Independent Energy Production Assessment (Solar Yield Report)

PUBLIC RELEASE VERSION

RATCH-Australia

Collinsville Solar Thermal Power Station

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EXECUTIVE SUMMARY

Ratch Australia (the Client) engaged a solar consultant (Solar Consultant) to carry out an independent energy production assessment for a solar plant to be constructed in two areas adjacent to the decommissioned coal-fired power station near Collinsville in Queensland. The proposed solar plant is referred to in this report as the Collinsville Solar Farm (CSF or the Project).

The results of independent resource and energy assessment conducted by the Solar Consultant, together with the associated uncertainties, are presented here.

The layout, single line diagram and specifications of the Project were provided to the Solar Consultant.

Solar resource assessment

A measurement campaign has been conducted at the site for a period of approximately 1.1 years. Installation and maintenance information have been provided by the Client, together with raw data records. The following parameters have been recorded:

- Global Horizontal Irradiance (GHI);
- Direct Normal Irradiance (DNI);
- Ambient temperature;
- Relative humidity;
- Rainfall and hail; and
- Wind speed and direction.

Solar data recorded at the site have been correlated with high quality satellite-derived reference data in order to derive the long-term annual average kWh/m^2.

Similarly, the ambient temperature data recorded at the site have been correlated with longer-term ground-based measurements recorded at the nearby Proserpine Airport Bureau of Meteorology (BoM) meteorological station. The long-term annual average ambient temperature was predicted.

Energy production assessment

Based on the long-term assessment conducted by the Solar Consultant and the Project design characteristics, the following data were estimated:

- The long-term average annual energy yield ratio in kWh/kWp;
- The corresponding long-term average energy production in MWh/year; and
- The long-term average annual performance ratio.

The net energy prediction presented represents the long-term mean, 50 % exceedance level, for the annual energy production of the plant, not considering the effects of degradation (P50). This value should therefore be considered as the P50 for the first year of operation.

The production predictions were computed at the connection point to the Ergon Energy electricity grid at the existing 33 kV substation (as shown in the single line diagram that was provided). Therefore, the energy figures include the losses in the low and medium voltage cabling, in the generating equipment and in the low to medium voltage step up transformers, as well as estimation for the auxiliary services and the system and availability. The grid availability has not been considered.

Trees on or in the vicinity of the site have not been considered as it is assumed that these will be cleared prior to construction. The Solar Consultant recommends that the energy production assessment be revised when details of the clearing program are finalised.

Uncertainty analysis

The main sources of deviation from the P50 energy estimate have been quantified and added as independent errors, giving uncertainties in net energy production of the Project. These represent the standard deviation of what is assumed to be a Gaussian process.

The uncertainty of the final result is a consequence of the uncertainty in the solar radiation data, the inaccuracies of the simulation procedure itself (e.g. choice of models), and uncertainties associated with "external" influences (e.g. shading, soiling, deviation of components from specification, cabling losses, etc.).

INTRODUCTION

The Solar Consultant has been contracted by Ratch Australia Pty Ltd (the Client) to carry out the independent energy production assessment for the plant, to be constructed adjacent to the decommissioned coal-fired power station near Collinsville in Queensland. The proposed plant is referred to in this report as the Collinsville Solar Farm (CSF or the Project).

The results of independent resource and energy assessment conducted by the Solar Consultant, together with the associated uncertainties, were presented.

The layout and the single line diagram of the Project were provided by the Client, as were the technical specifications.

Site description

The Project is located approximately 4 km west of Collinsville and 75 km southwest of Bowen, as presented in Figure 0.1. The representative coordinates of the Project are as follows:

- Latitude: 20.5° S;
- Longitude: 147.8º E; and
- Altitude: 180 – 212 m a.s.l.

Figure 0.1: Location of the Project

An inspection of the proposed Collinsville Solar Farm site was conducted by the Solar Consultant in February, 2014.

The Project is adjacent to the decommissioned coal-fired Collinsville Power Station. The Project is proposed to be connected to the existing 33kV Ergon Energy substation. The substation is located adjacent to the decommissioned power station.

The terrain can be described as undulating and forested. The Client has provided drawings showing cut and fill works that will be conducted to smooth out the terrain slopes where the Project is to be installed. It has been assumed that all vegetation within each area will be removed.

Plant design

The design characteristics of the project were provided by the Client.

RESOURCE AND ENERGY ASSESSMENTS

Meteorological data

Site measurements

The meteorological measurement campaign at the proposed Collinsville Solar Farm site commenced in December 2012 with the installation of a pole-mounted meteorological station.

Equipment installed at the site met station includes a First Class pyranometer, First Class pyrheliometers, solar tracker (pyranometer and pyrheliometers mounted on this) and weather sensor.

The data logger has been programmed to record Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI), ambient temperature, relative humidity, wind speed and direction, rainfall and hail.

In general, the Solar Consultant considers the instrumentation and data logging to be of good quality.

An installation report has been provided, together with calibration certificates. During a site inspection conducted in February, 2014, the Solar Consultant confirmed the serial numbers, mounting arrangements and negligibility of shading impacts of the instruments installed at the site.

Cleaning records and associated photographs have not been provided. However, the Solar Consultant was advised during the site visit that cleaning and alignment checks of the irradiance instruments have been conducted on a daily basis, usually in the mornings.

Raw data and the logger configuration files were provided to the Solar Consultant for the 1.1 year period from December 2012 to January 2014. A number of days contained one or more missing GHI data points and some days contained one or more missing temperature data points. The meteorological data have been subjected to a quality checking procedure by the Solar Consultant to identify records which were affected by equipment malfunction and other anomalies. No erroneous GHI data were identified. One erroneous temperature data point was removed.

The annual average conditions recorded during the measurement period were calculated as follows:

- The measured data were combined into daily values. The daily average for each month was then determined from the average of all valid daily data recorded in that month over the measurement period. This was taken as the monthly mean thereby assuming that the valid daily data were representative of any missing days.
- The mean of the monthly means (MoMM) was taken to determine the annual mean ("mean of means") to eliminate the effect of seasonal bias in the data.

Reference datasets

In the assessment of the solar resource at a potential solar farm site, it is desirable to correlate data recorded at the site with reference meteorological data. This allows the estimate of the long-term solar resource at the site to be representative of a longer historical period. When selecting an appropriate reference dataset for this purpose it is important that data are consistent over the period being considered and that they correlate well with the site data.

The Solar Consultant procured four long-term meteorological datasets for this assessment to use as reference data sources. This includes time series data from two satellite-derived datasets.

A review of the reference data were undertaken to assess the general consistency of all datasets available for each meteorological parameter.

There may be some inconsistencies in one of the satellite-derived datasets, although the results of the analysis are inconclusive due to the limited number and time period of datasets available for comparison. That particular satellite-derived data was therefore not considered to be an appropriate reference dataset for the assessment of long-term irradiance conditions at the site.

One of the temperature datasets appeared to overpredict low temperature conditions, particularly at night, and was therefore not considered to be an appropriate reference dataset for the assessment of long-term temperature conditions at the site.

Consequently, one satellite-derived dataset was considered as an irradiance reference and two datasets were considered as temperature references.

Long-term meteorological conditions at the site

The analysis of the long-term meteorological conditions at the Collinsville Solar Farm site included consideration of both solar and temperature parameters, which are used as inputs to energy production assessments of solar plants.

Approximately 0.9 years of valid daily irradiance data had been recorded at the Collinsville Solar Farm site. In order to extend the period of data available to represent the long-term conditions at the site, the site measurements were correlated to the reference data described in Section 3.1. The analysis methodology is described in the following sections.

Irradiance

The long-term irradiance conditions at the CSF site were analysed using the following steps:

- Various correlations between the site measurements and each reference dataset were conducted to identify the most appropriate reference and the lowest uncertainty correlation.
- Long-term data correlated to the site data on a monthly basis was identified as the most appropriate method for iradiance, showing strong correlation.
- The long-term data and the site data were combined separately into daily totals. The daily average for each month was then determined from the average of all valid daily data sums recorded in that month, separately for each dataset. This was taken as the monthly mean thereby assuming that the valid data were representative of any missing data.
- The monthly correlation between concurrent site measurements and long-term satellite-derived data was used to adjust the complete long-term dataset;

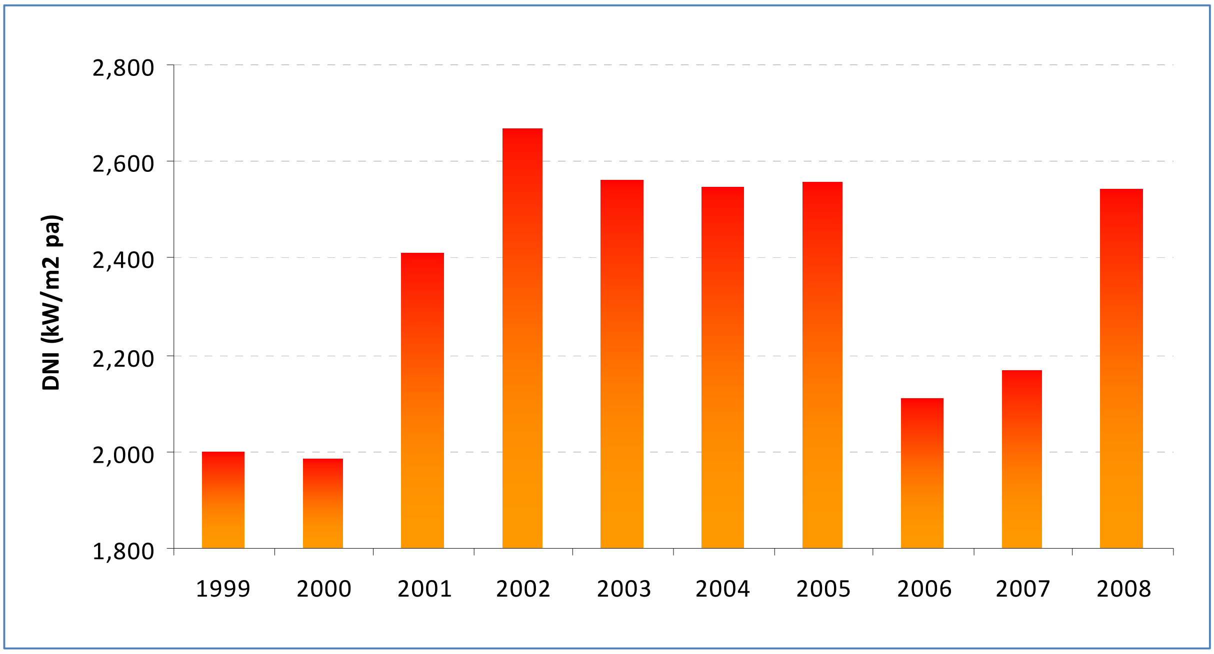
- The site data was spliced together with the adjusted long-term data, thereby determining the long-term irradiance at the proposed CSF site.
- The mean of the monthly means (MoMM) was taken to determine the annual mean ("mean of means") to eliminate the effect of seasonal bias in the data.

Ambient temperature

The long-term ambient temperature conditions at the CSF site were analysed using the following steps:

- Various correlations between the site measurements and each reference dataset were conducted to identify the most appropriate reference and the lowest uncertainty correlation.
- One particular measured data correlated to the site data on a monthly basis was identified as the most appropriate method for ambient temperature, with a high correlation.
- The long-term data and the site data were combined separately into daily averages. The daily average temperature for each month was then determined from the average of all valid daily data averages recorded in that month, separately for each dataset. This was taken as the monthly mean thereby assuming that the valid data were representative of any missing data.
- The monthly correlation between concurrent site measurements and reference data was used to adjust the complete long-term temperature dataset;
- The site data was spliced together with the adjusted reference data, thereby determining the long-term ambient temperature at the proposed CSF site.
- The mean of the monthly means (MoMM) was taken to determine the annual mean ("mean of means") to eliminate the effect of seasonal bias in the data.

Resource Assessment Summary



The typical satellite-derived dataset is shown above for the ten years from 1999 to 2008. The typical meteorological year (TMY) DNI over the 10 years is 2,149 kWh/m^2/year. This was found to be representative when taking into account the data measured on site.

Energy production assessment methodology

The estimation of expected solar power generation is typically performed by the Solar Consultant in several steps:

1) The solar climatic conditions are determined. The typical hourly dataset over one year that is required for performing energy yield simulations has been obtained from the average profiles by means of synthetic generation.

2) Irradiation losses (due to optical effects and usable irradiation) are calculated by using the known layout of the solar plant, site and surrounding topography, any nearby objects and standard assumptions regarding atmospheric properties and soiling;

3) The electrical simulation takes into account the properties of the solar plant equipment, transformers and plant design (cabling characteristics, etc.) in order to calculate the power delivered at the Connection Point on a time series basis; and

4) Other production losses such as the power consumption of the Project and system availability are estimated in order to derive the long-term annual average energy production of the proposed solar plant.

The methodology used to estimate the uncertainty in both the irradiation data and the simulation model was presented.

Plant simulation

The solar plant simulation consists of an electricity production calculation corresponding to the site meteorological conditions – steps 2 to 4 described in Section 3.3 above. The Solar Consultant has undertaken a simulation of the Project based on the layout, electrical configuration and components provided by the Client.

Loss factors

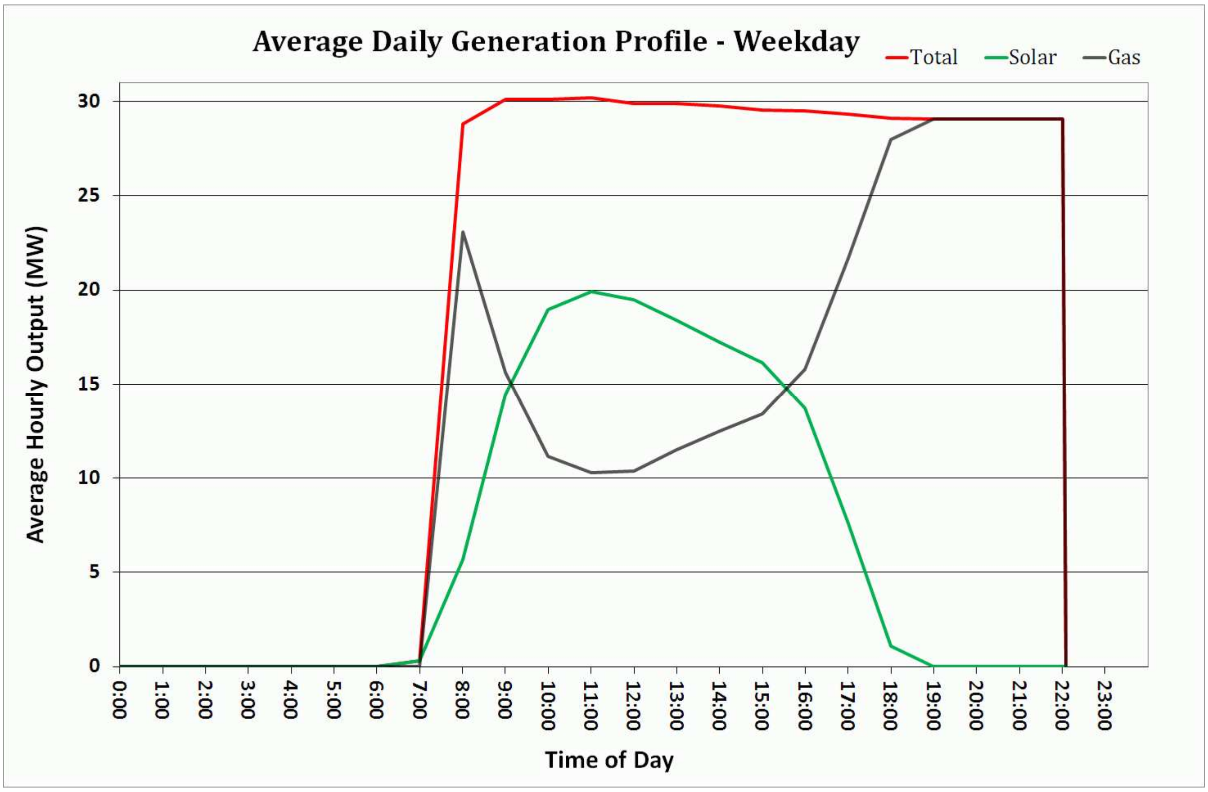
The net energy produced by the plant (kWh per year) was estimated. Several loss factors are calculated, applied or estimated during the simulation, including shading, soiling, irradiance level losses, wiring losses, transformer losses, parasitic loads, system availability and grid availability.

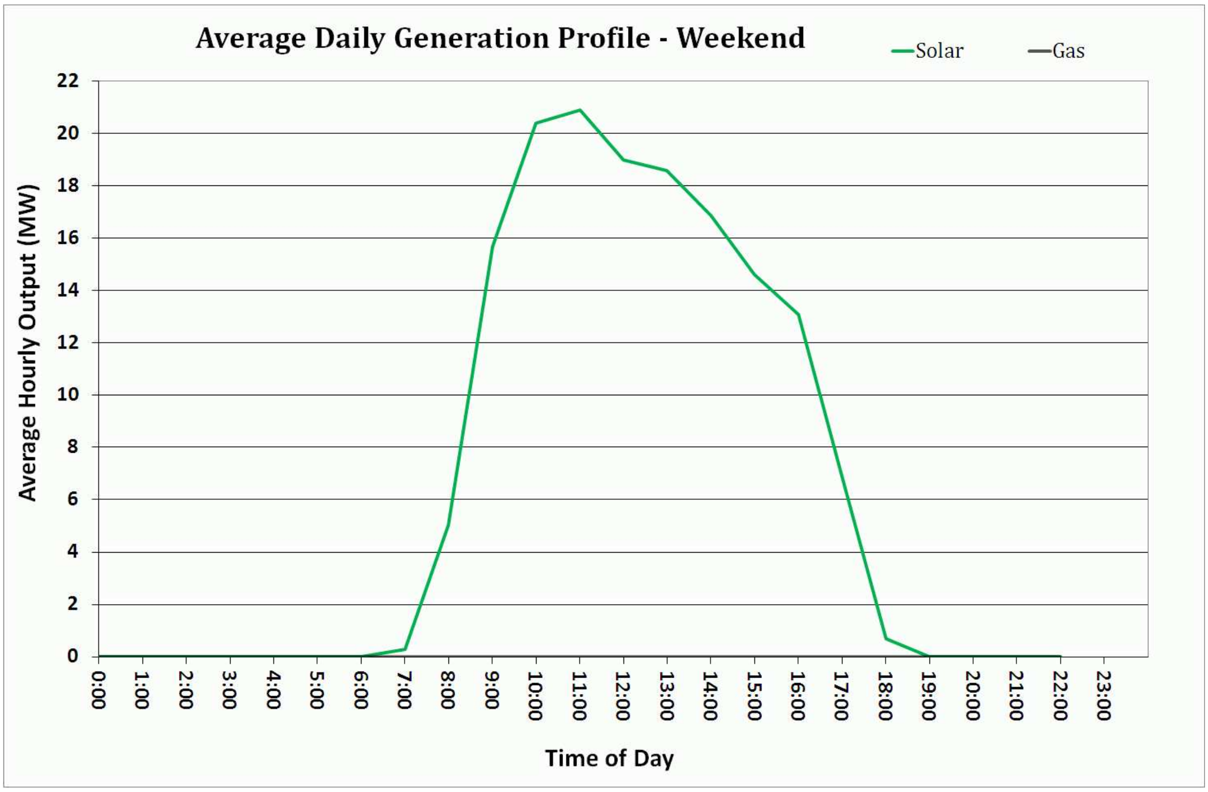
Performance and energy yield

The predicted long-term annual energy production for the Project was calculated, taking into account the various loss factors described above, on an annual basis.

The net energy prediction presented represents the long-term mean, 50% exceedance level, for the annual energy production of the solar plant (P50). This value should therefore be considered as the P50 for the first year of operation.

The long-term energy production is summarised by the following average daily solar generation profiles (shown in green) for the hybrid solar thermal plant, for weekday and weekend operation. The average energy yield (generation) from solar is 152 MWh/day.





Uncertainty analysis

The uncertainty of the final result is a consequence of the uncertainty in the solar radiation data, the inaccuracies of the simulation procedure itself (e.g. choice of models), and uncertainties associated with "external" influences (e.g. shading, soiling, deviation of components from specification, cabling losses, etc.).

The above sources have been considered for the Project and the Solar Consultant notes the following:

- Solar irradiance at the site has been measured using First Class equipment according to ISO 9060, with a measurement uncertainty of 5% relating to the daily totals;
- the Solar Consultant has been advised that site instruments have been cleaned and realigned daily;
- Condensation is apparent in the site data, although the impact on irradiance measurements appears to have been minimised by daily cleaning of the instruments early in the morning;
- The interannual variability at the site is relatively high. This has been assessed using the long-term satellite-derived data available for the site location and long-term historical ground-based measurements available in the vicinity of the Project;
- The site and some surrounding areas have considerable tree coverage. It has been assumed trees within the site will be removed and that those remaining in the vicinity would have a negligible impact on the plant's performance; and
- Cabling resistances and lengths for some cables have not been provided.

A summary of the resulting uncertainties was provided. It was assumed that all errors are independent and that the Gaussian distribution is applicable. Therefore the total uncertainty represents the standard deviation of what is assumed to be a Gaussian process.

The confidence limits for probabilities exceeding 99%, 90%, 75% and 50%, for one year and ten year future periods were presented for the Project.

CONCLUSIONS

Solar resource assessment

A measurement campaign has been conducted at the site for a period of approximately 1.1 years. Installation and maintenance information have been provided by the Client, together with raw data records.

The site irradiance data have been correlated with high quality satellite-derived reference data in order to derive the long-term annual average. The typical meteorological year (TMY) DNI was approximately 2,149 kWh/m^2/year.

Similarly, the ambient temperature data recorded at the site have been correlated with longer-term ground-based measurements recorded at a nearby ground meteorological station. The long-term annual average ambient temperature was estimated.

Energy production assessment

Based on the long-term solar irradiance assessment conducted by the Solar Consultant and the Project design characteristics, the long-term average annual energy production was predicted. The average energy yield (generation) from solar is 152 MWh/day.

The net energy prediction presented represents the long-term mean, 50 % exceedance level, for the annual energy production of the solar plant (P50). This value should therefore be considered as the P50 for the first year of operation.

The production predictions above are computed at the connection point to the Ergon Energy electriciy grid at the existing 33 kV substation (as shown in the single line diagram provided by the Client).

Uncertainty analysis

The main sources of deviation from the P50 energy estimate have been quantified and added as independent errors, giving uncertainties in net energy production of the Project. These represent the standard deviation of what is assumed to be a Gaussian process.