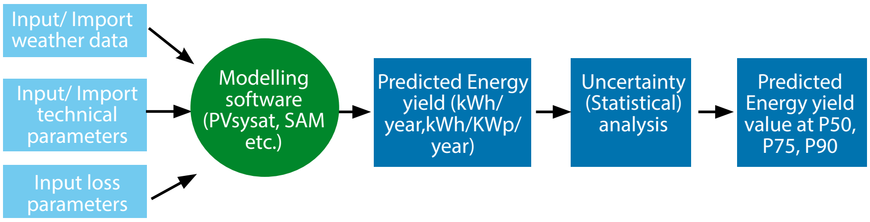
CRITICALITY OF ENERGY YIELD ASSESSMENT

For Solar Projects

Saurabh Motiwala, in this article, discusses the criticality of energy yield assessment for solar projects. The objective of this article is to present readers with an overall idea of the procedure and importance of energy yield assessments carried out for any solar project. The article does not capture a detailed technical assessment of this exercise.

Long-term estimation (typically for project life of 25 years) of energy generation from solar projects is critical for techno-financial viability of the project. Energy Yield Assessment (EYA) of solar projects forms the basis for project developers and financial institutes for financial modelling of the project. Several modelling softwares are available in the market for the EYA of solar projects, including PVsyst, PV*SOL, RETScreen, HOMER, HelioScope, PlantPredict, Archelios, and SAM amongst others. Over the years, PVsyst has emerged as the most bankable modelling software for the EYA of utility scale solar PV projects while SAM has been used by few developers to predict energy yield from utility scale Concentrating Solar Power (CSP) projects. The objective of employing these modelling softwares is to predict actual energy generation with maximum possible accuracy. The solar PV industry in general follows established norms to carry out the EYA of projects worldwide. However, the CSP industry is yet to identify such common norms.



» **Figure 1:** Procedure for predicting energy yield from modelling softwares

COMMON PROCEDURE FOR PREDICTING ENERGY YIELD

Usually, simulation softwares for predicting energy yield from solar projects broadly involves the following steps:

I. *Importing weather data*: Solar irradiance, wind speed, ambient temperature, etc., form a part of weather data. The weather data for the project location can be satellite based, ground measured, or a combination of both. Prior to importing weather data, the most relevant data source is identified through the exercise of solar radiation resource assessment. Users can also import weather data from the software library.

II. *Input/import technical parameters*: The technical parameters to these softwares will mostly rely on the suppliers of major components. For instance, the technical parameters of PV modules and inverters would be captured in .pan and .ond files certified by respective suppliers. These files are imported directly to PVsyst for simulation. Users can also choose equipment of a different make for project design from the software database.

III. *Applying losses*: The application of loss parameters for simulation requires some level of technical expertise. Some losses are quantifiable while others have to be assumed with appropriate basis. The calculation or assumption of loss values will depend on the present status of the project (planning, execution, commissioned, etc.)

IV. *Statistical analysis of energy yield output:* The predicted yield value would have acquired uncertainties from the input values particularly solar resource and performance of major equipments. The inherent uncertainties with solar resource data has to be studied while estimating confidence interval of final energy predication.

CRITICALITY OF EYA

An underestimation or overestimation of energy yield may significantly impact risks imposed on project finance. For instance, the solar resource of any project reduces by a variable (unknown) factor every year for the project life. Consequently, the annual energy yield from the project would be less than the planned yield. Revenues from the project would be lower than expected, the expenses (e.g., O&M cost) would remain unchanged and hence the project would pay less dividends as planned.

Even so, the return on equity from the project would reduce. The project would eventually turn out to be less attractive financially and this may raise concerns to the lenders.

A few critical aspects of EYA of solar projects have been discussed below:

➢ Weather (solar resource) data:
Unavailability of bankable solar resource data is one of the key barriers in the development of CSP projects in India. Godawari Green CSP Project in India with parabolic trough technology struggled to achieve the estimated output which led to re-engineering of the project; 80 loops of parabolic mirrors were increased to 120 loops.

➢ Consideration of losses:
The consideration of loss values in simulation will significantly impact the performance ratio[1] of the project. In case of turnkey projects, the project developer will take over and accept the project from EPC contractor on the basis of a guaranteed PR% value. The input loss values will depend on the current development stage of the project and level of expertise of the designer. Some key loss values input to PVsyst software for simulation have been discussed in Table 1.

1 Performance ratio is a percentage to express performance of PV plant. This also provides a benchmark to compare plant performances over a given time period.

Table 1: Estimation of key losses for the EYA considered in PVsyst

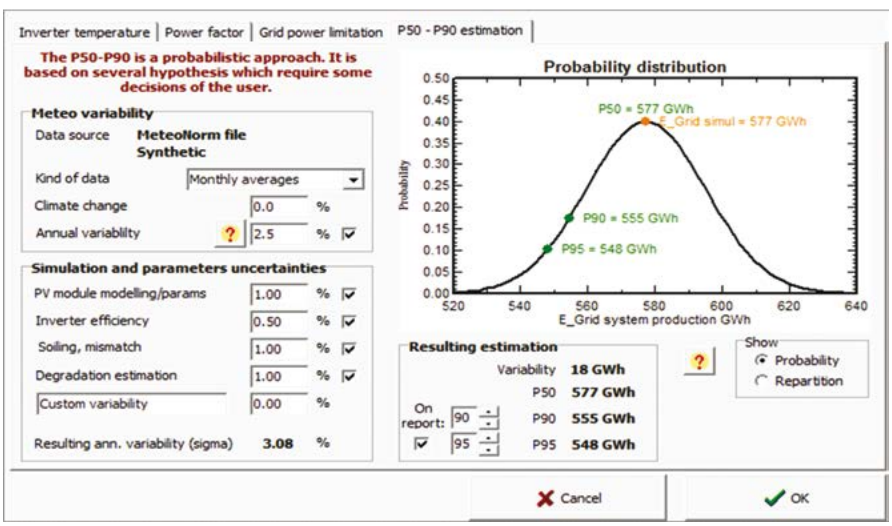
S. No.	Key technical losses	Remarks
1	Shading losses	These losses occur due to obstacles, mutual shading between different rows of PV modules. Can be estimated with an accurate 3D modelling of the plant.
2	IAM (Incidence Angle Modifier) factor	These losses occur when the radiation does not strike the front glass of PV modules in perpendicular. User-defined IAM factor is considered, when manufacturer certified .pan file is available.
3	Soiling losses	The soiling losses occur generally due to dust and bird droppings. It generally depends on the site location, module cleaning cycle, and tilt angle. Difficult to quantify/estimate and require expertise.
4	Module degradation losses	The performance of PV modules degrade over time. The manufacturer also warrants a particular degradation rate of its module over time based on third-party tests. These losses can be considered as per manufacturer's recommendation for a conservative analysis.
5	Irradiance level losses	The reduction in power output of modules under actual irradiance as compared to Standard Test Conditions (Irradiance of 1,000 W/m^2). These losses are quantified by PVsyst as per the site weather data and characteristics of the selected module make.
6	Loss due to module temperature	The characteristics of PV modules are defined at 25 °C. At higher temperature, the efficiency of modules reduces. These losses are quantified by PVsyst as per the site weather data.
7	Module quality losses	These losses occur due to deviation in nominal peak power of PV modules suggested by manufacturer and actual power. Usually, a positive quality value is taken as input for simulation.
8	Module array mismatch losses	These losses arise due to variation or 'mismatch' in current/voltage profiles of modules actually connected in a string produce. Difficult to estimate and require expertise.
9	DC ohmic wiring losses	The I^{2}R losses in the cables between modules to inverter input contribute to DC ohmic losses. These losses can be quantified during detailed engineering of the project.
10	Inverter losses during operation	DC to AC conversion efficiency of inverter varies with load. These losses are quantified by PVsyst as per the characteristics of the selected inverter make.
11	Inverter losses over inverter nominal power	These are generally clipping losses, occurring due to overloading of the inverters. These losses depend upon designed DC/AC ratio of the inverters and characteristics of the selected inverter make. If the DC power connected to an inverter is more than its rated DC input, the inverter adjusts/limits this excess input which leads to be output power being clipped.
12	Transformer losses	These are no-load and full-load losses of the transformer. These losses can be quantified from the GTP (general technical parameters) provided by transformer manufacturer.
13	AC ohmic losses	These are ohmic losses in AC cables from inverter output till metering point. These losses can be quantified during detailed engineering of the project.
14	Auxiliary consumption	Load consumption by security systems, main control room including HVAC, lighting and plant monitoring systems during day and night time contribute to these losses. These can be quantified during detailed engineering of the project.
16	System (Plant + Grid) unavailability	Plant unavailability: These losses are assumed in terms of hours/day, to account for breakdown maintenance grid unavailability: The ability of plant to evacuate power depends entirely on the availability of the grid/ transmission network. If the transmission network is down due to maintenance, the generation from the plant would be affected. These losses are assumed in terms of hours/day, if detailed information about the network is unavailable.

Predicted energy yield

The predicted yield values from EYA exercise are expressed at P50, P75, and P90 confidence level. These values indicate that the predicted energy yield value will exceed with 50%, 75%, and 90% probability, respectively. Lenders/financing institutions or other stakeholders rely on consultants to furnish bankable EYA reports to feed information into their financial models. A bankable report would generally provide P50, P75, or P90 values as minimum.

Quantification of uncertainty

The predicted annual yield values for the project would be associated with uncertainties, which would propagate throughout the predication period. Till date, there is no standard framework for calculation of uncertainty of predicted yield values. The associated uncertainty would propagate in predicted annual yield values for the project lifetime. Parameters, such as solar resource measurement, modelling software, module



» **Figure 2:** PVsyst interface depicting input uncertainty parameters and Gaussian distribution of energy yield

characteristics, performance of inverter, transformers, cables, module degradation, inter-annual variability, shading and soiling, etc., would tend to introduce uncertainty in the EYA. Research and developmental work are under progress to establish a better understanding of uncertainties which can assist in portfolio assessment, design and execution, O&M activities, etc.

CONCLUSION

The EYA plays a critical role in decision making of not only project developers but other stakeholders, such as suppliers, investors, lending institutions, and insurers. There is a common approach worldwide for the EYA of solar PV projects. However, for CSP projects, a generalized approach is essential to significantly reduce risks associated with project financing. AU

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