Energy Yield Estimate

NJDPMC

Project:	Edna Mahan Correctional Institute for Women Solar PV Feasibility		
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1 Introduction

Mott MacDonald ("Engineer") has been appointed by NJDPMC ("Client") to undertake an Energy Yield Estimate (EYE) for a proposed photovoltaic (PV) project at the Edna Mahan Correctional Institute for Women near Union Township, New Jersey (the "Project").

The procedure adopted to estimate the energy generated by the PV plant typically considers the following:

- Meteorological data;
- System configuration;
- System losses and the Performance Ratio; and
- Expected degradation.

The PV system's performance and losses discussed in this report have been calculated mainly by using in-house tools as well as the software PVsyst version 6.86, in line with the market standard practice.

The energy yield estimate has been based on the information derived from the conceptual site layout (Edna Mahan-GA-001-RevD.pdf).

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2 Methodology

2.1 Assessment of Meteorological data

The energy yield of a PV plant is strongly dependent on the weather conditions onsite mainly the irradiation and ambient temperature.

Irradiation data can be obtained from ground-mounted weather stations or from satellite data and is usually recorded as Global Horizontal Irradiation (GHI – total amount of sunlight received per unit area on a horizontal surface). Irradiation on an inclined plane or a tracking plane (GII) can also be measured or derived from the horizontal values.

For determining the plant's energy yield, it is essential to use reliable and recent sources of long-term data for the energy yield estimations.

In this case irradiation data recorded at the Project's site are not currently available. Therefore, meteorological data acquired from SolarGIS-iMaps, a high-resolution meteorological database, has been used.

SolarGIS-iMaps dataset consists of the following parameters:

- Solar radiation: monthly Global Horizontal Irradiation (GHI) and monthly Diffuse Horizontal Irradiation (DIF); and
- Meteo: monthly average diurnal (24-hour) Air Temperature.

Furthermore, the SolarGIS-iMaps database:

- Provides high spatial (1 km ×1 km) resolution;
- Has been validated by GeoModel Solar[1] (the company is currently named as SolarGIS) for locations worldwide;
- Has been validated by two[2,3] independent studies from the University of Geneva; and
- Provides recent data.

Given all the above, SolarGIS iMaps is considered to be a representative data source for the Project location.

2.1.1 Site Meteorological Conditions

The site-representative monthly meteorological conditions (Global Horizontal Irradiation, Diffuse Horizontal Irradiation & Temperature), as obtained from SolarGIS, are presented in the table below.

Table 2.1: Meteorological Conditions for the Project Site

Month	Global Horizontal Irradiation (kWh/m^2/period)	Diffuse Horizontal Irradiation (kWh/m^2/period)	Ambient Temperature (°C)
January	61	26	-1.3
February	81	33	-0.7
March	123	50	3.2
April	149	57	9.0
May	175	73	14.5

[1] "SolarGIS Database version 1.8 satellite-derived solar radiation and meteorological data", GeoModel Solar, 2012.

[2] "Long term satellite global, beam and diffuse irradiance validation", Pierre Ineichen, University of Geneva, 2013.

[3] "Five satellite Products deriving beam and global irradiance validation on data from 23 ground stations", Pierre Ineichen, University of Geneva, 2011.

Month	Global Horizontal Irradiation (kWh/m^2/period)	Diffuse Horizontal Irradiation (kWh/m^2/period)	Ambient Temperature (°C)
June	178	80	20.0
July	191	82	22.6
August	164	71	21.9
September	131	52	17.7
October	95	38	11.4
November	65	27	6.2
December	51	23	0.8
Year	1,464	612	10.5

Source: SolarGIS iMaps

2.1.2 Global Inclined Irradiation

Assuming that ground-mount portions of the Project will use fixed structures with a tilt angle of 25°, the annual value of the irradiation received on the plane of the PV arrays is estimated to be 1,691 kWh/m^2 and has been obtained from PVsyst, using the Perez transposition model. The overall uplift when compared to the GHI is 15.5%.

Table 2.2: Global Inclined Irradiation for the Project site

Parameter	Value
Global Horizontal Irradiation (kWh/m^2/year)	1,464
Irradiation on the plane of the array (kWh/m^2/year)	1,691
Uplift	15.5%

Source: PVsyst version 6.86

2.2 System losses and Performance Ratio

A PV system's performance and quality is measured by the Performance Ratio (PR). PR incorporates the system losses and Standard Test Conditions (STC) corrections for a PV plant in a given location, with a given specific design and using specific components. The PR provides a means to estimate the expected energy yield of a proposed PV system. The PR is a measure of both the performance and the efficiency of the system.

In order to carry out the PR calculation, certain assumptions have been made based on market standards and project experience. Some assumptions could be reviewed and updated (if required), if additional information is made available, or as development of the design progresses.

The Performance Ratio (PR) for the PV project has been calculated using the widely-used software PVsyst as well as our in-house tools for calculating certain losses.

Plant availability of 99% will typically be assumed for a system of this type. The Engineer has not made provisions for any additional loss due to the grid unavailability in our PR calculation. The Client could consider a suitable grid unavailability value in its Financial Model.

Based on the simulation and assumptions, a PR of between 80% and 86% for the Project is estimated. Actual PR and energy production are dependent on the actual technology and design installed as well as actual weather and environmental conditions during operation. A listing of typical losses is provided in the table below.

Table 2.3: System losses breakdown

Loss	Mott MacDonald's comments
Near Shading (related to irradiance and electrical effect)	PVsyst and corresponds to the mutual shading on the diffuse and albedo components of the irradiation. This loss strongly depends on the trackers' width and pitch.
Incidence Angle/Reflection	PVsyst calculation for the Project site location. The incidence angle effect was typically simulated in PVsyst considering anti-reflective coating. This loss may be revised to reflect the customized IAM profile of the manufacturer if the results of a reflectivity test report indicating the IAM profile at various incidence angles for the proposed module is made available.
Soiling	Preliminary assumption based on site location and project technology. This loss can be revised through analysis of historical rainfall and if a specific number of module cleanings per year or a soiling warranty is defined in the O&M Contract.
Low irradiance performance (LIP)	PVsyst calculation based on the Rseries and Rshunt values of the applicable PV module's .pan file.
Temperature	PVsyst calculation based on the meteorological data for the chosen location and the selected PV module technology.
Light-induced degradation (LID)/	The LID loss typically occurs when the PV modules are first exposed to sunlight and should be accounted for the first year of operation.
Light and elevated Temperature-induced Degradation (LeTID)	Though not accounted for in our base-case PVsyst model or PR calculation, we note that PERC-type PV modules are known to experience LeTID, potentially. We recommend LeTID testing to be conducted with reference to the forthcoming IEC 61215.
Power tolerance	Assumption based on the fact that BNEF Tier 1 PV modules typically guarantee a positive power tolerance.
Mismatch	Loss due to variation of module performance within strings/PV arrays. Standard assumption based on our project experience.
DC wiring	Calculated by PVsyst under the environmental conditions of a representative year, based on the assumption of 1.5% loss at Standard Test Conditions (STC). This loss is highly dependent on the cable specifications and length and therefore this figure may be reconsidered when this information becomes available.
Dynamic Maximum Power Point Tracking (MPPT) performance	Assumption based on publicly available inverter tests which indicate a dynamic MPP tracking efficiency loss range of 0.1% to 1.0%.
Inverter	PVsyst calculation based on the module's and inverter's characteristics, sizing of the inverters, and the environmental conditions.
Inverter undersizing and curtailment	PVsyst calculation based on the energy production that exceeds the Project's AC installed capacity and Project's AC capacity at the point of interconnection
AC wiring	Calculated by PVsyst under the environmental conditions of a representative year, based on the assumption of 1.0% loss at Standard Test Conditions (STC). This loss is highly dependent on the cable specifications and lengths and therefore this figure may be reconsidered when such information is made available.
Transformers	Assumption based on our project experience, assuming a distribution grid voltage with one-step from the inverter output. This loss can be revised if the transformers' electrical specifications are made available to us.
Auxiliary consumption	Assumption based on our project experience.
Plant unavailability	Standard assumption based on our project experience in the region. This loss may be revised once the O&M contract is made available.

Source: Mott MacDonald

3 Conclusions

According to the solar resource assessment, based on SolarGIS-iMaps, an annual irradiation has been estimated for ground-mount portions of the Project of 1,691 kWh/m^2 at PV modules' plane.

The Engineer has undertaken an independent assessment of the expected energy generation of the Project. Based on the assumptions made in this report and considering satisfactory construction operation and maintenance of the plant, a 10 MWac Project would be able to produce an average annual energy yield of 17,680 – 19,020 MWh over 20 years of operation.

In addition, for Year 0 excluding unavailability and long-term degradation:

- The PR has been estimated as between 80% and 86% at the delivery point depending on the technology and design installed as well as actual environmental conditions during operation; and
- Corresponding to a specific yield of 1,350 - 1,455 kWh/kWp.