Solar Power Demonstration Site

Annual Performance Report – 2017

Version :1.0 **July 12, 2018**

INTRODUCTION

The Solar Power Demonstration Site is located at the Landfill Gas Power Generation Facility, just southwest of the Circle Drive South & Valley Road Interchange. It is a ground-mounted solar panel installation, as shown in the picture below, and was built on a vacant part of the property that will eventually be used to expand the building to accommodate two additional landfill gas engine-generator units. Solar power that is generated on-site is used to offset power purchases from SaskPower to operate the facility. When the facility is shut down for maintenance or other reasons, any excess power is delivered to SaskPower's grid through a net metering operating agreement.

Solar Power Demonstration Site – Looking West-NorthWest toward Montgomery Place

The demonstration site consists of 92 solar panels configured in four different arrays. The site is situated at Latitude/Longitude coordinates of 52.13˚ / -106.7˚, aligned along an azimuth of 205˚ (or 25˚ west of due south). The Landfill Gas Power Generation Facility was built on the road allowance for the old access road to the Saskatoon Landfill, which was constructed parallel to the CN Main Line, aligned along this same azimuth of 205˚.

The NorthWest array consists of 6 solar panels on a single-axis tracking system that follows the sun's relative position through the day to maximize energy production. This tracking system is capable of tracking both horizontally and vertically, however is currently locked at a vertical angle of 45˚. The NorthEast array consists of 6 solar panels on a dual-axis tracking system, and in this case will follow the sun's relative horizontal and vertical position through the day to maximize energy production. Both tracking systems are owned by Saskatchewan Polytechnic.

The SouthWest array consists of 40 panels set at a fixed vertical angle of 45˚. The SouthEast array consists of 40 panels on an adjustable racking system that can be set at a vertical angle of 30˚, 45˚, or 60˚, and adjustments are made through the different seasons to maximize the energy production from the array. The two south arrays are co-owned by the SES Solar Co-operative and Saskatoon Light & Power.

Each array is individually metered with Saskatoon Light & Power's smart meters that record energy production in Kilowatt-Hours (KWh) for every 15-minute period through the day. Over the course of a year, over 35,000 15-minute intervals are recorded and stored in the City of Saskatoon's Meter Data Management System (i.e. 4 intervals per hour x 24 hours per day x 365 days per year = 35,040 intervals per year). These records are automatically verified, and were then analyzed and aggregated to produce this performance report for 2017.

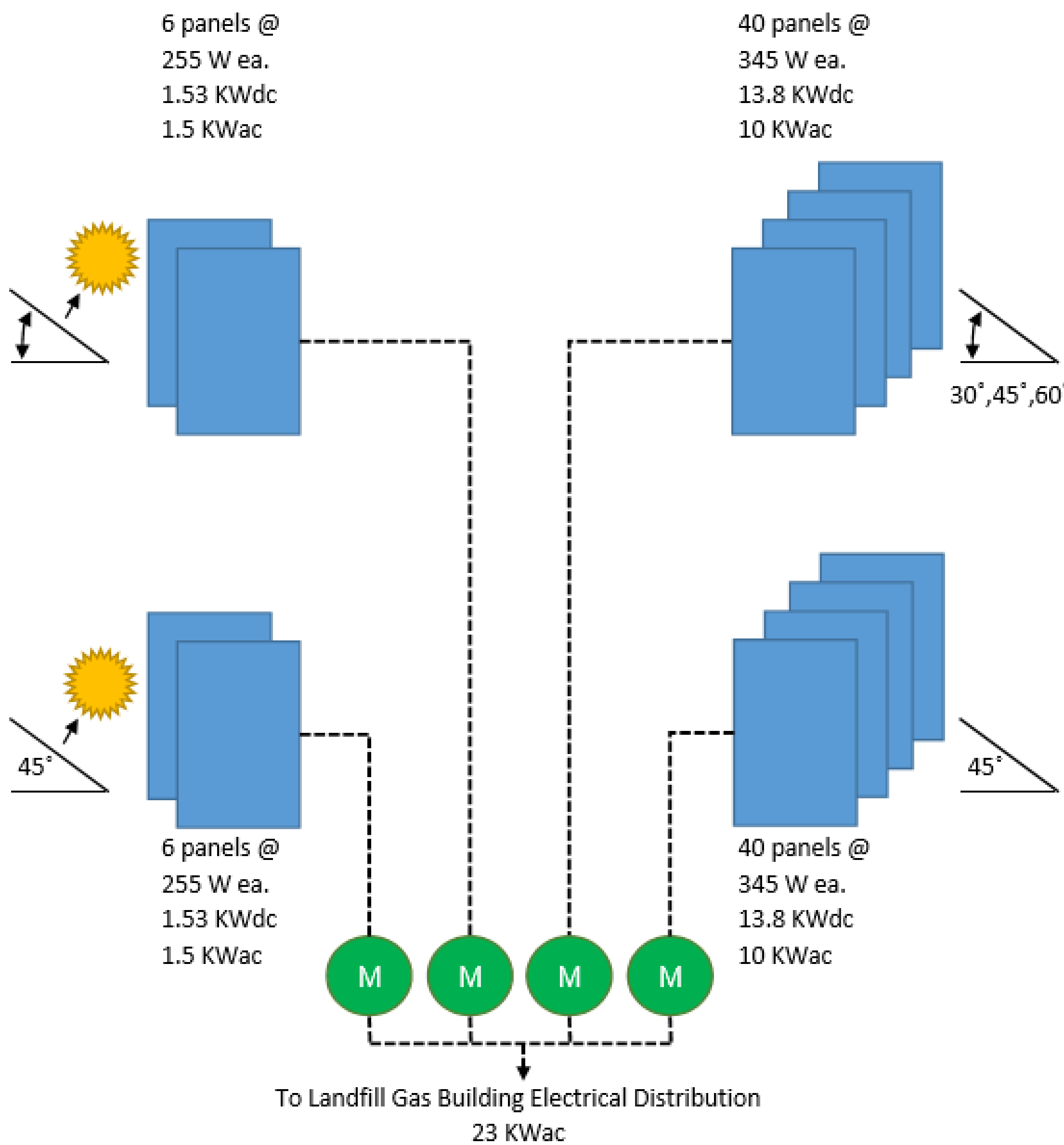
In addition to the smart meters, each array also includes a solar irradiance instrument that measures the solar energy incident on each array in Kilowatts (KW) per square meter of panel area. This data is used to calculate the efficiency of the solar panels in converting sunlight to electricity. The irradiance monitors were installed and commissioned in November, 2017, and therefore only one month of full data was available, for the month of December, 2017.

The demonstration site was commissioned in December, 2016 and operated throughout 2017. It is intended that this site will remain in operation until the Landfill Gas Power Generation Facility is expanded in the future. The performance of the demonstration site will be used to inform future decision-makers for future deployment of solar power in Saskatoon and area.

TABLE OF CONTENTS

SECTION I – SYSTEM DESCRIPTION

The diagram below illustrates how the solar panels are interconnected with the electrical distribution system at the Landfill Gas Power Generation Facility.



The two large arrays are shown on the right-hand side. Each of these arrays consist of 40 panels, rated at 345 Watts each, each with a 250 Watt micro-inverter (for a total capacity of 13.8 KWdc, or 10KWac per array).The two trackers are shown on the left-hand side. Each tracker consists of 6 panels, rated at 255 Watts each, each with a 250 Watt micro-inverter (for a total capacity of 1.53 KWdc, or 1.5 KWac per tracker.

The overall system capacity is 30.66 KWdc, or 23 KWac.

SECTION II – OVERALL PERFORMANCE

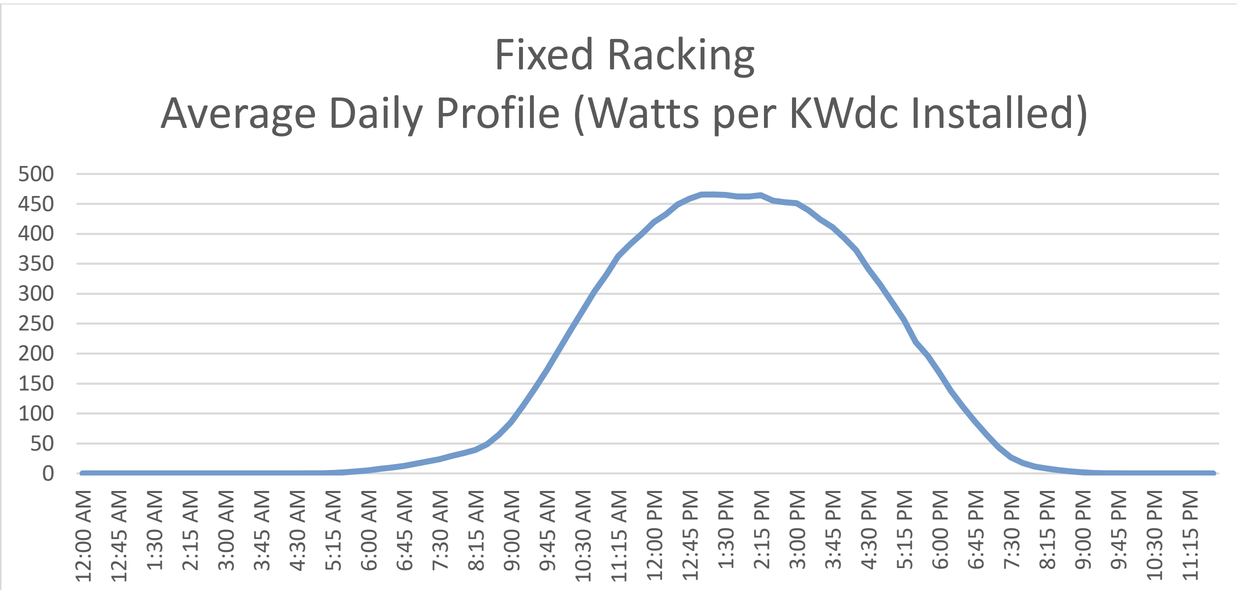
The table below indicates how each of the arrays performed throughout 2017. The Capacity Factor of each array is calculated by dividing the annual energy production by the (DC capacity x 8,760 hours), and is a measure of the average output throughout the year in relation to the rated generating capacity. For Saskatoon and area, a typical solar power system, aligned due south, unshaded and without snow cover, should perform with an annual capacity factor of around 14% (or around 1,226 KWh per year per KW of solar panels installed).

	FIXED ARRAY	ADJUSTABLE ARRAY	SINGLE AXIS TRACKER (WEST)	DUAL AXIS TRACKER (EAST)
DC CAPACITY	**13.8 KW**	**13.8 KW**	**1.53 KW**	**1.53 KW**
AC CAPACITY	10 KW	10 KW	1.5 KW	1.5 KW
ANNUAL ENERGY PRODUCTION	17,065 KWh	18,069 KWh	2,588 KWh	2,715 KWh
ENERGY PER KW	1,236 KWh/KW	1,309 KWh/KW	1,691 KWh/KW	1,774 KWh/KW
CAPACITY FACTOR	**14.1%**	**14.9%**	**19.3%**	**20.5%**
INSTALLED COST	$4.70/Watt	$5.10/Watt	$9.84/Watt	$9.84/Watt

SECTION III – FIXED ANGLE ARRAY

1.0 AVERAGE DAILY PRODUCTION PROFILE

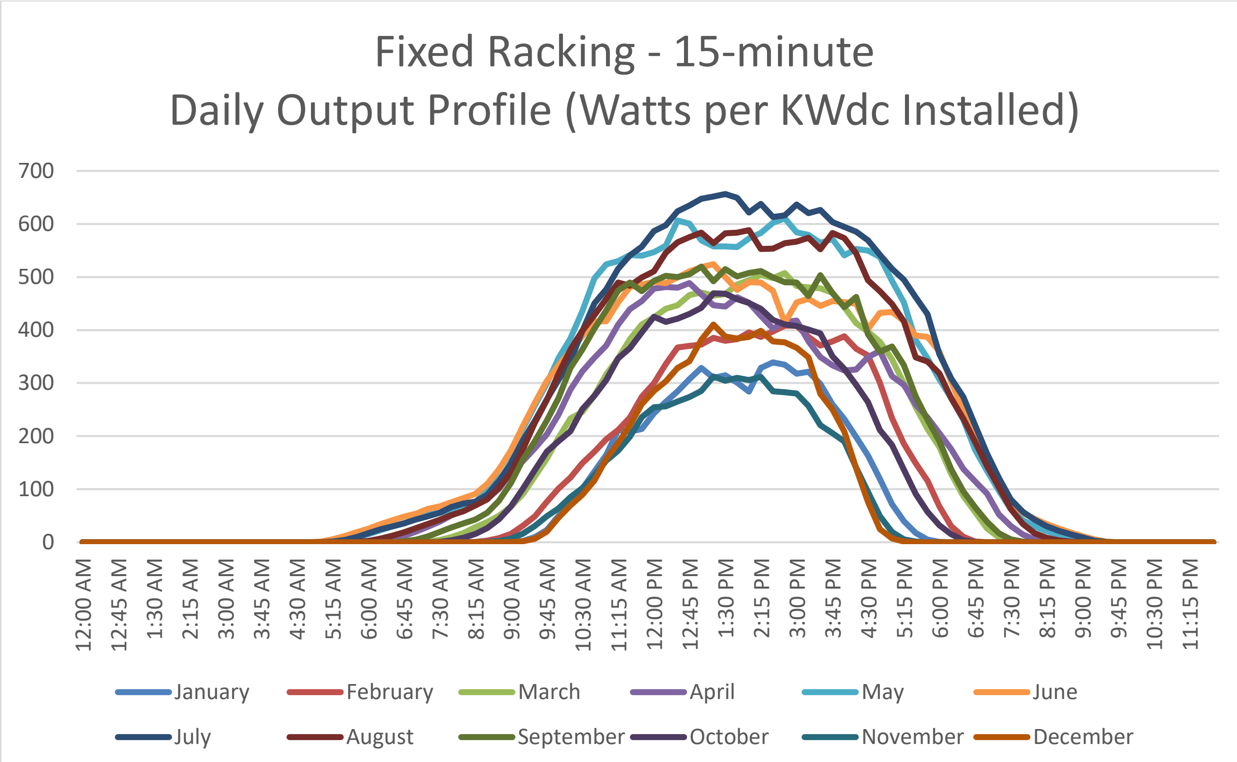
The graph below shows the average daily power production profile, in Watts per KWdc of solar panels installed. This was determined by averaging every 15-minute interval period over the 365 days throughout the year. For example, the average power production from 1:00pm to 1:15pm (peak solar radiation period for Saskatoon and area) throughout the year in 2017 (averaged over 365 days) was about 465 watts per KWdc of solar panels installed.



2.0 MONTHLY PRODUCTION PROFILES

The next graph shows the average daily power production profile, averaged for each month throughout 2017, and hence indicates more variability in production, as well as time of production throughout the year.

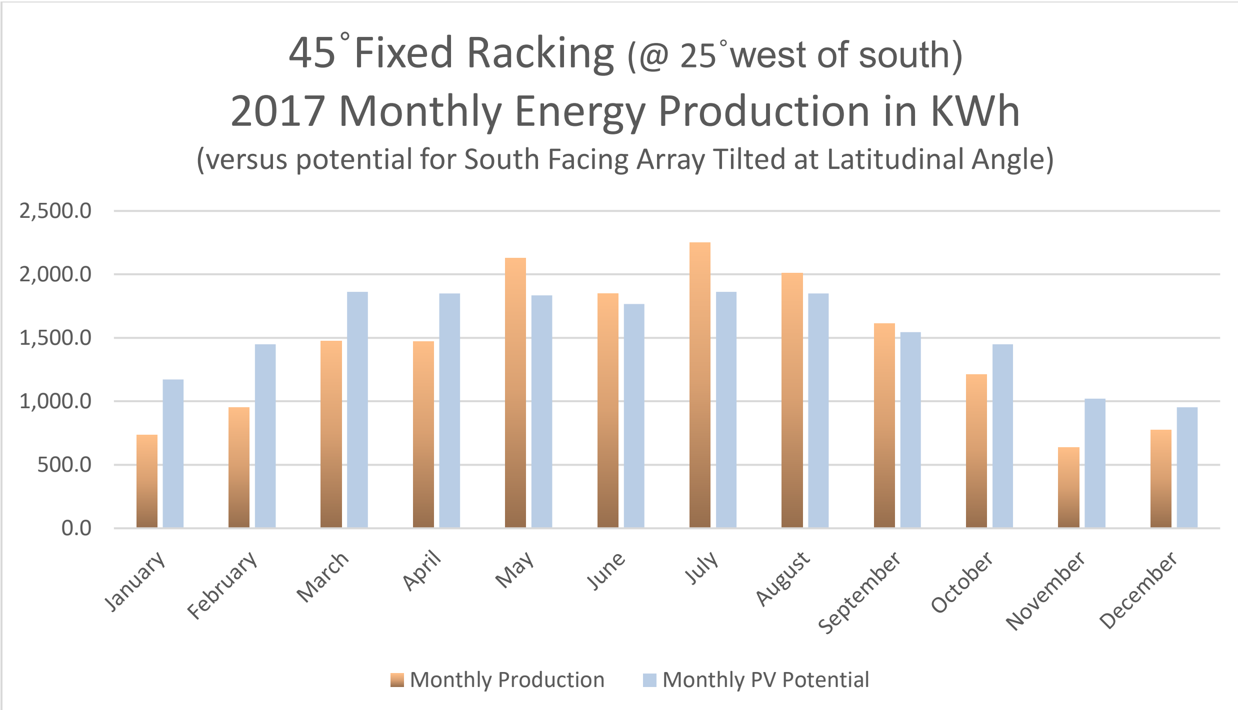
This information may be of interest to commercial electricity customers who pay demand charges on their electricity purchases. Depending on the time of day when the peak power use typically occurs for a customer's facility, the addition of solar power to the facility may help to reduce monthly demand charges. For example, if a customer's peak demand typically occurs sometime between mid-morning to mid-afternoon, adding solar power may be a good option to help reduce peak demand charges.



3.0 PRODUCTION VERSUS POTENTIAL

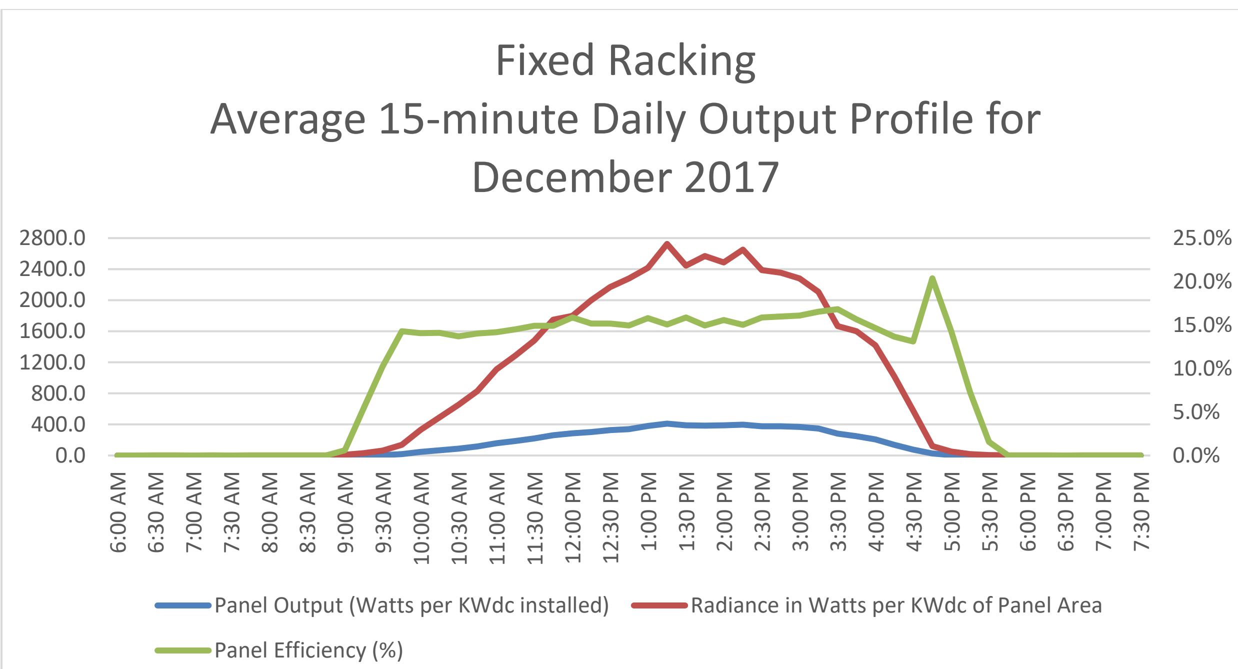
Natural Resouces Canada (NRCan) publishes data for locations across the country, that indicates the potential solar energy production in KWh per KW installed for each month of the year. This data applies to a south-facing array, set at a vertical angle equal to the latitudinal position for the location. For Saskatoon, this means a vertical angle of 52˚. This is the vertical angle that will produce theoretically the highest energy production throughout the year for fixed panels.

The next graph shows the monthly energy production (in KWh) for the array, compared to the theoretical energy production potential for Saskatoon. From January to April in 2017 the array under-produced its theoretical potential, from May through September it over-produced its potential, and from October through April it under-produced its potential again. Overall throughout 2017, the array produced 92% of its theoretical energy production potential. This is due to the angle set at a lower value (45˚) than the latitudinal position for Saskatoon (52˚).



4.0 SOLAR IRRADIANCE AND PANEL EFFICIENCY

The next graph shows the average daily solar irradiance profile for the month of December, in Watts per KWdc of panel area. This data was used to calculate the conversion efficiency of the solar panels, dividing power production by irradiance.

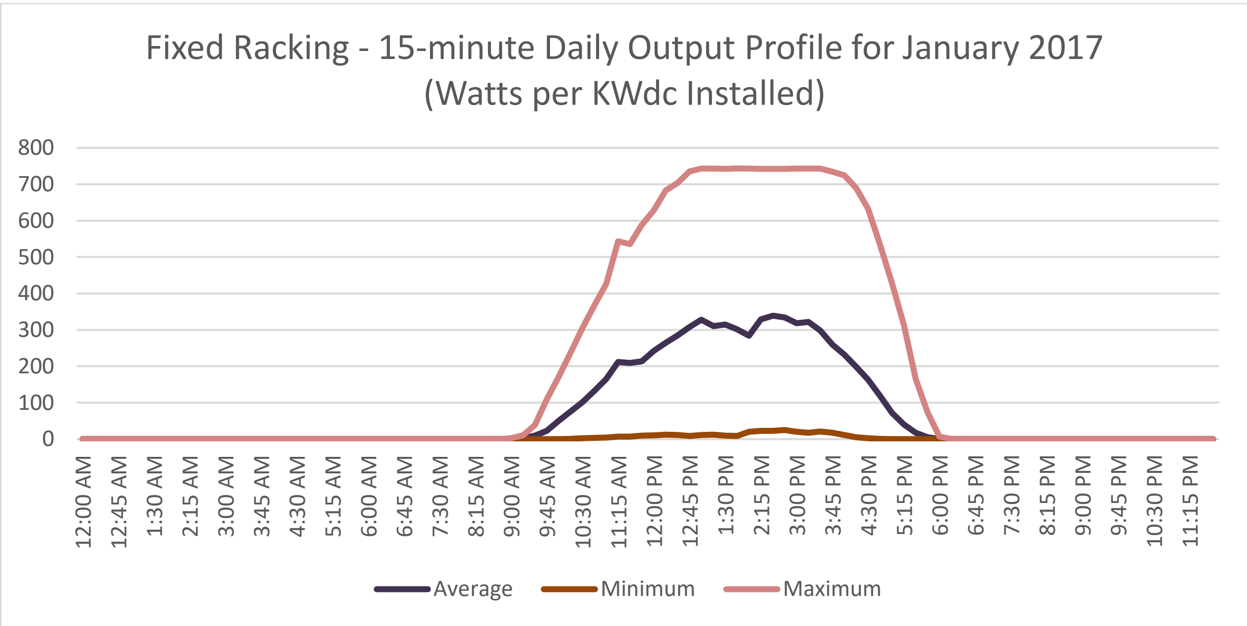


At the knees of the efficiency curve (i.e. morning start-up and late-afternoon shut-down) the data is less reliable for efficiency calculation purposes, and should be disregarded. The average conversion efficiency for the solar panels throughout the day, following the vertical scale on the left-hand side of the graph, hovered just over 15%. The conversion efficiency will be higher at cooler temperatures, and will typically be lower in the warmer months.

5.0 MINIMUM AND MAXIMUM PERFORMANCE

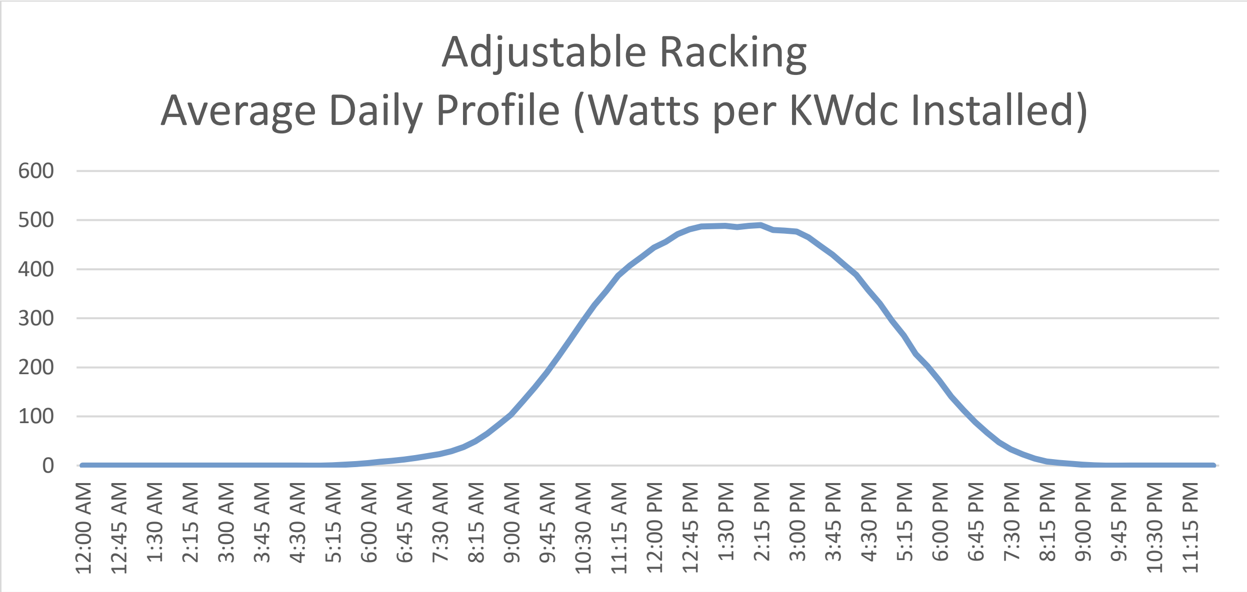
The graph below shows the minimum, maximum, and average power production for the array for the month of January. This indicates the variability in solar power production that is typical for most installations, due to local weather and cloud cover conditions.

It is interesting to note that the top part of the maximum output curve is flat through most of the morning to late afternoon. This indicates that at times during the day, the solar panel output has exceeded the capacity rating of the micro-inverter. This is a trade-off that solar power owners sometimes make, to install an over-sized panel that produces more energy throughout the day, but sometimes may exceed the capacity rating of the inverter during periods of peak power output.

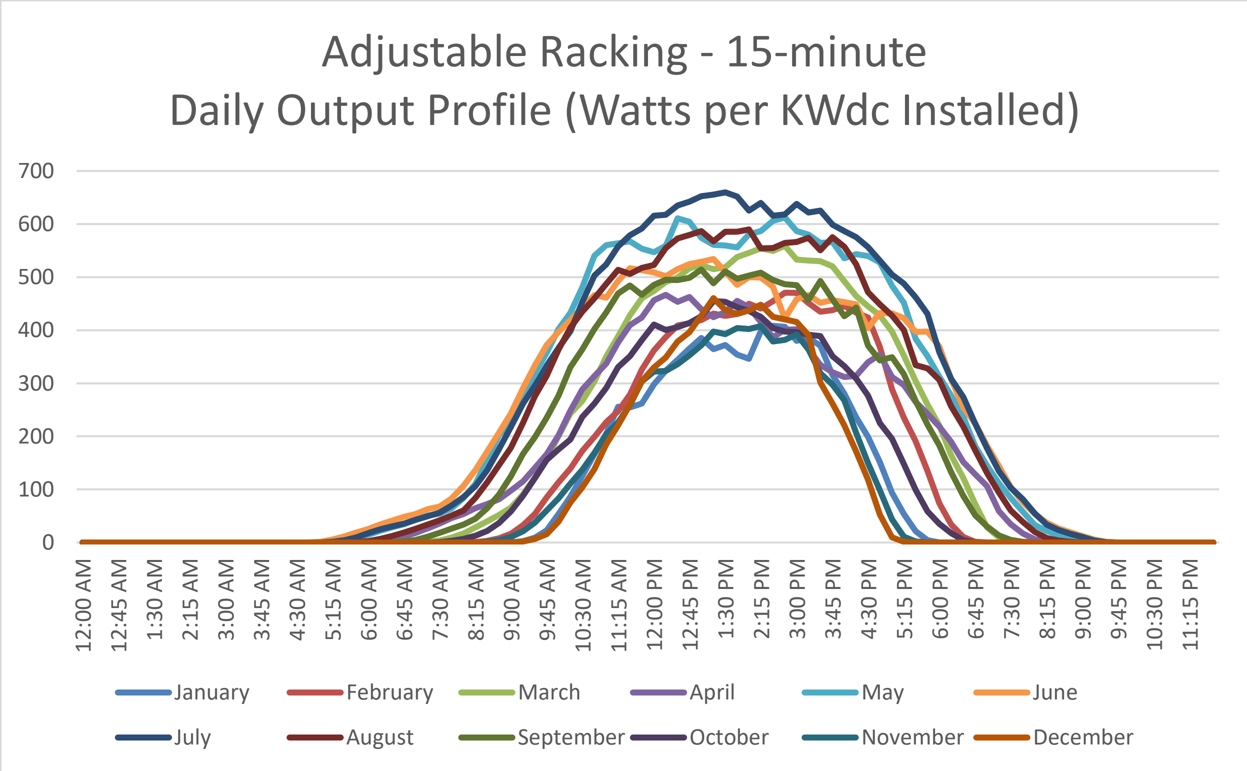


SECTION IV – ADJUSTABLE ARRAY

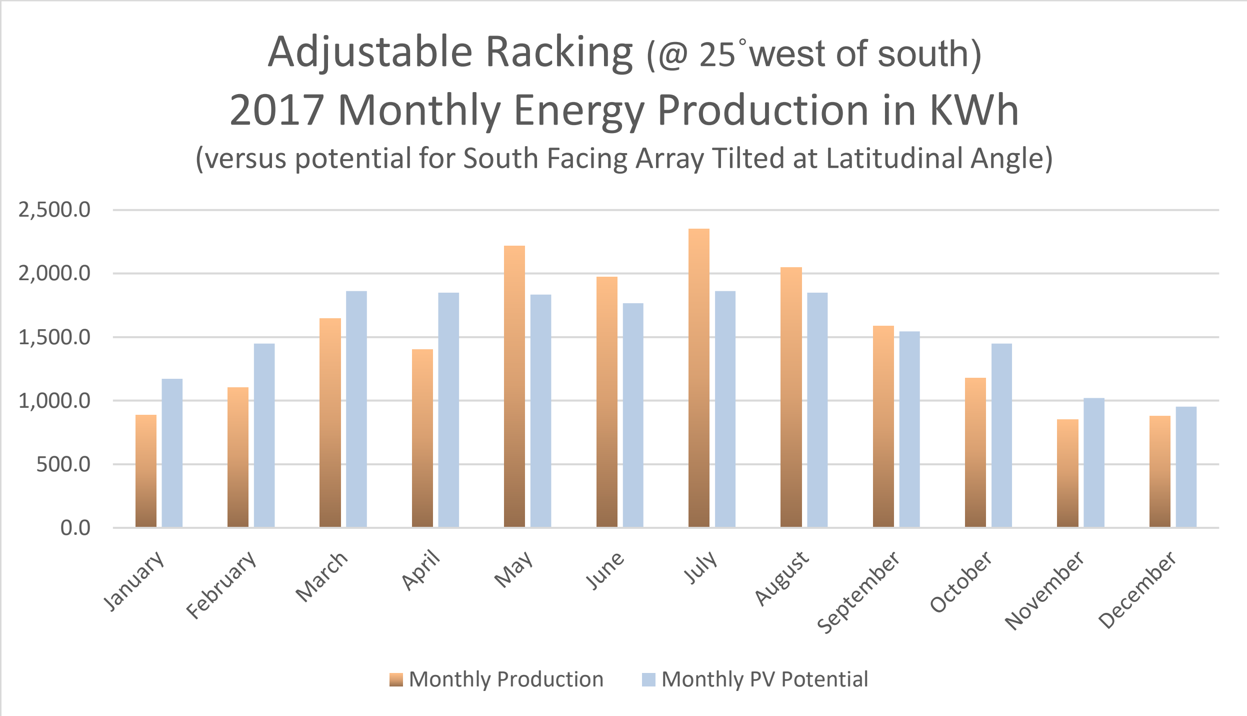
6.0 AVERAGE DAILY PRODUCTION PROFILE



7.0 MONTHLY PRODUCTION PROFILES

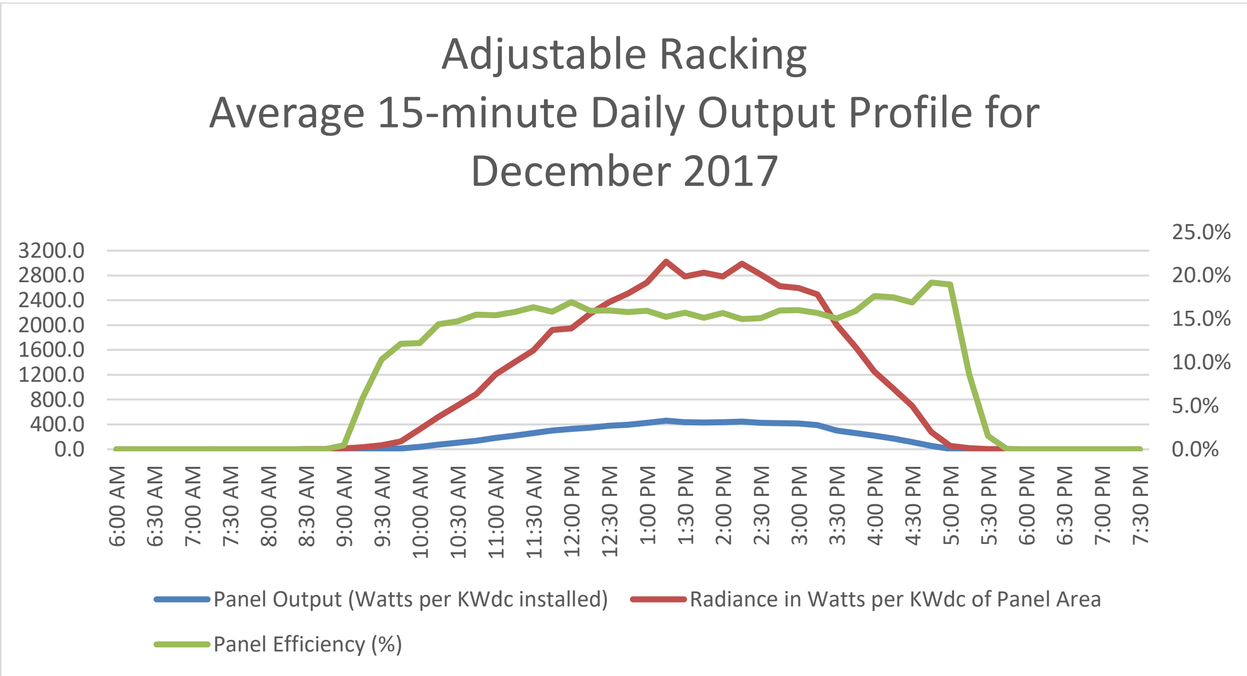


8.0 PRODUCTION VERSUS POTENTIAL



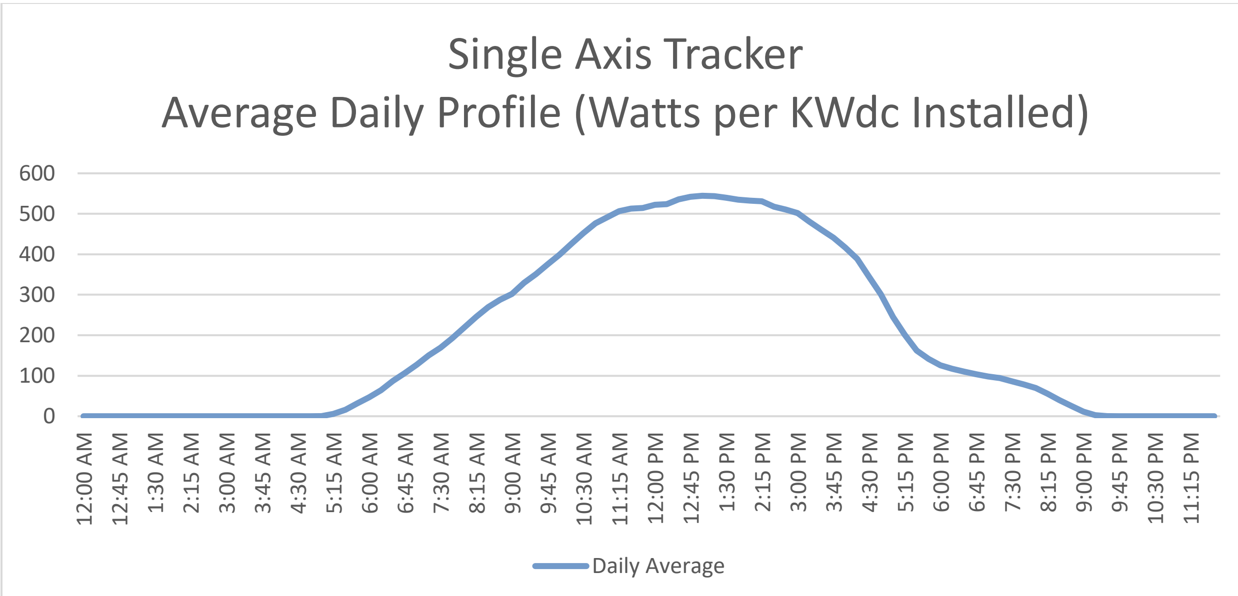
Overall throughout 2017, the array produced 97% of its theoretical energy production potential. In 2018, angle adjustments will be optimized to increase performance.

9.0 SOLAR IRRADIANCE AND PANEL EFFICIENCY

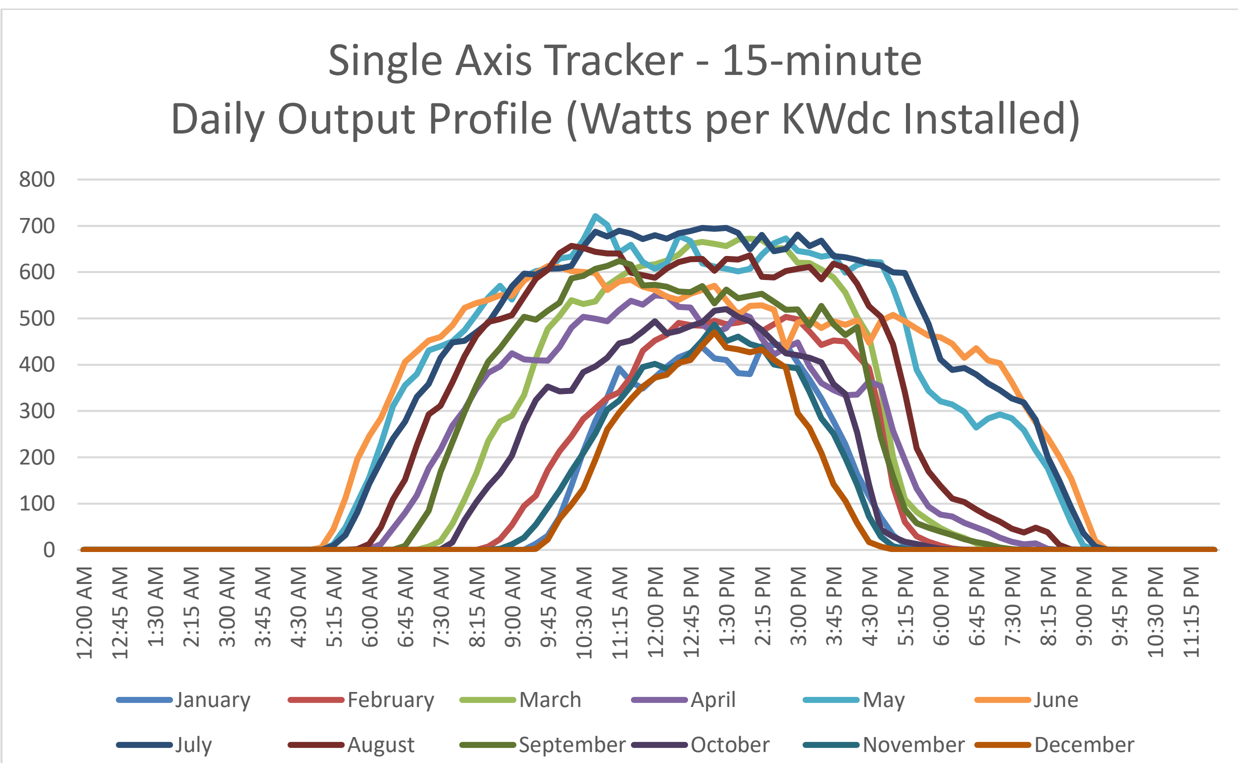


SECTION V – SINGLE AXIS TRACKER

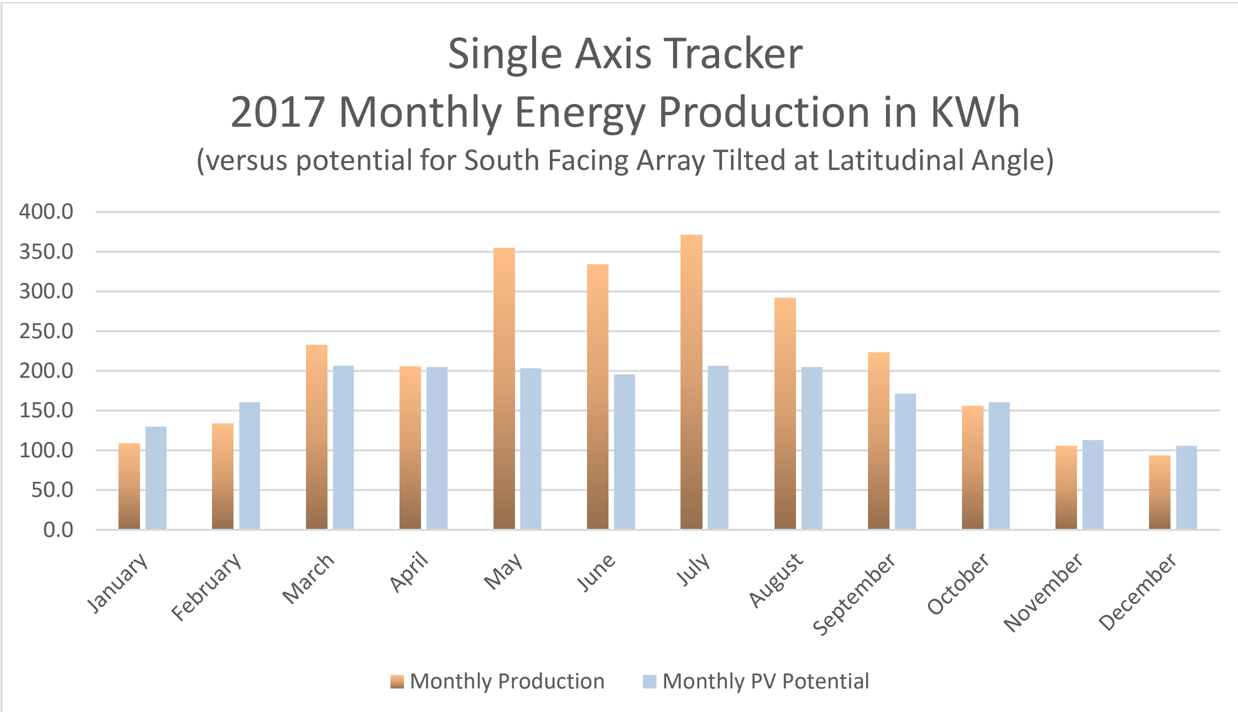
10.0 AVERAGE DAILY PRODUCTION PROFILE



11.0 MONTHLY PRODUCTION PROFILES

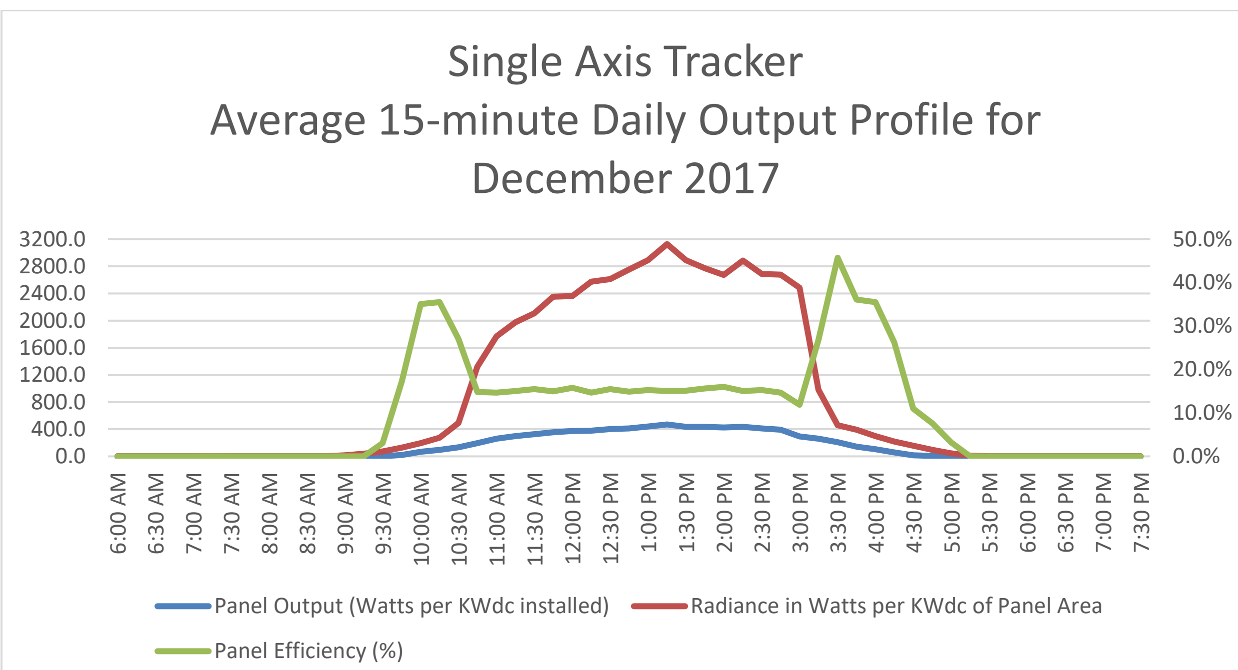


12.0 PRODUCTION VERSUS POTENTIAL



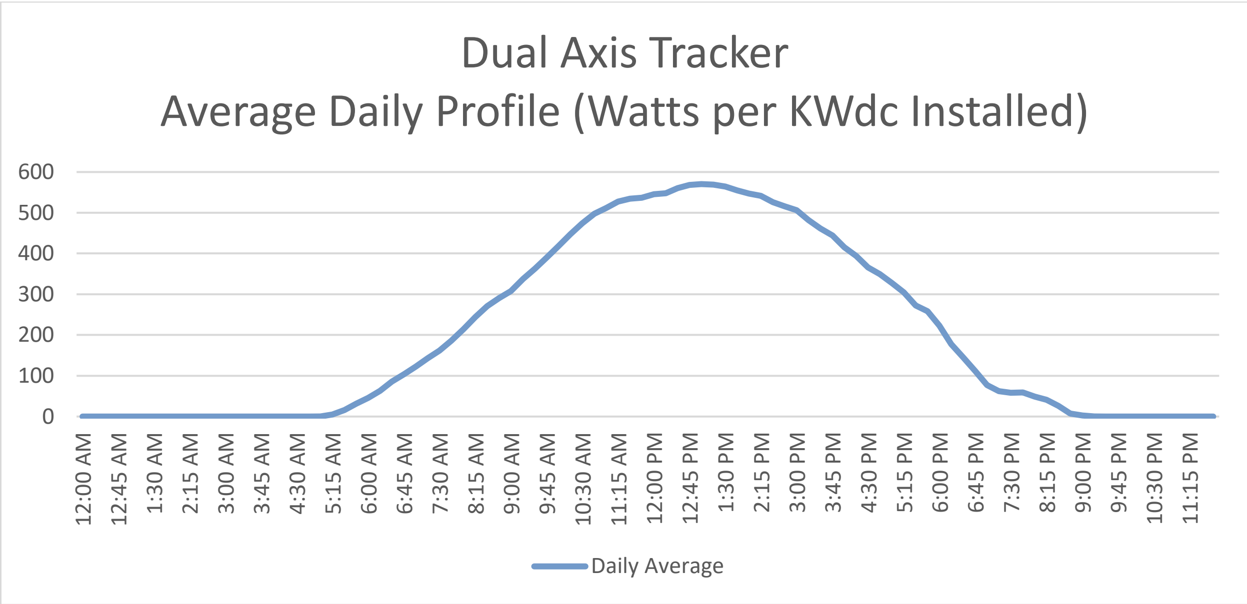
Overall throughout 2017, the single axis tracker produced 126% of the theoretical energy production potential for a south facing array set at the latitudinal angle.

13.0 SOLAR IRRADIANCE AND PANEL EFFICIENCY

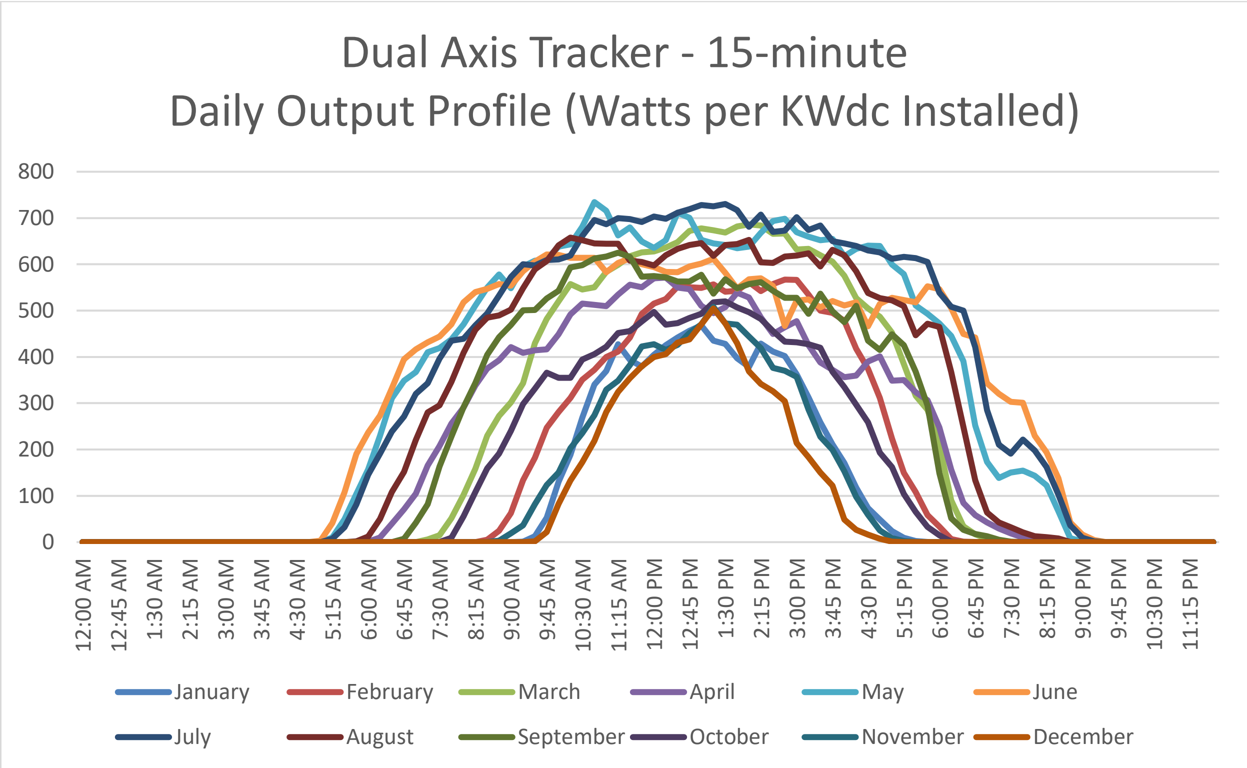


SECTION VI – DUAL AXIS TRACKER

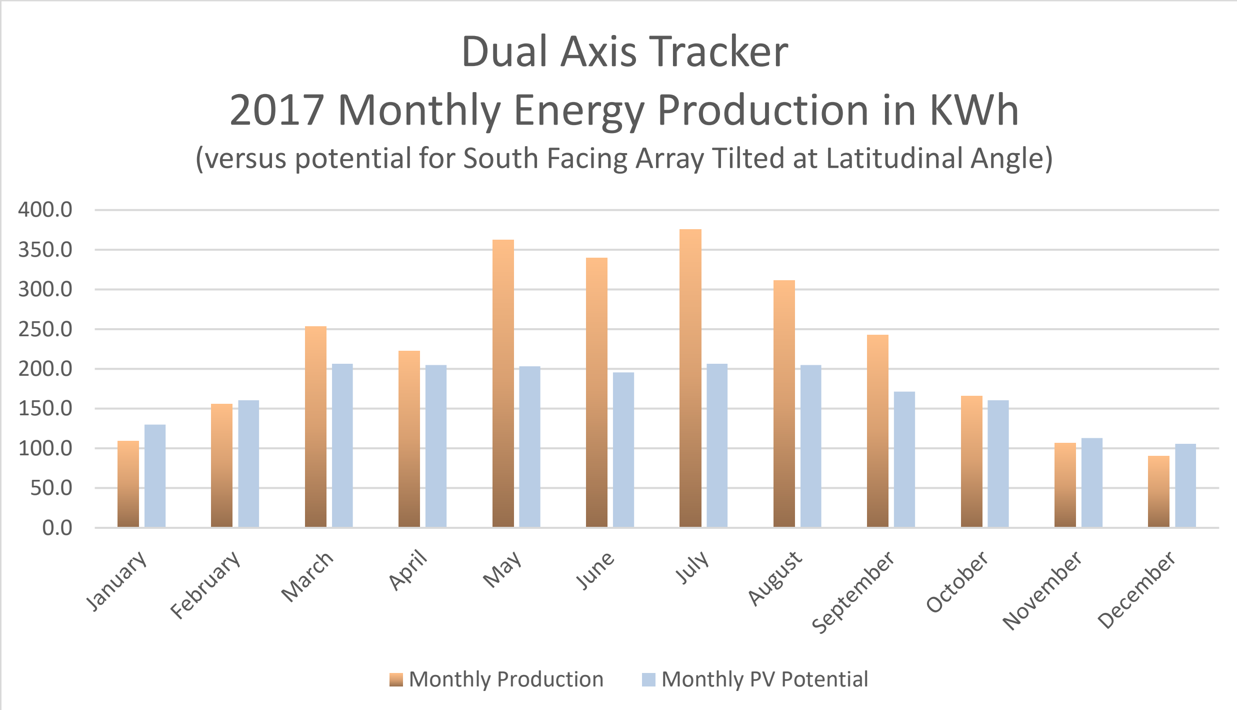
14.0 AVERAGE DAILY PRODUCTION PROFILE



15.0 MONTHLY PRODUCTION PROFILES

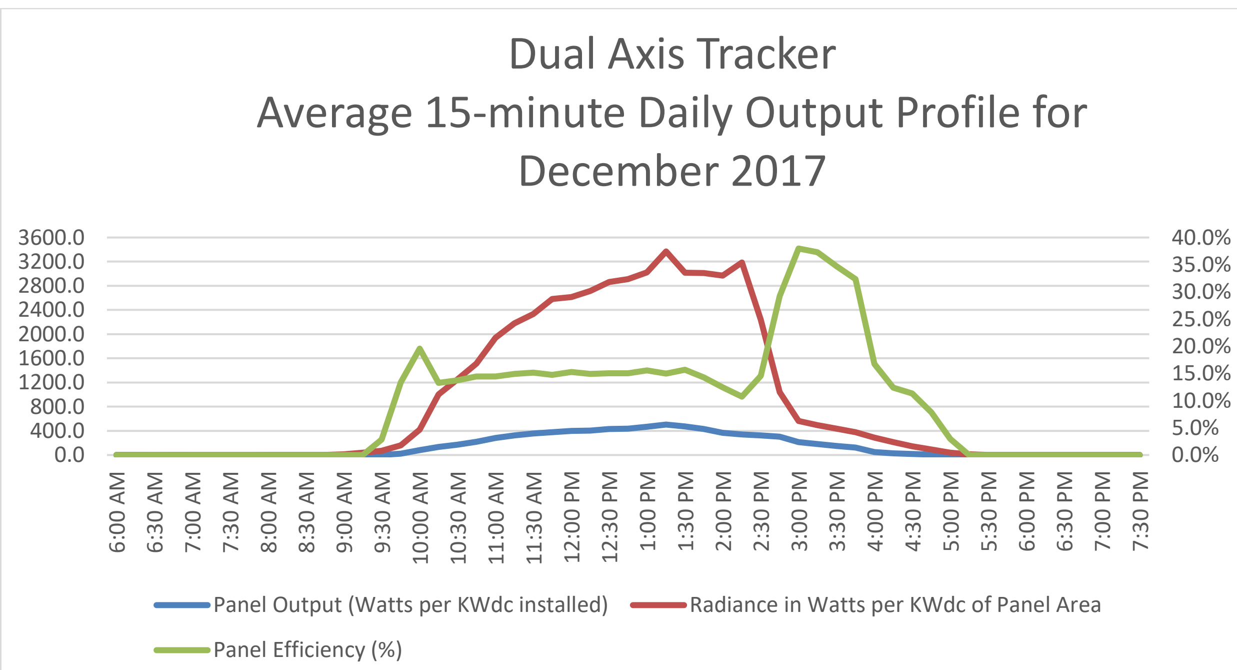


16.0 PRODUCTION VERSUS POTENTIAL



Overall throughout 2017, the dual axis tracker produced 132% of the theoretical energy production potential for a south facing array set at the latitudinal angle.

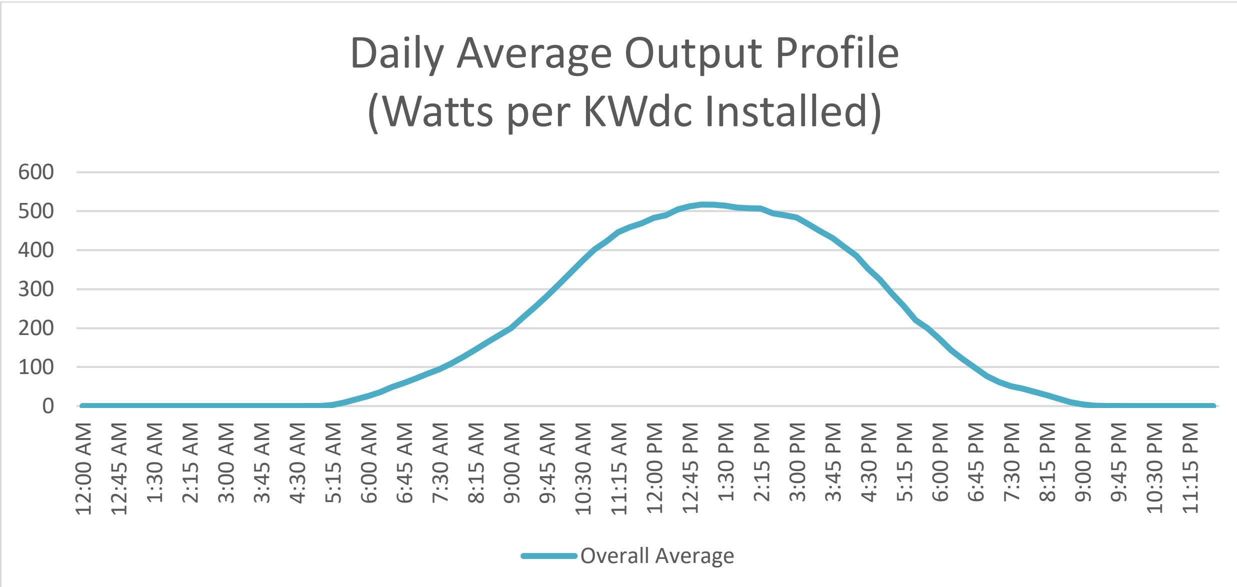
17.0 SOLAR IRRADIANCE AND PANEL EFFICIENCY



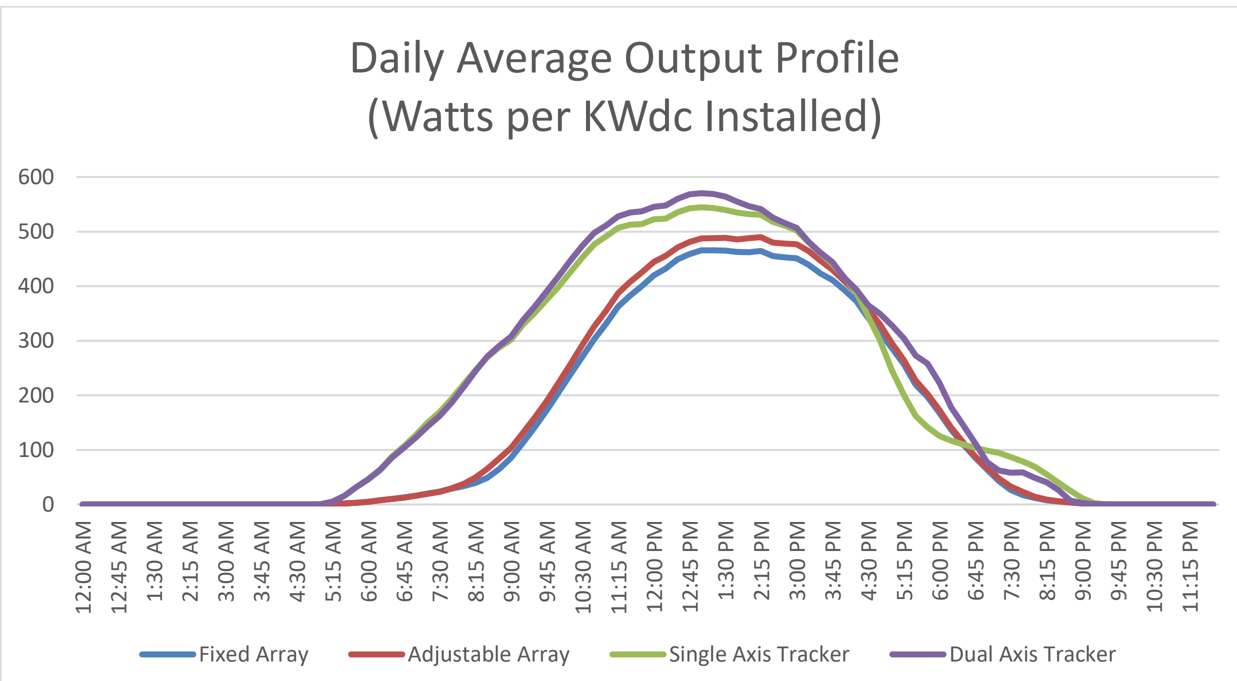
SECTION VII – COMPARATIVE PERFORMANCE

18.0 AVERAGE DAILY OUTPUT PROFILE – COMBINED

The graph below shows the daily average power production profile for all solar panels combined, averaged throughout 2017.



19.0 AVERAGE DAILY PRODUCTION PROFILES



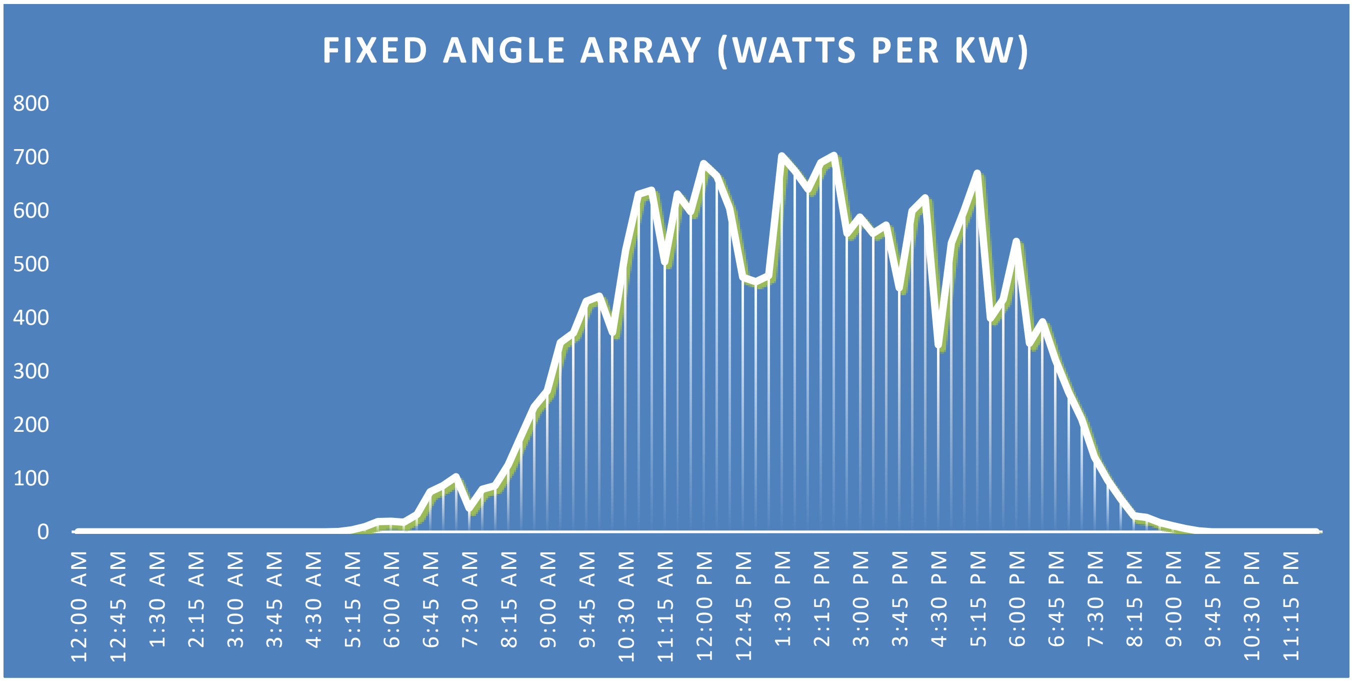
The preceding graph shows the daily average power production profiles for each of the four arrays, averaged throughout 2017.

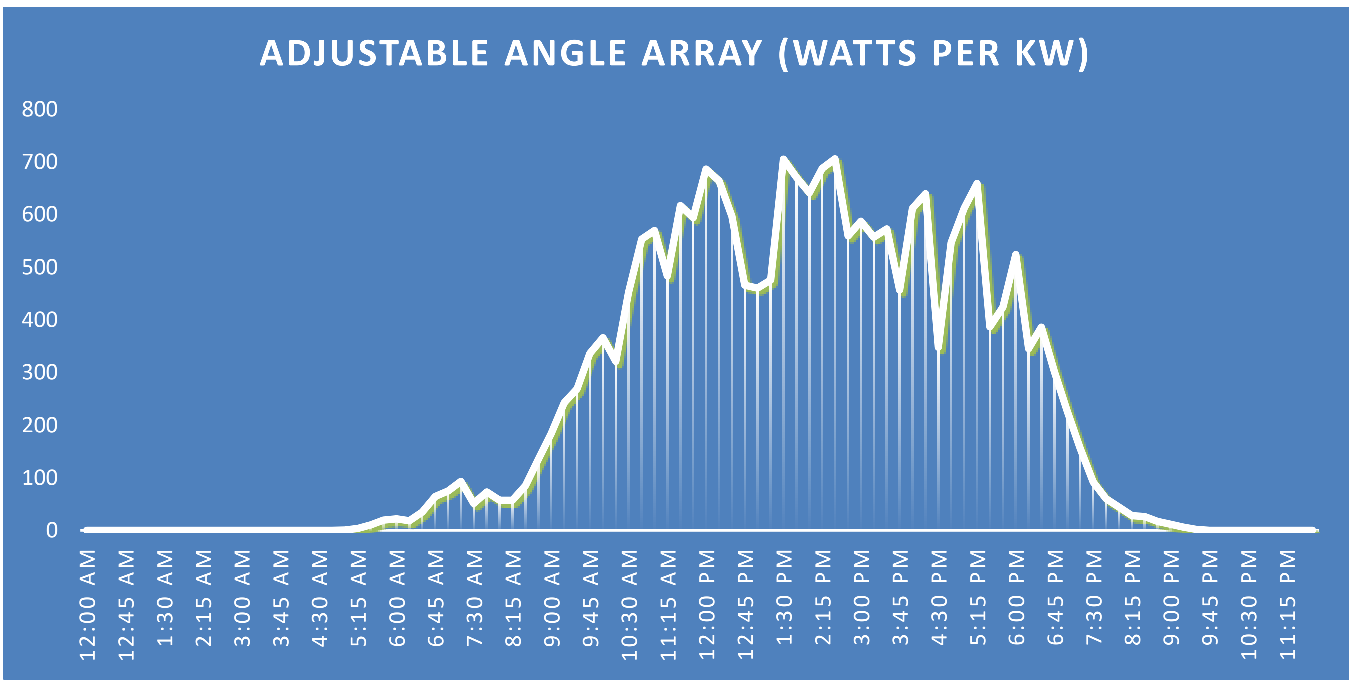
It is interesting to note that the peak power production occurs earlier in the day for the two tracker systems, than for the large arrays. This is due to the large arrays aligned with an azimuth of 205˚, or 25˚ west of south.

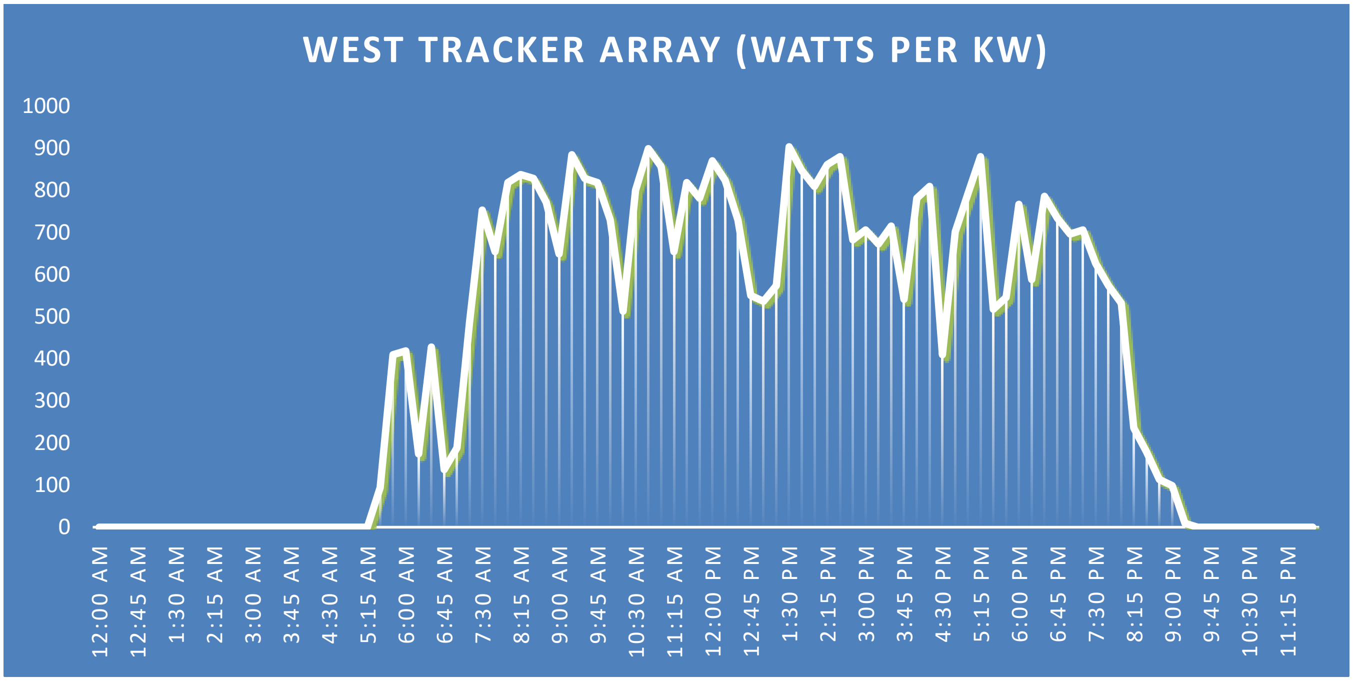
The graph also shows that the power production falls off in the late afternoon for the two tracker systems, due to shading from the building. The single axis tracker is closer to the building, and therefore experiences more shading than for the dual axis tracker. This is also evident in the graphs showing solar irradiance in sections 13 and 17.

20.0 SUMMER AND WINTER SOLSTICE

The next four graphs show the power output profile for the summer solstice on June 21, 2017. These illustrate the variability in solar power production due to cloud cover






WEST TRACKER ARRAY (WATTS PER KW)
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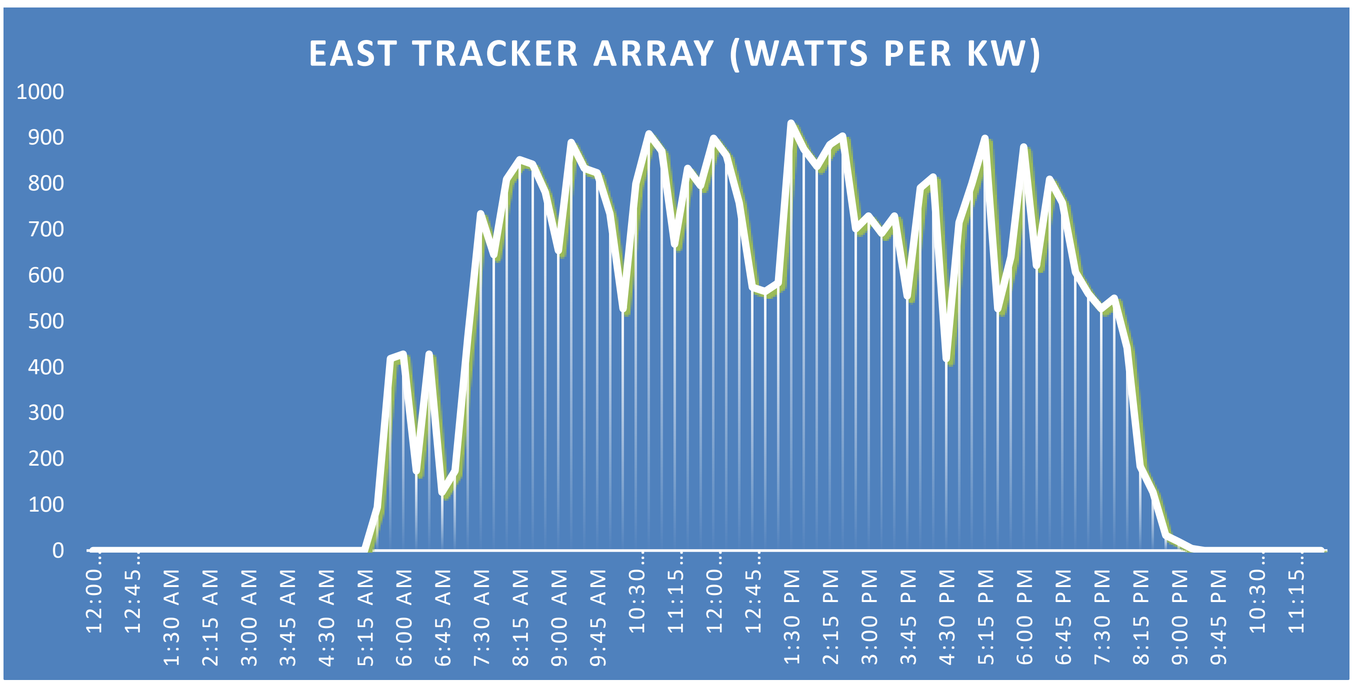
EAST TRACKER ARRAY (WATTS PER KW)
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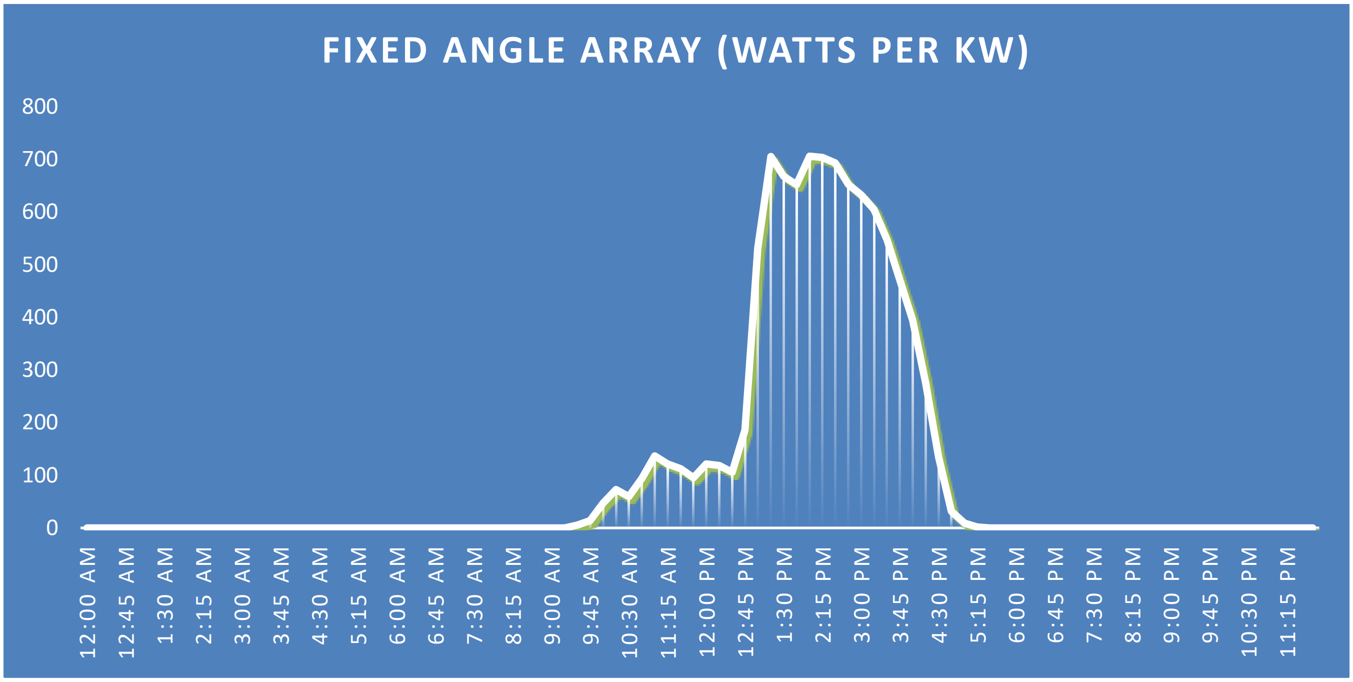
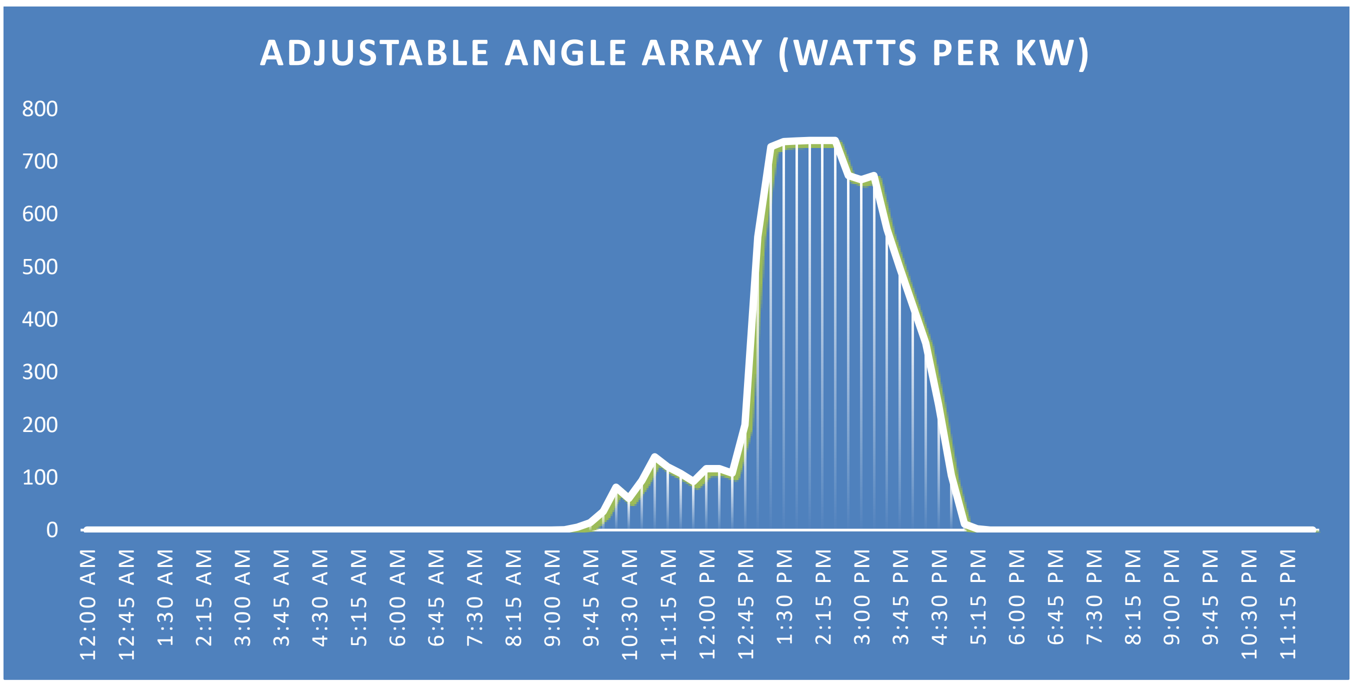
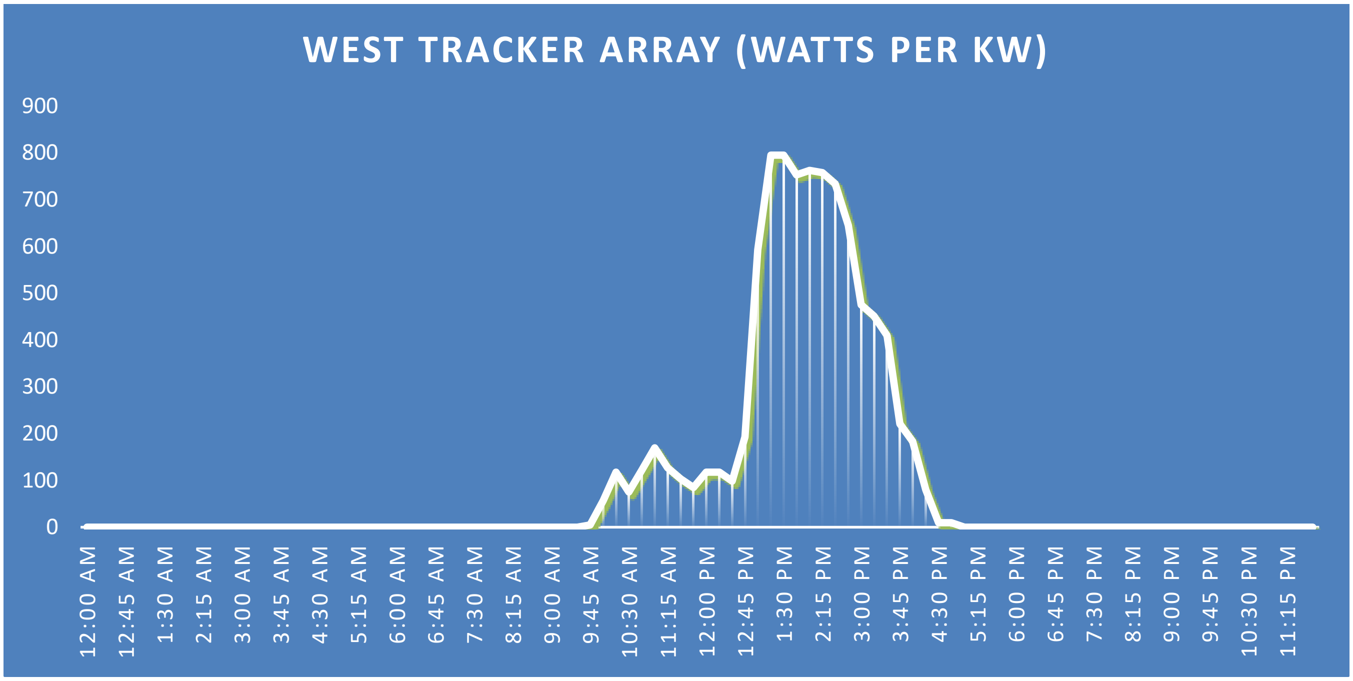
The next four charts show the power output profile for the day prior to winter solstice, on December 20, 2017. The actual winter solstice had much lower energy production and was considered atypical.






WEST TRACKER ARRAY (WATTS PER KW)
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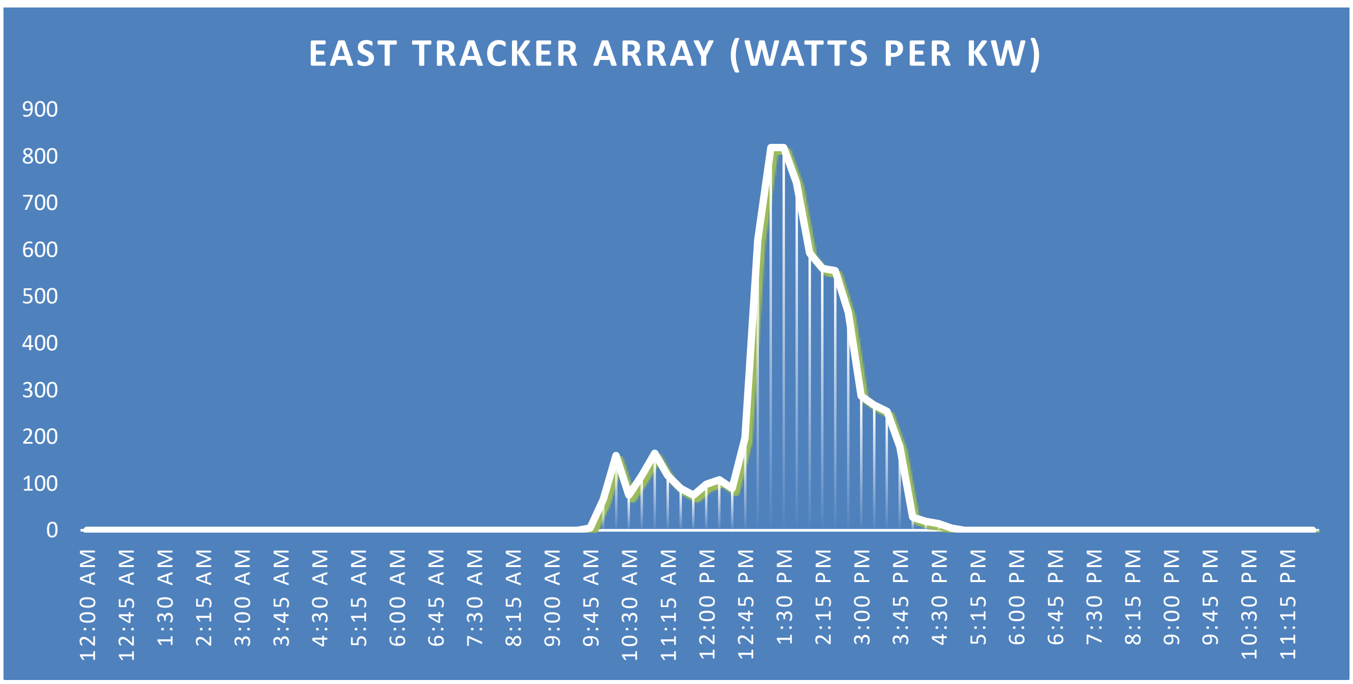
EAST TRACKER ARRAY (WATTS PER KW)
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