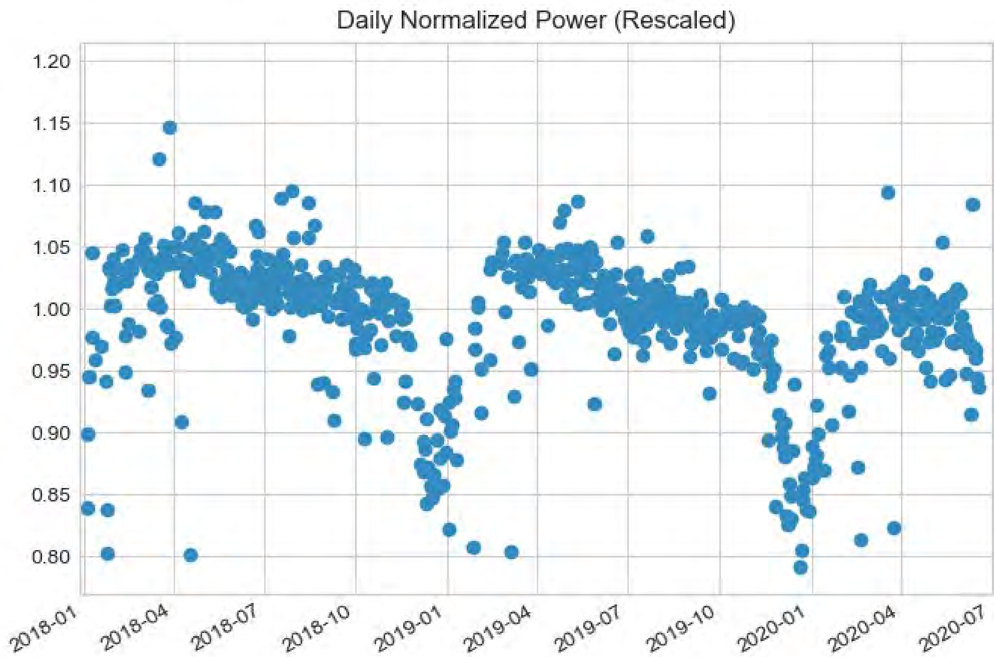

Figure 24. Daily Normalized Plant Performance

7.8 Time-of-day power capacity and availability

PV plant energy production can change throughout the year due to seasonal irradiance and weather fluctuations. Thus, it is important to understand the power capacity information to aid energy balancing in the system. For this analysis, the calendar year was broken into four quarters. Then, power output from the system was averaged into one-hour windows.

Figure 25 depicts hourly statistics on how power varies each quarter from January 2018 to June 2020. Power changes are expressed as a percentage of the system's DC nameplate power rating. A few key takeaways from this analysis:

- Power production varied from season to season. There is much less production in winter than in summer. This is consistent with the insolation and capacity factor analysis.
- There are more variations in Q1/Q4 than Q2/Q3 despite there are more clear days in winter (depicted in Figure 12). This is likely due to the snow cover events discussed earlier.
- There are big variations during the day as well. The inner quantile variations are > 20% of nameplate capacity even during the middle of summer days. This is in alignment with the small number of clear sky days and high variation of cloud coverage during summer days at this plant (depicted in Figure 12).
- As temperature rises throughout the day power production slightly decreases. This is most apparent in the power output median of Q2 and Q3. This is caused by the PV module temperature coefficient that modules produce less power as temperature increases.

- Power production ramps up then down in a bell shape without a plateau. This is mainly due to the fixed tilt design when modules do not tracker the movement of the sun. This could be improved by using a tracker system.

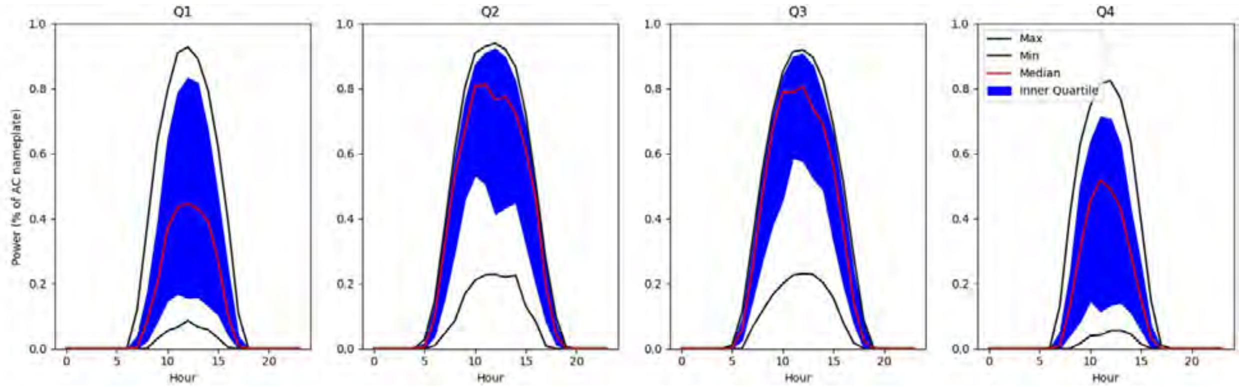

Figure 25. Hourly power ramping for Evergy Greenwood PV plant during each quarter.

To visualize the difference of fixed tilt vs. a tracker system, Figure 26 show power profile examples for 3 different tracking types: fixed-tilt (similar as Greenwood PV plant), single-axis tracker (SAT), and dual-axis concentrating PV (CPV). The DC:AC ratios of all three arrays in this diagram are less than one. Additionally, the values for global horizontal irradiance (GHI) and direct normal irradiance (DNI) are displayed.

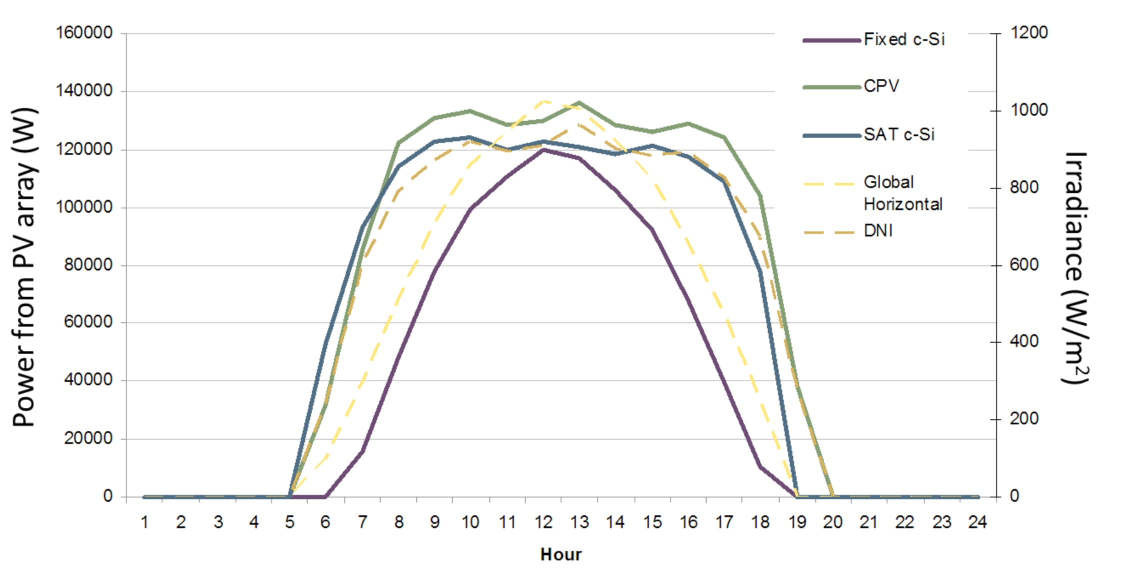

Figure 26. General power profiles for PV arrays with different racking design when dc:ac ratios less than unity [9]

[9] *Solar Power Fact Book, 8th Edition: Volume 1 – Photovoltaics (PV)*. Electric Power Research Institute. Product ID 3002009944. Palo Alto, CA: 2016.

7.9 ALIGNMENT OF POWER PROFILE WITH LOAD SHAPE

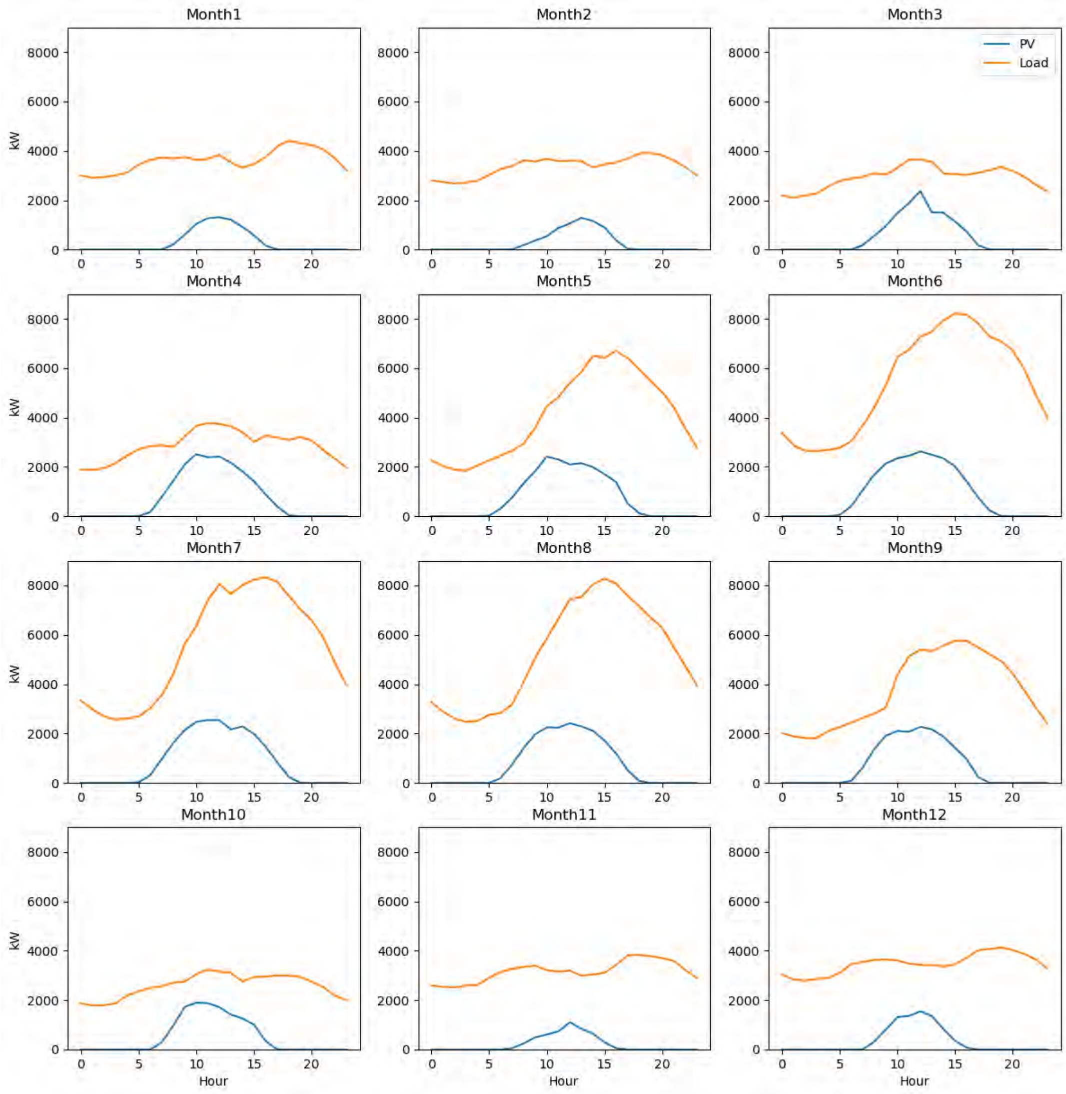

Figure 27. Hourly profile of PV supply against load from January to December in 2018

Solar energy is difficult to dispatch due to its dependance on solar irradiance[10]. Thus, it is important to understand the actual power production alignment with load demand. The monthly production of Evergy Greenwood PV plant during 2018 is plotted against monthly load profiles (provided by Evergy). As shown in Figure 27, PV production from Evergy Greenwood is generally in line with the mid-day load peak at each month. However, since PV plants do not produce energy at night, the overall shape of PV production is much steeper than load demand. The increased load demand close to sunset from May to September contributes to some additional misalignment. Figure 28 shows the weekly PV production profile against the load demand. Although the peak of PV production aligns with the peak load demand in summer, the overall shape of the load is different from PV production. There are two aspects to this mismatch. One is due to lower energy production from PV plants during the winter, which is primarily

[10] Statement is for pure PV production only and does not include coupling solar with storage.

caused by low irradiance. The other is due to increased load demand during the winter as people spends more time at home and needs to keep the house warm.

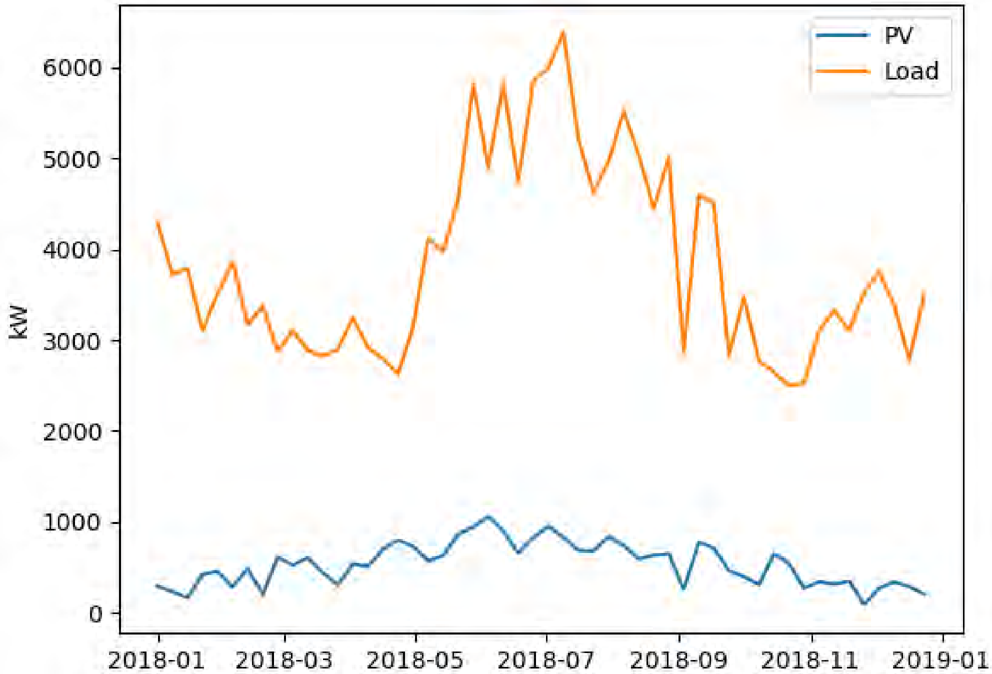

Figure 28. Weekly profile of PV supply against load for 2018

8 BENEFITS OF COLOCATION

Figure 29. Evergy Greenwood PV plant location relative to existing gas plant

PV plants are usually constructed at a remote area due to the land usage, cost, and environmental side of considerations. Evergy Greenwood PV plant was constructed close to an existing gas plant to understand the benefit of colocation (see Figure 29), such as inventory, training, and operation and maintenance (O&M) activities. Some colocation benefits can be found in

Appendix B – Comments from Evergy about the Greenwood PV plant. The key takeaways for co-location benefits are:

- The PV plant uses same maintenance crew as the gas plant, the shared resources reduce cost.
- The existing facility can be utilized to store inventory for the PV plant, such as module, parts for tracker, inverter, etc.
- Remote plant has problems specifically for O&M. Due to the driving distance, small issues are not tended typically. This can result in big issues later.
- Colocation increases security and eases inspection, troubleshooting and ground maintenance.
- Maintenance crew are already familiar with many components of the PV plant, such as switchgear and transformer, although they need to be trained on operation of the panels, trackers (not in this project), combiner boxes, and inverter.

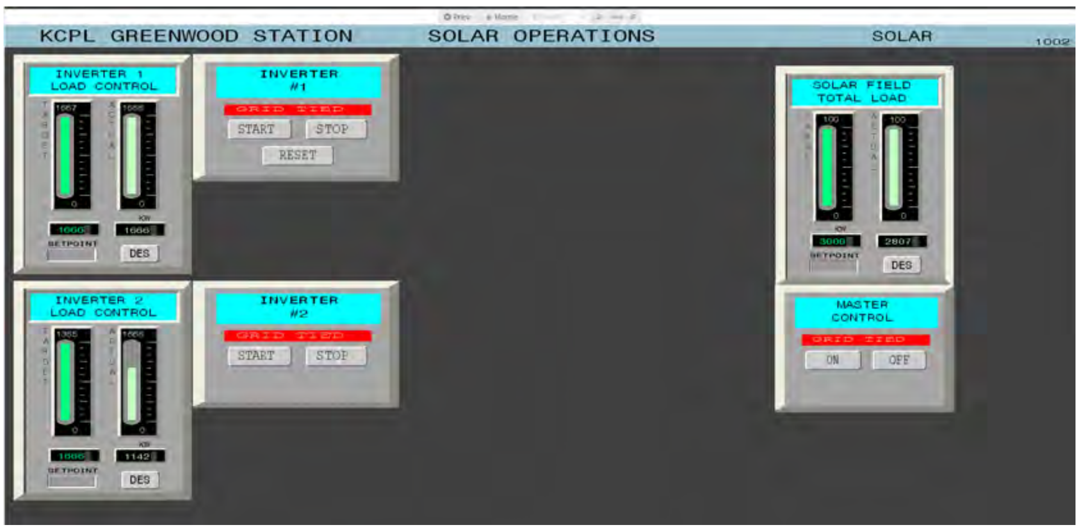

Figure 30. A view of the Emerson Ovation control platform

It was also noted that controlling the site and pulling historical data became easier after switching to the common control planform of Emerson Ovation.

9 Cost of O&M

PV plants do not use consumables like coal or gas plants. However, operation and maintenance (O&M) expenses for a specific plant can vary greatly based on plant capacity, location, climate, technology selection, contract scope, operator experience and many other factors.

Figure 31 shows the trends of utility scale PV plan O&M cost from 2011 to 2019. The mean cost is close to each other, and overall cost trends down nicely from multiple sources. The range of the cost, however, can be 2-5x different according to LBNL report (comparing LBNL min to LBNL max). Greenwood PV plant O&M costs are at the lower end of the distribution in 2019, at \$7.2/kW-yr. And, more recently, \$2.8/kW-yr. This compares to a mean of ~\$12/kW-yr from a typical plant. This could indicate the cost saving opportunity from collocating the PV plant with existing power plant.

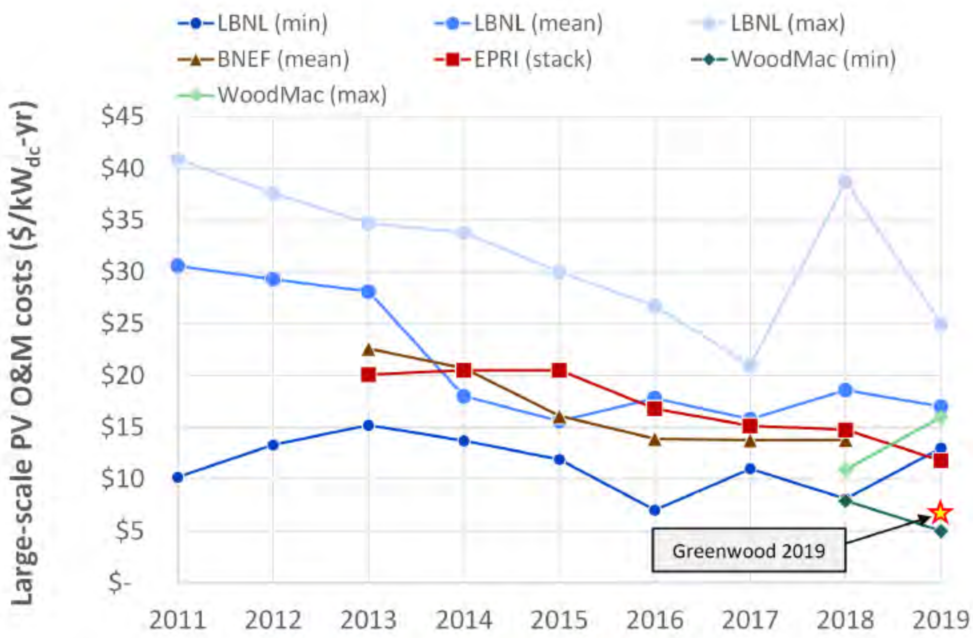

Figure 31. Trend of utility scale PV O&M cost [11]

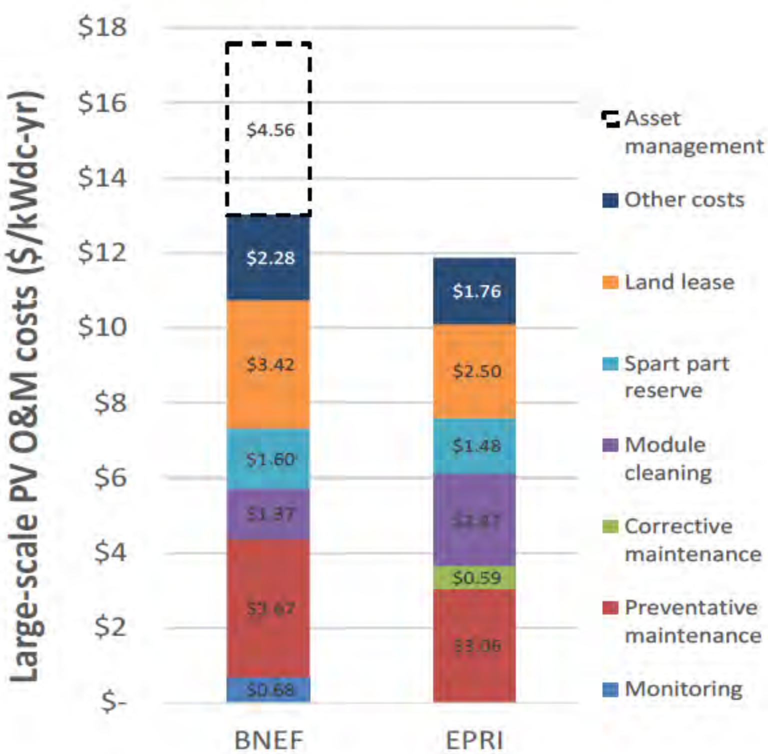

Figure 32. Factors that affect utility scale PV O&M cost [12,13]

[11] *LBNL Utility-Scale Solar, Mercatus / BNEF, EPRI, Wood Mackenzie*

[12] *2020 Solar Technology Status, Cost and Performance.* EPRI. Palo Alto, CA: 2020. 3002018729.

[13] *PV O&M 2020: Plant Owners Get More with Less.* BloombergNEF, 2020-07-13

There are many factors that can affect PV plant O&M cost. Figure 32 shows a breakdown of the O&M cost for a typical utility scale PV plant. The fixed tilt PV plant with c- Si modules can spend ~$12/kW-yr for operation and maintenance. Among these, there are several big categories:

- **Preventive maintenance:** ~1/4 of the O&M cost is spent on preventive maintenance. Preventative maintenance is very important to keep the plant running with least unexpected interruptions. Preventive maintenance is usually scheduled based on needed intervals for specific equipment or components of the plant. Examples are visual inspecting the PV plant, cleaning and calibrating sensors, replacing components that are prone to fail, and lubricating any moving parts of equipment, etc.

- **Module cleaning:** Module cleaning need is site specific. It is dependent on impact of soiling level impact to energy production and precipitation frequency of the site. Some plants do regular cleaning before sunrise and after sunset, others rely on rain to naturally wash the modules. The Greenwood PV plant does not regularly clean their modules. This can save ~12% of the O&M cost of the plant.

- **Spare part reserve:** Both preventative and corrective maintenance require spare parts, and adequate capital must be available to cover the inventory required for robust operation of the plant. E.g., inverter reliability remains a major concern, although the technology has advanced quickly in past years. Trackers use moving parts that might break more frequently. Modules may need to be replaced as well due to breakage or underperformance.

- **Corrective maintenance:** This category is the cost to repair or fix any unexpected failures, such as replacing damaged modules due to inclement weather, repairing a tracker that was stuck at a fixed angle, or replacing a failed component on an inverter. Corrective maintenance cost is relatively low from O&M cost perspective. However, it should be minimized due to its large impact on energy production.

- **Land Lease:** Solar farms use lots of land. As a result, the cost of leasing the land can be rather significant. Land lease costs are determined by the property value and vary greatly depending on the state, the type of land, and any known structural and environmental barriers. According to EPRI and BNEF reports, land lease costs can account for ~ 20% of annual O&M costs. It should be noted that the Greenwood O&M costs do not include the land lease.

- **Other costs:** Other costs might not be included in a typical maintenance contract for a project. For example, plant owners will be responsible for insurance, property taxes (where solar facility are taxed), and various administrative expenses. Due to the colocation with existing gas plant, the Greenwood PV plant can reduce costs on these miscellaneous expenses.

- **Asset management:** This refers to the systematic management of a site's physical assets to achieve optimal financial performance. Such as monitoring and reporting project's real-time performance, tracking costs/warranties, ensuring regulatory compliance, and monitoring investment performance, etc. Asset management is typically not included in O&M costs.

It is important to note that the numbers shown in Figure 32 are based on a particular technology. O&M cost varies due to differences in plant design, equipment, material, and module efficiency etc. For instance, the need for preventative maintenance is higher for tracking systems than for fixed tilt systems. This is due to the increase in moving parts in the design. And O&M costs per watt can be reduced by using high efficiency modules. This explains some of the differences between EPRI reported number vs. BNEF reported number.

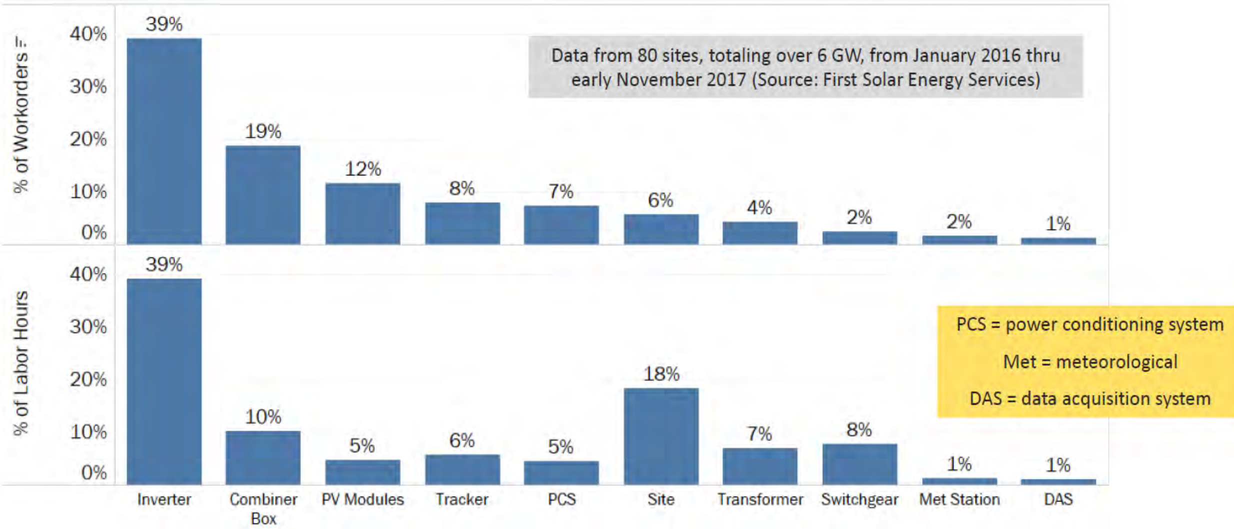

Figure 33. common failures in large scale PV plants [14]

The pareto analysis of common failures in a large-scale PV facility is shown in Figure 33. Obviously, inverters continue to be the most common causes of plant failures, as evidenced by the number of work orders and the percentage of labor. Site-related O&M contributes for 18% of annual labor hours despite accounting for only 6% of work orders. Furthermore, switchgear failures can be very costly to repair due to the long labor hours involved, although they only make up 2% of the work orders. The Greenwood PV plant recorded a switchgear failure in 2017, and details of the troubleshooting and repair can be found in Appendix A.

10 GRID DISTRIBUTION IMPACT

[redacted]

[14] *Solar Power Fact Book, 10th Edition: Volume 1—Photovoltaics (PV).* EPRI, Palo Alto, CA: 2020. 3002017189.

[redacted]

Figure 34. Feeder F_27722 showing the locating of the Greenwood plant.

[redacted]

Table 3. Characteristics of Feeder F_27722

[redacted]

[redacted]

[redacted]

Feeder View of Node-Level Hosting Capacity
Feeder New_Greenwood_original_HC: 2.35 MW
Centralized

[redacted]

Figure 35. Modeling result showing hosting capacity of 2.35 MW without the Greenwood plant.

Feeder View of Node-Level Hosting Capacity
Feeder New_Greenwood_original_HC: 0.9 MW
Centralized

[redacted]

Figure 36. Modeling results with the Greenwood plant showing hosting capacity of 0.9 MW at the end of the feeder.

[redacted]

- [redacted]
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- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

EPRI | ELECTRIC POWER RESEARCH INST New_Greenwood_original_HC-Centralized

[redacted]

Figure 37. Of the various potential issues, primary voltage deviation is anticipated to be the liming factor for hosting capacity.

[redacted]

[redacted]

Figure 38. Feeder model with locations of existing PVs, Greenwood plant, new utility-scale plant, capacitor banks, and voltage regulator indicated

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Figure 39. Settings used for DPAT modeling.

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[redacted]

[redacted]

Figure 40. Potential protection issues on the feeder based on modeling in DPAT.

11 CONCLUSION

11.1 KEY TAKEAWAYS

- The Greenwood PV plant appears to be operating as expected. System Advisor Model (SAM) from the National Renewable Energy Laboratory was used in this report. When comparing actual vs. predicted vs. expedited output, the actual power output is slightly better than expected. The expected power output is lower than the predicted output at the plant. This is cause by the lower insolation at the plant comparing to a typical meteorological year, at 4.09 kWh/m^2/day vs. 4.45 kWh/m^2/day, respectively.
- The site was impacted by many snow events and a few outages. The snow events contributed to ~4.9% or more energy loss. The power outages contributed to ~0.7% of power loss. These losses are hard to predict. However, they should be estimated and accounted for when designing future plants.
- The capacity factor of the system is ~0.15, this is in alignment with the capacity factor of 0.14-0.16 in the region. When filtering the snow cover and outage events, the capacity factor of the fully capable system is ~0.167. In comparison, the expected capacity factor is 0.166 using the SAM model. This indicates good design, construction, and performance.
- The performance ratio shows that when unobstructed by snow, the system performs to about 88.5% of its nameplate rating. The fully capable system performs about 2.5% higher than the modeled system with the assumed losses. There is some indication of gradual system degradation over time. More data spanning a longer timeframe is needed to accurately measure the rate.
- The colocation appears beneficial, mainly from operation and maintenance and training perspective. The shared resources with existing plant, the convenience for inspection, troubleshooting and ground maintenance and increased security can reduce cost.
- Modeling of the grid impacts suggest that the Greenwood PV plant would not pose any technical issue to feeder F_27722.
- Current Synergi Electric Model data should be checked to prevent load masking due to increased DER on F_27722.

12 Appendix A – Switchgear issue

An switchgear failure event recorded by Evergy at the Greenwood PV Plant is shown below.

Switchgear failure event early in plant operations		
#	**Date**	**Description and Actions**
1	**Jan 25, 2017**	Switchgear event
2	**Jan 30, 2017**	Failure observed onsite
3	**Feb 2, 2017**	Mark One begins onsite assessment
4	**Feb 3, 2017**	Pole switch is opened so work can begin on switchgear
5	**Feb 7, 2017**	Eaton and Mark One perform more detailed inspection inside of switchgear. Cables were damaged and needed to be repaired.
6	**Feb 8, 2017**	Meter is damaged, relay appears to be working, switch is questionable
7	**Mar 17, 2017**	Cables replaced. New meter from internal group was not compatible so another was placed on order
8	**Apr 4, 2017**	New meter installed and coordination begins for start-up
9	**Apr 11, 2017**	Pole switches closed. Testing begins. Modem was damaged and needs to be replaced.
10	**May 1, 2017**	Modem replaced. Communications working except for the relay. The relay is functioning, but the communications port was damaged in the event. A new relay is ordered.
11	**June 6, 2017**	New relay installed. Plant energized. Communications issues persist but plant is fully functional.

Note: Evergy staff commented, "Had we replaced all questionable components in the beginning we would have likely saved 2 months, but some failures were not apparent until the switchgear was powered on."

13 Appendix B – Comments from Evergy about the Greenwood PV plant

Some comments from Damon Rea email from 2021-10-19 and 2021-10-20

- Realtime market pricing for 2019 & 2020 averaged out to be approximately $25.70 for daytime hours at that location.
- The design life, I would suggest at least 25 years now. Most projects we're currently working on are designed for 30 to 35 years.

Some comments from John Arthur email on 2021-10-19

- I reduced the O&M costs as we have had next to nothing the last few years.
    - O&M cost: $10,000/year

Some comments from John Arthur email on 2017-12-14

- The cost was approximately $8.5M to construct the 3 MW solar site. Design decisions on this project should reduce the future cost of any expansion on the site.
- Though the engineering and construction was sourced locally, the use of a single EPC contractor made it easier to manage the project overall. Even with the knowledge gained on this project it would make sense to utilize hire a single contractor vs. coordinating the engineering, procurement, and construction separately.
- The benefits of colocation include increased security along with ease of inspection and ground maintenance.
- Many components of the switchgear and transformer are already well understood by the plant personnel. They required (and will continue to require) training on the operation of the panels, combiner boxes, and inverter.
- Ongoing maintenance has 2 main components:
    - Semi-annual inspections will be performed by Burn and McDonnell to ensure that all the equipment is functioning properly. This includes panels, inverters, transformers, and the switchgear. The cost is $15,900 per year.
    - Routine maintenance (such as rock and pond upkeep) is anticipated to cost around $10,000 per year.
- The fixed mount system for the solar panels has proven maintenance free thus far. I believe this will outweigh any advantages the tracking mounts would have provided.
- The use of rock vs. natural grass has proven to be beneficial. Though the cost of the rock was more money up front the maintenance has been minimal. Initially we struggled with washout during heavy rains, but rock check dams have kept those to a minimum.
- Sungevity declared bankruptcy in March 2017. Items that continue to work in our favor:
    - The installation contractor, Mark One, is local and continues to support the project
    - The engineering firm, DLR Group, is local and continues to support the project
    - All equipment is still supported by the original equipment manufacturer (OEM)
    - The warranties were covered based on manufacturer's warranty. Sungevity was going to handle any issues, now we will have to process warranties on our own.