Sun to Market Solutions

IFC – ESMAP – Renewable Energy Training Program
Solar Module

Project Development and Financing

June 16 – 18, 2014 IFC Washington, DC

Schedule

PV Technology Overview, Market Analysis, and Economics

PV Project Development, Implementation, and Financing

Case Study

Schedule

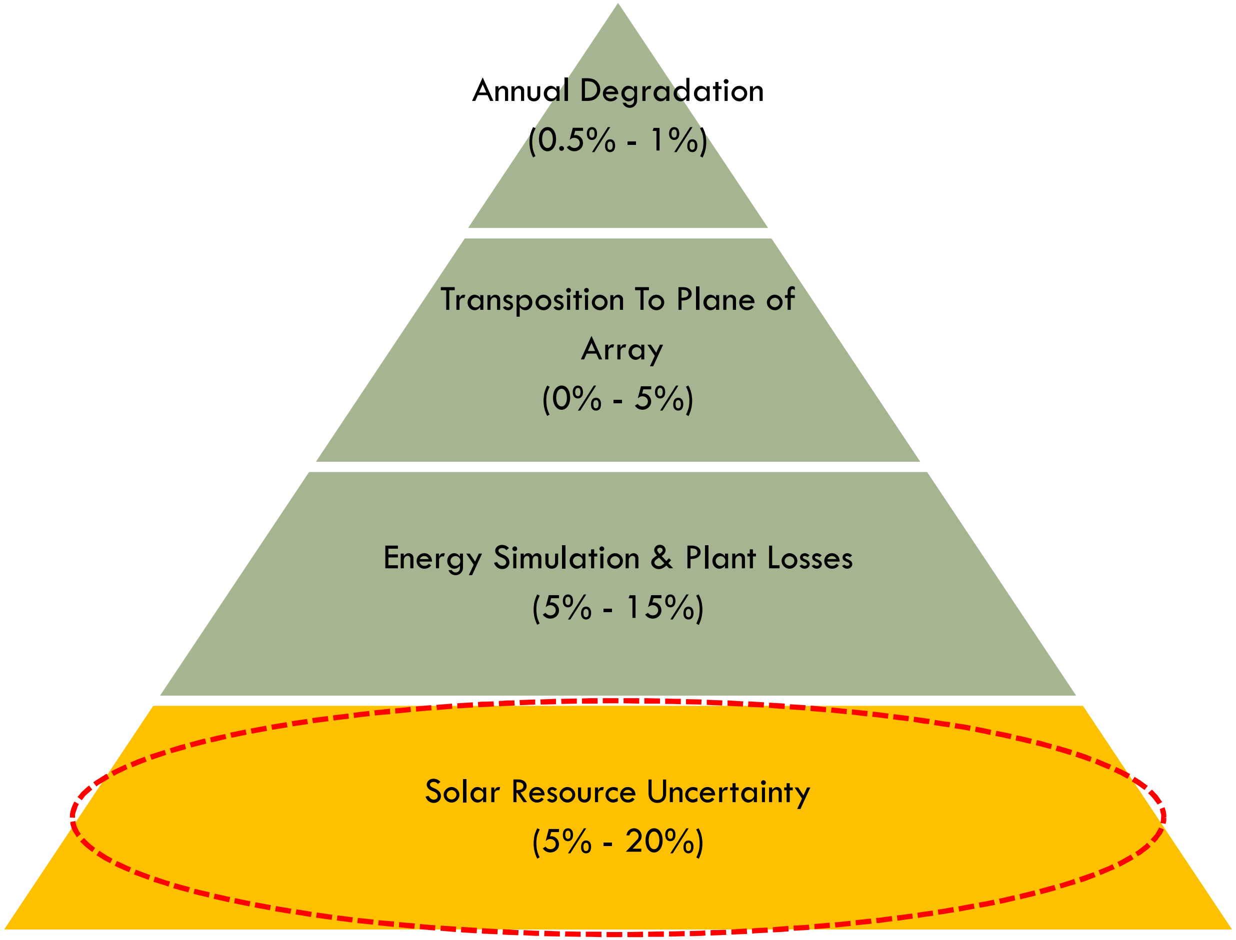
PV Project Development, Implementation, and Financing

- Planning
- Development
- Implementation
- Finance

How can we assess the project accurately?

PV plant energy estimates

How to reduce uncertainty in solar energy estimates?



Sources and usual values of Energy Uncertainty

Use real test data: 0.5%

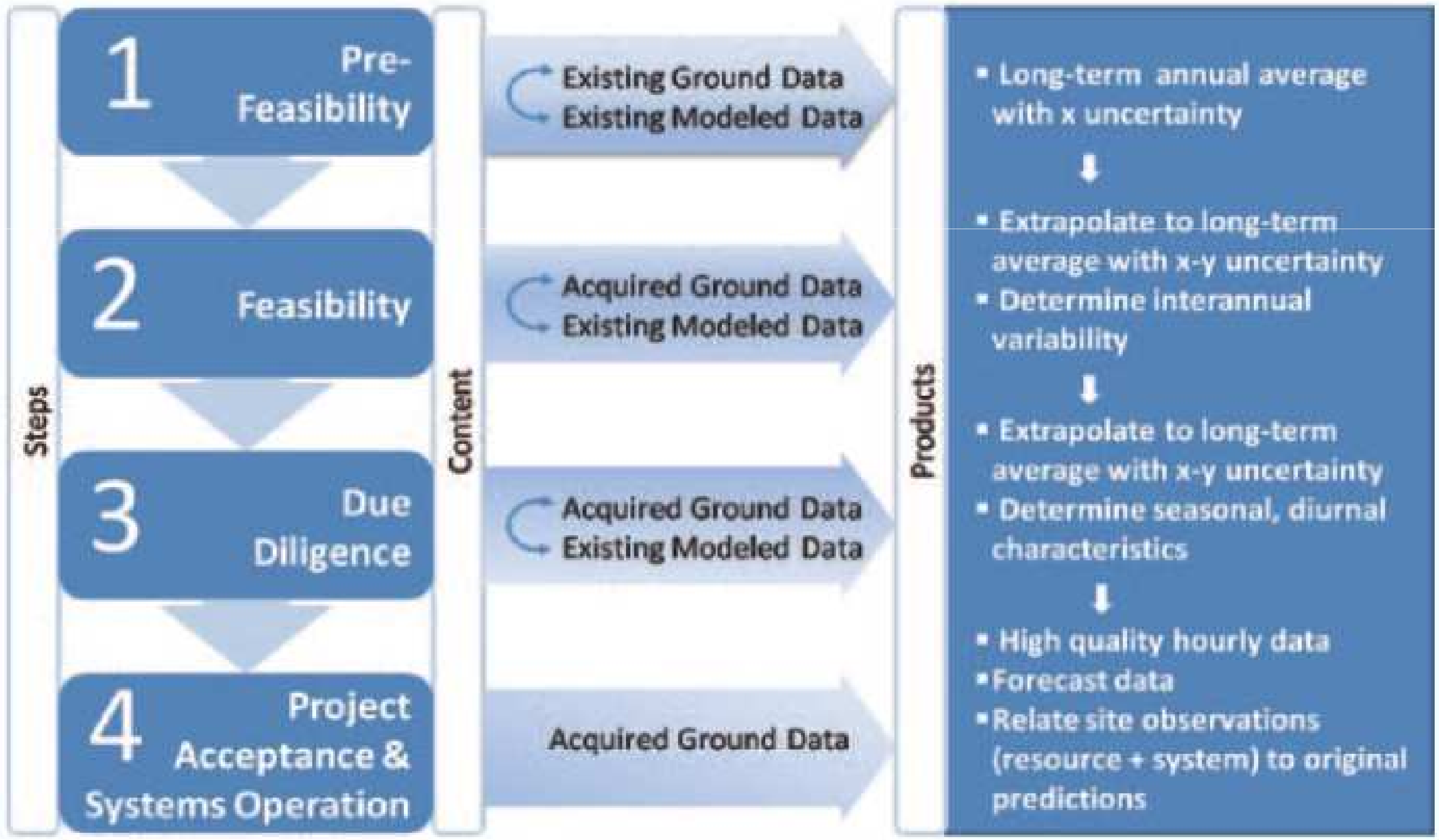
Calculate the actual radiation to plane of array (POA) using the real components: 0%

Use real data: shadowing, AC/DC losses, mismatch, etc: 5%

Carry out the solar resource using satellite and numerical model data: GHI 2%, DNI 5%

PV plant energy estimates

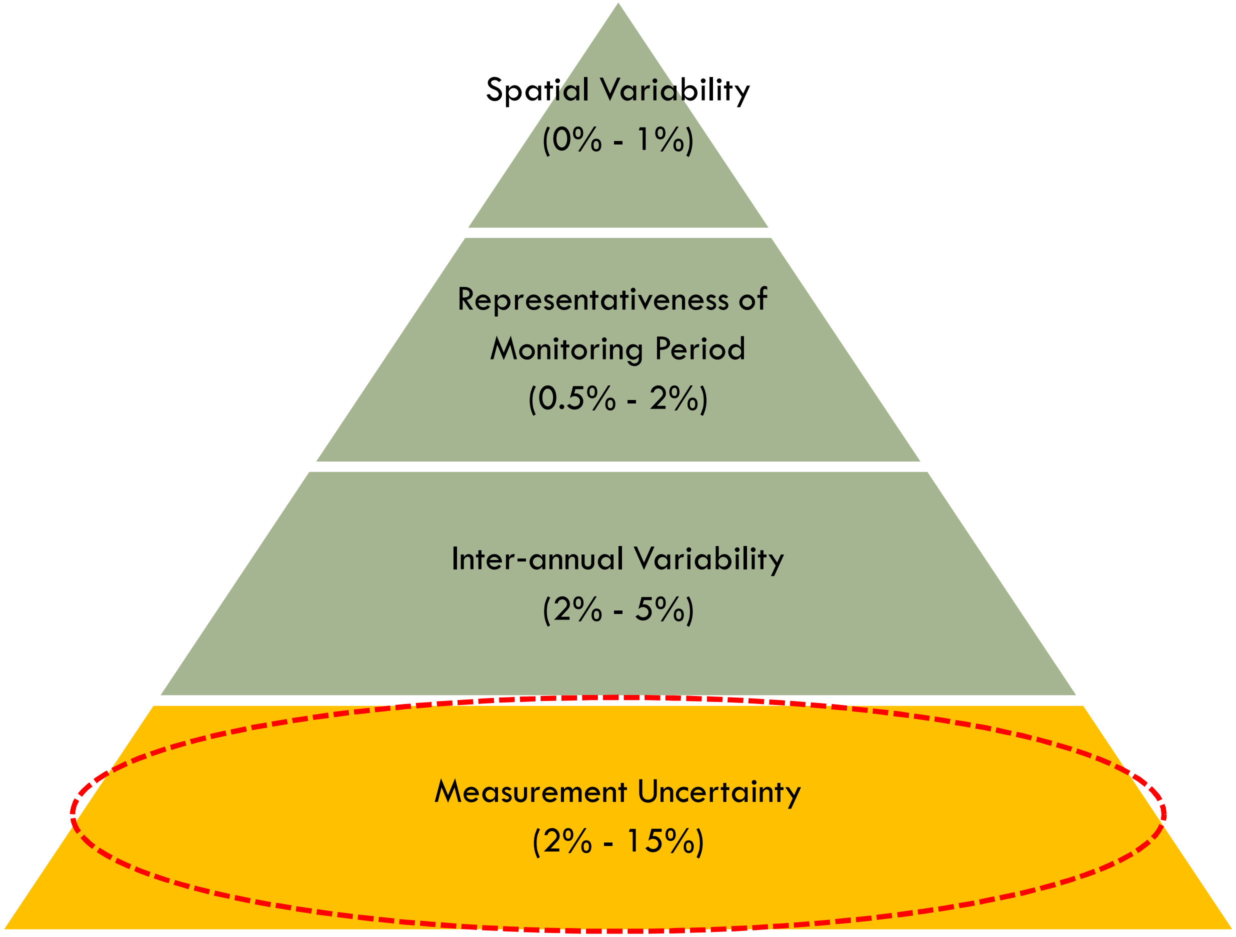
It is very important to have reliable solar resource data (satellite derived and ground measured) in each stage of the project



NREL, 2010

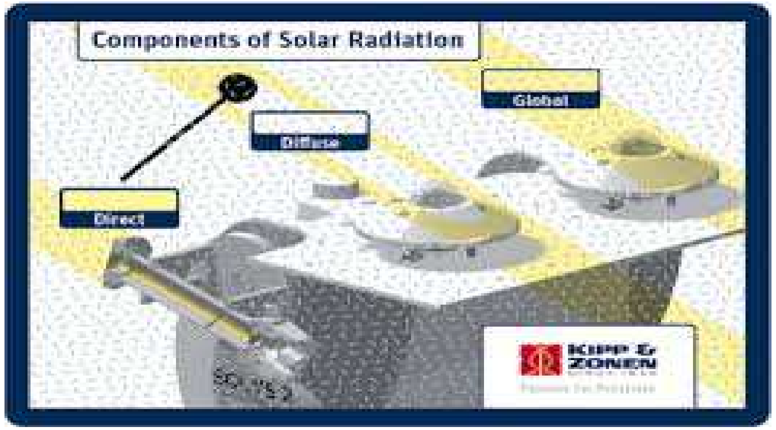
Sources of solar resource uncertainty

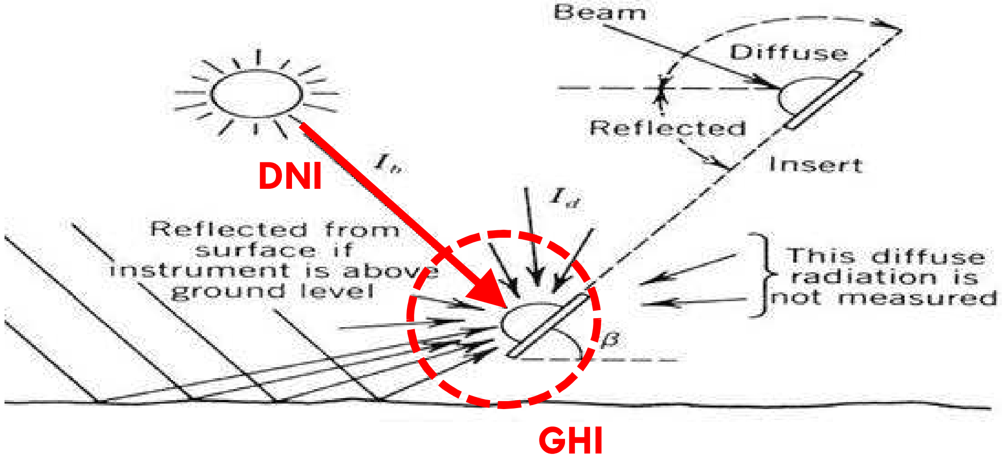
Reducing measurement uncertainties in the solar resource assessment will make the project more attractive and less risky to outside investors

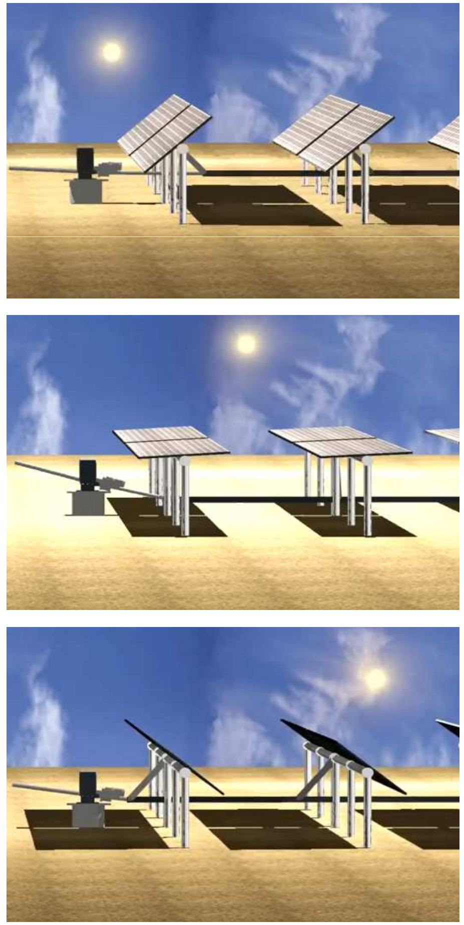


Solar radiation components

Solar PV primarily relies on GHI for energy estimates. However increased production by tracking systems depends also on DNI







SunPower, 2010

Solar resource & data sources

There are many sources of data available (free / commercial). Know how for using these data is a critical issue

On-site Measured Data

spatial and temporal resolution

10 x 10 km

Hourly data

maps

TMY

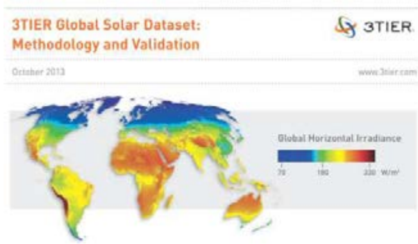
5 x 5 km

30 x 30 km

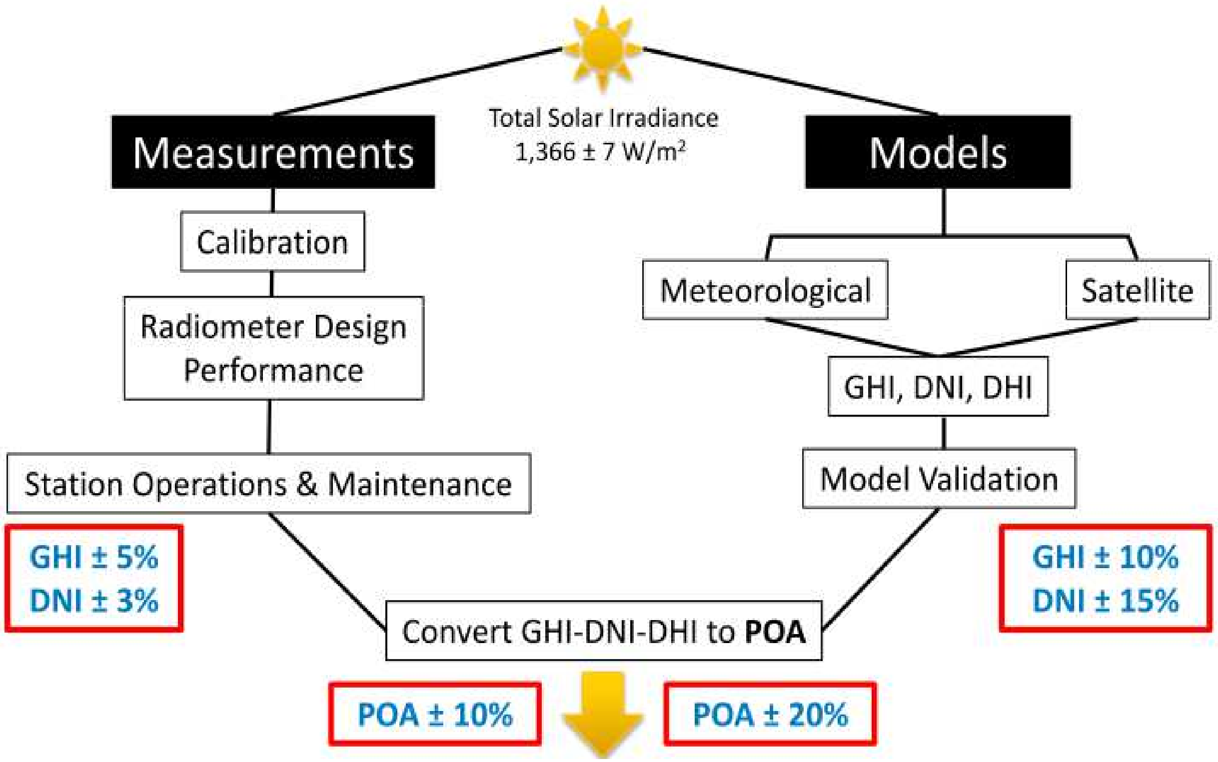
Nearby Reference Station Data

Modeled Data

- Interpolation and stochastic models
- Numerical models
- Satellite imagery and data



Solar resource & data sources



NREL, 2013

	Global
GHI	
MBE	0.9%
MAE	3.8%
STDEV	5.0%
Median	0.6%
Hourly RMSE	24.1%
N	120
DNI	
MBE	0.7%
MAE	8.6%
STDEV	11.6%
Median	2.5%
Hourly RMSE	43.1%
N	96

3Tier, 2013

Data source advantages and limitations

Data Source	Advantages	Limitations and Risks	Intended Use
Modeled	• Grid-cell specific • Publicly available • High data recovery	• Grid resolution • Regional biases • Greater uncertainty	• Initial prospecting • Smaller projects • Correlation with on-site data - Bankable reports
Observed Reference Station	• Ground measurements • Period of record may be longer • Publicly available	• Scarcity of sites • Location compared to project site • Uncertainty: quality of O&M, instrumentation, inconsistencies in data	• Confirm trends • Identify regional biases • Correlation with on-site data
On-Site Measurements	• Site-specific data • Customized for project needs • Station details well-known • Reduced uncertainty	• Shorter period of record (correlate with long-term data)	• High-confidence resource and energy estimates • Bankable reports • In-depth characterization of seasonal and diurnal climate

AWS TruePower, 2011

Typical meteorological year TMY

TMY (Typical Meteorological Year) files were first created by the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) in 1981. These files are created by looking at 15 – 30 years of hourly data at the site in question and selecting, in series, the most typical January, February, …and so on of all available years based on a weighted average of eleven weather variables with the selected months knitted together into one synthetic year of typical months

<u>Caution with TMY files:</u>

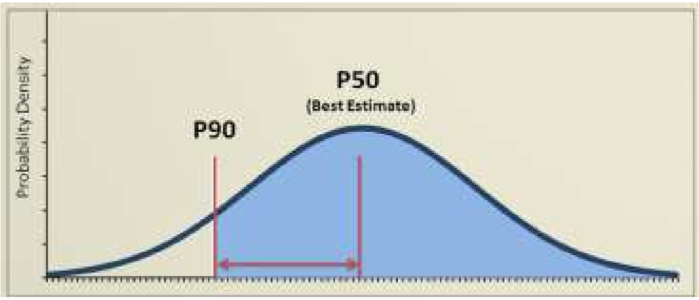
- They miss the extremes. They do a good job capturing typical conditions but (by design) do not show the extremes.
- They are not all current and built with all the years. Not all TMY files are constructed with 15 – 30 years of data and some may have been constructed as much as 5 or 10 years ago.
- The goal of a TMY is to represent the long-term average meteorological conditions at a site. True?
- It shall represent the P50 case?

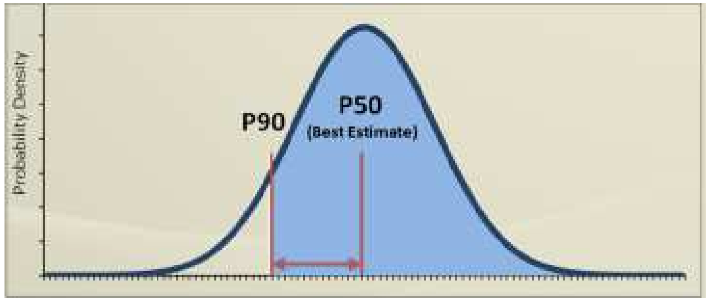
P - values

P-measures represent a value that is exceeded by XX % of the population of a data set. Thus, P-values of solar radiation are provided to judge the reliability of the solar resource of a project. TMY shall represent the P50 case

<u>Caution with P-values:</u>

- The P-values shall be based on as many years as possible - ideally using up to 30 years of site-specific observations. 5 or10 years are not enough
- Reducing the uncertainty of data at a site does improves the P70 and P90 values and hence leads to more reliable energy production estimates and also to more favorable financing conditions for the project
- Lenders and banks normally use the most conservative (P90, P95…P99) approach for the commercial base case for financing of a project
- Low uncertainty is important because debt interest rates are calculated based on the most conservative P - values





AWS TruePower, 2011

Does the development of a solar PV project have something special?

Are there key parameters for the industry?

Engineering

Project Development

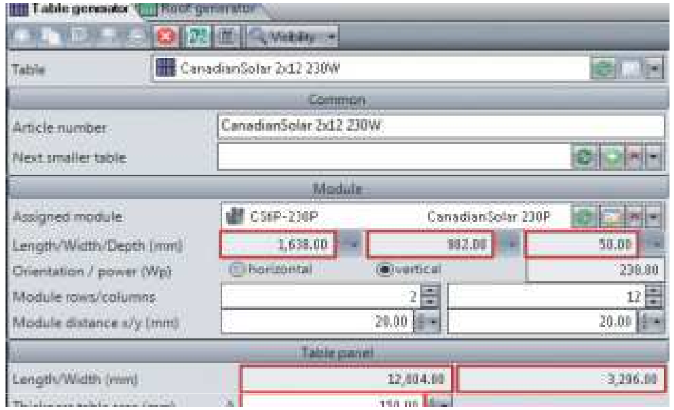
Analysis and evaluation of the terrain, rate of yield, online slope analysis

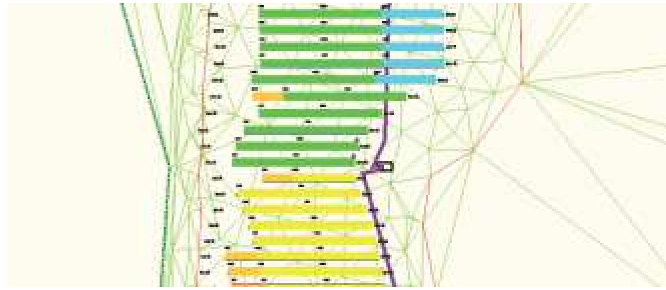
Project Layout

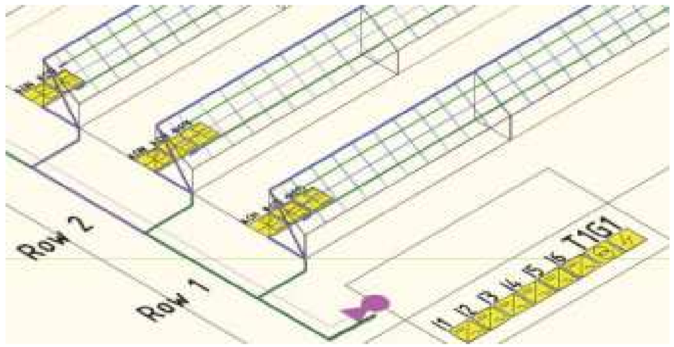
Structuring of the terrain, positioning of PV racks, optimize positioning for maximum yield, marking of shadowed racks, structuring the area, object shadows, optimizing the rack count and distance, etc.

Project Engineering

Electric layout, Bill of material, list of GPS coordinates, cable lists, general concept definition (device hierarchy, device areas with the physical, electrical devices, with the assigned amount and specific type, cable trenches describe the distribution of the cable trenches and the assignment to the fields, layout zones) string assignment, cable calculation

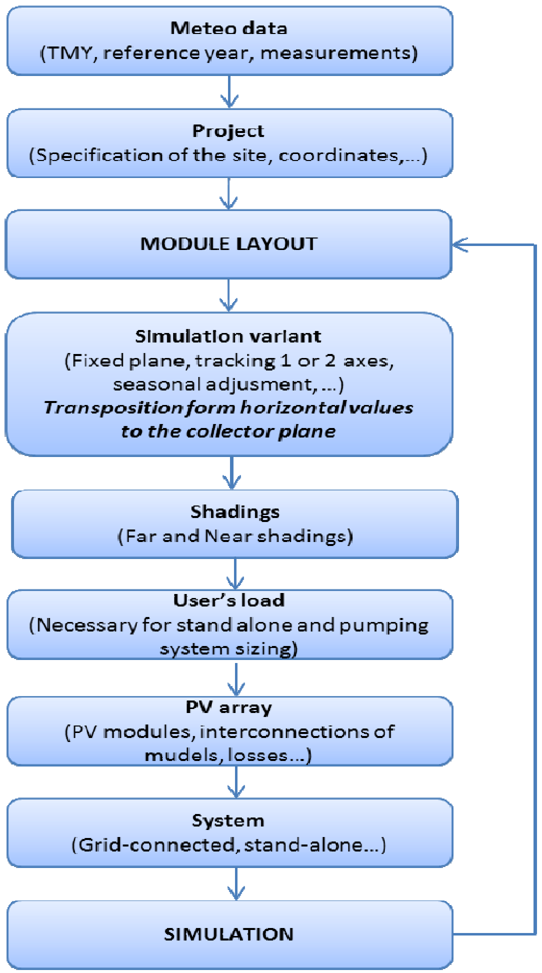


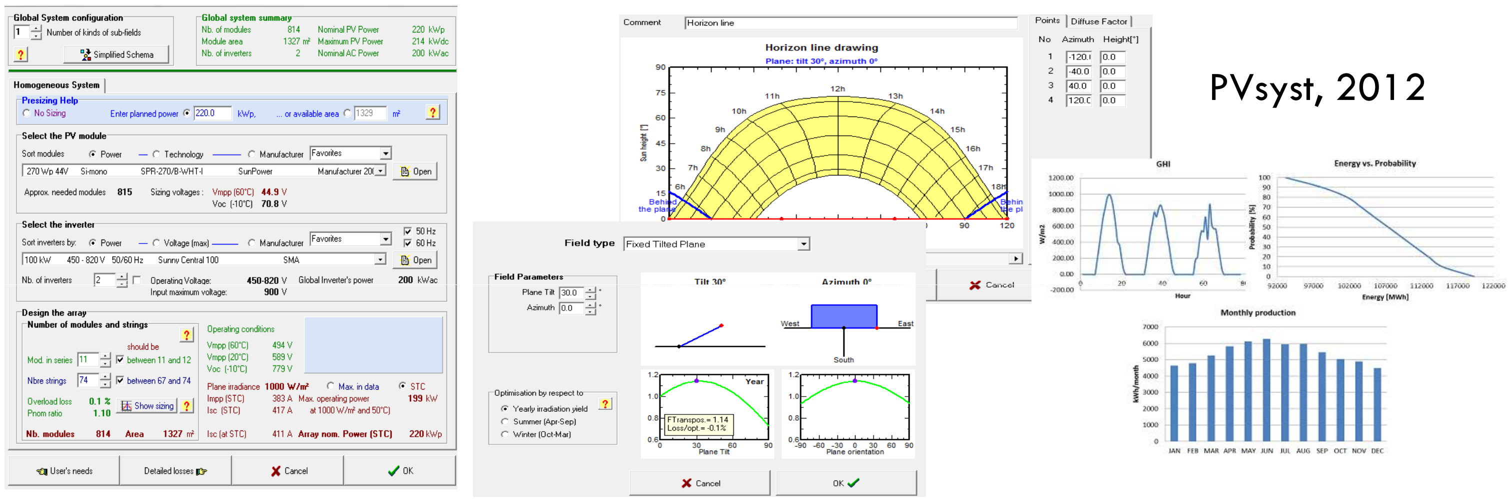




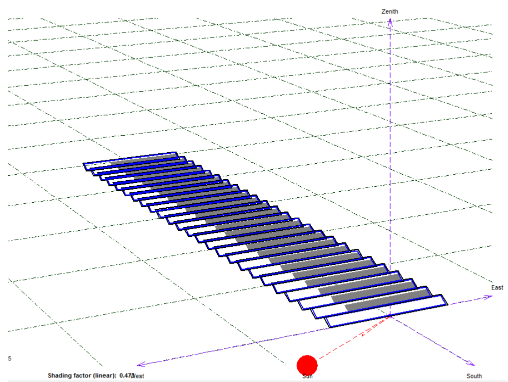
Helios3D, 2012

PV plant energy assessment





PVsyst, 2012



Detailed evaluation of PV plant configuration, defining the optimum PV plant configuration:

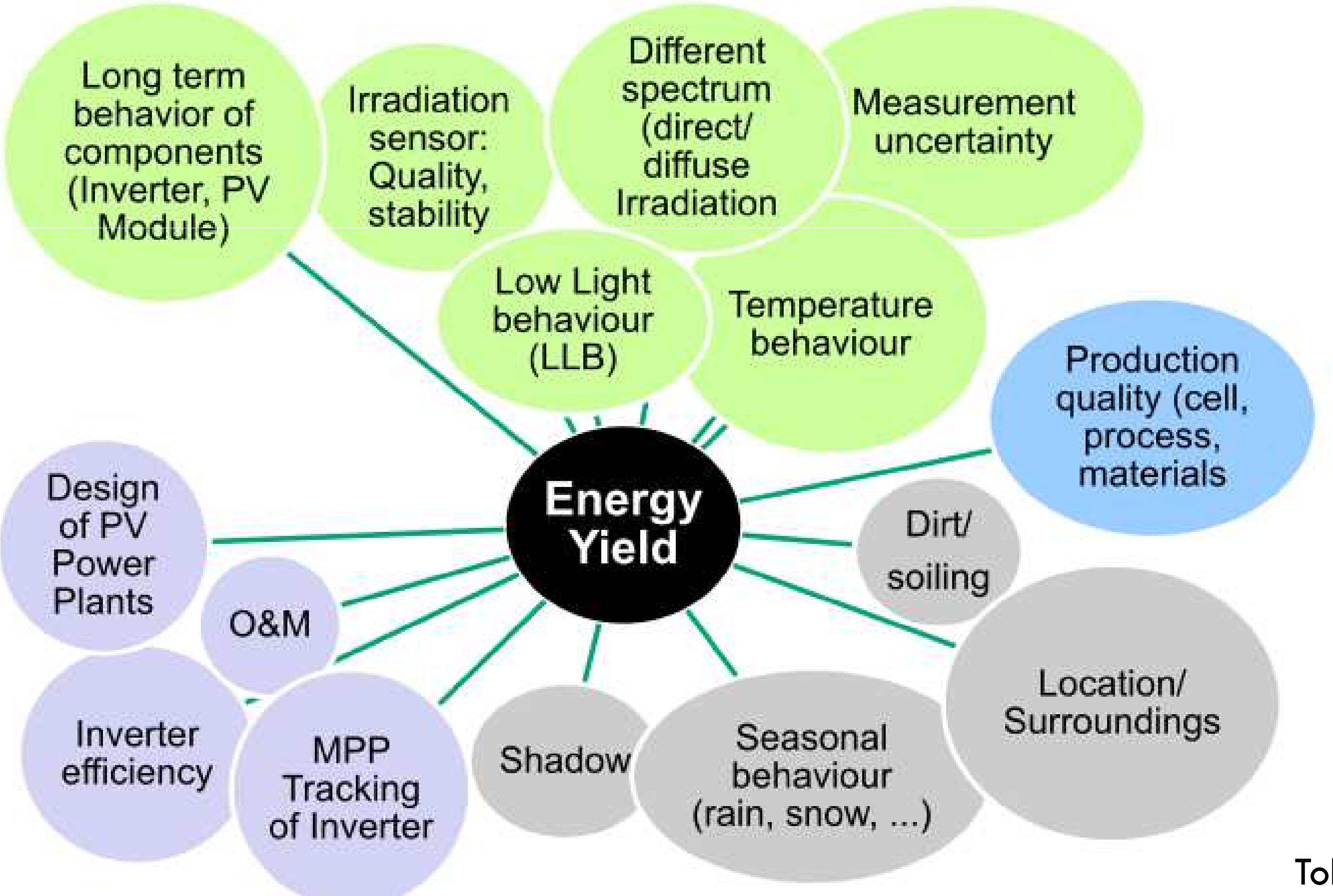
- **Plant Layout**
- **Energy production**
- **Loss and yields breakdown**
- **Deterministic and probabilistic calculation**
- **Sensitivity analysis**

Key parameters

- **Wp** (watts peak): In the context of PV sector that means the nominal power of total amount of modules
- **We** (watts nominal electric): In the context of PV sector that means the nominal power of total amount of inverters
- **kWh/kWp** (energy yield, specific production)
- **PR** (Performance ratio): The performance ratio, often called "Quality Factor", is independent from the irradiation (however is dependent from weather conditions on site) and therefore useful to compare systems. It takes into account all pre-conversion losses, inverter losses, thermal losses and conduction losses. It is useful to measure the performance ratio throughout the operation of the system, as a deterioration could help pinpoint causes of yield losses
- **CUF** (Capacity Utilisation Factor): how much of the stated capacity a plant actually generates compared to its total possible capacity. **¿Key parameter?**

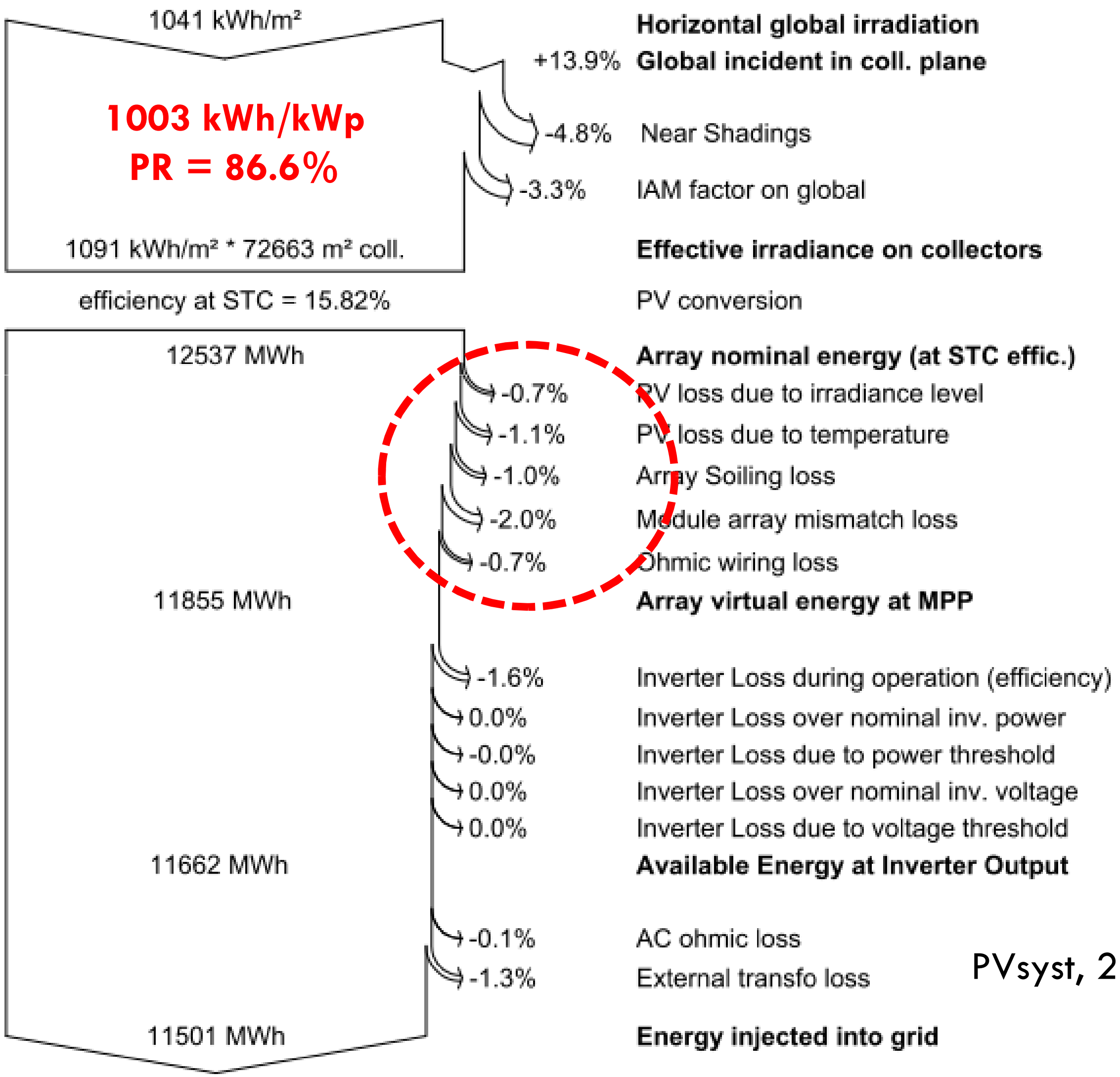
Energy yield

Which factors determine real world energy yield (kWh/kWp)? How can we measure, analyze & predict these factors?

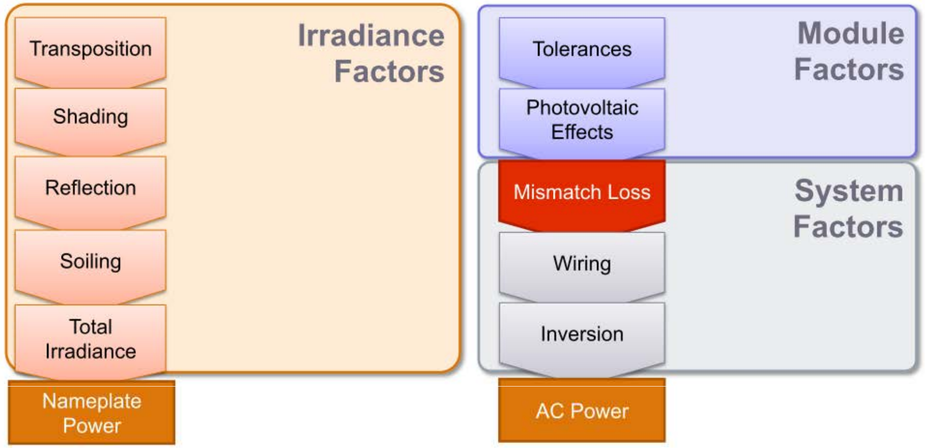


Tokyo Electric, 2013

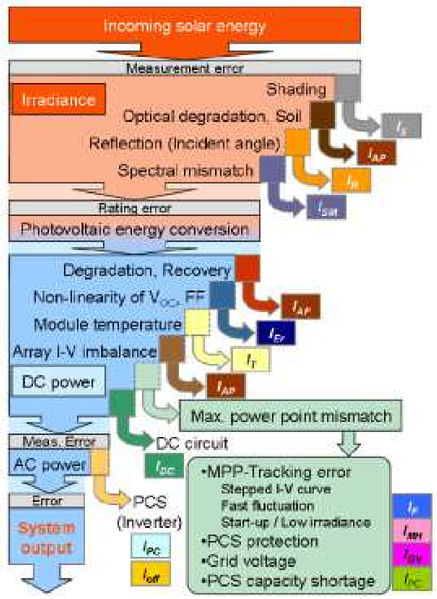
Perfomance ratio



PVsyst, 2013



FolsonLabs, 2013

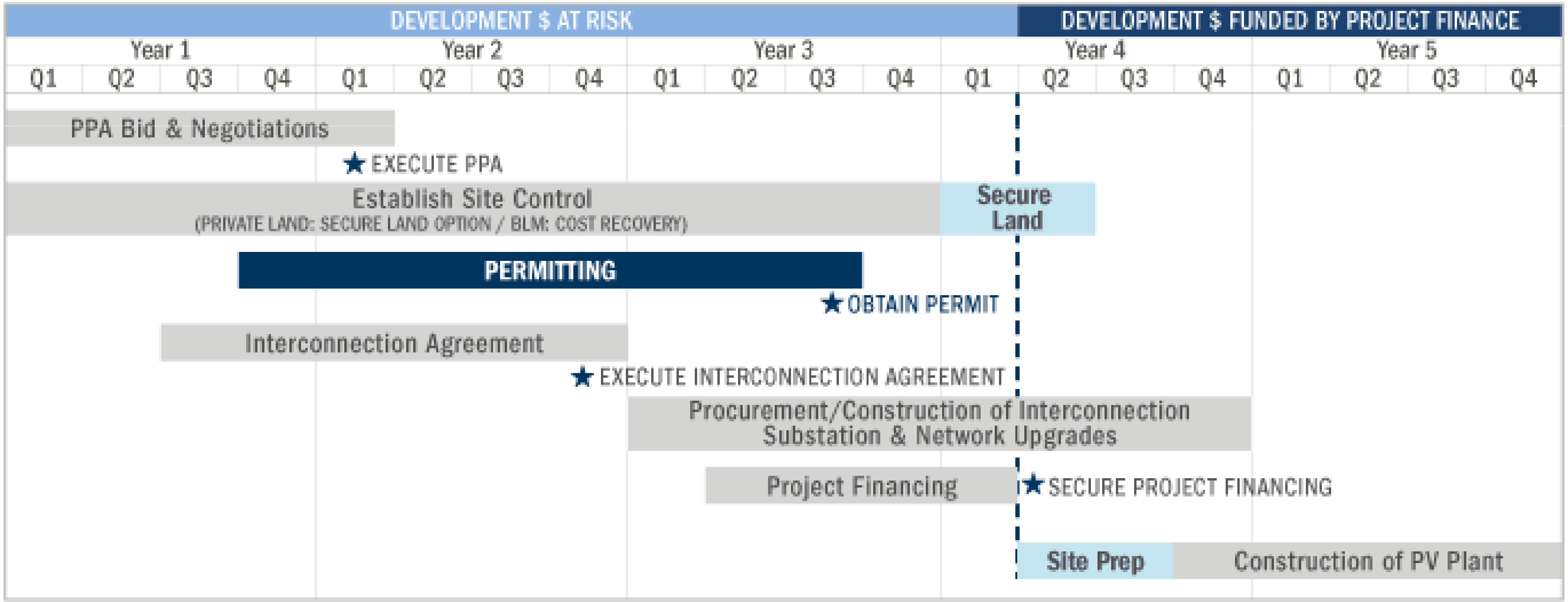


Tokyo Electric, 2013

How can we develop bankable solar PV projects?

Development

Development of a PV project has the same process (problems and difficulties) that other energy technologies. Special attention in the solar resource assessment and site measurements



First Solar, 2013

Procurement

The quality of a PV systems is the quality of its components. Panels and inverters are key component. Real energy yield test, track record, guarantee value and warranty, certifications, labs testing and performance validation are required to take into account, so you can be confident that you're making reliable decisions based on the most reliable data

Construction services

Solar plant construction conformity assessment services:

- Material Testing (concrete, structural steel for PV panel support, soil, steel for reinforcement)
- Plan review of systems and subsystems (civil, electrical, mechanical, ancillary facilities, etc.)
- Site inspection during construction for civil, mechanical and electrical installations.
- Certification of equipment and installations (IEC, CE marking and other European Directives)
- Audits of sub-contractors
- Project Management assistance
- Quality, Health and Safety on-site coordination
- Training

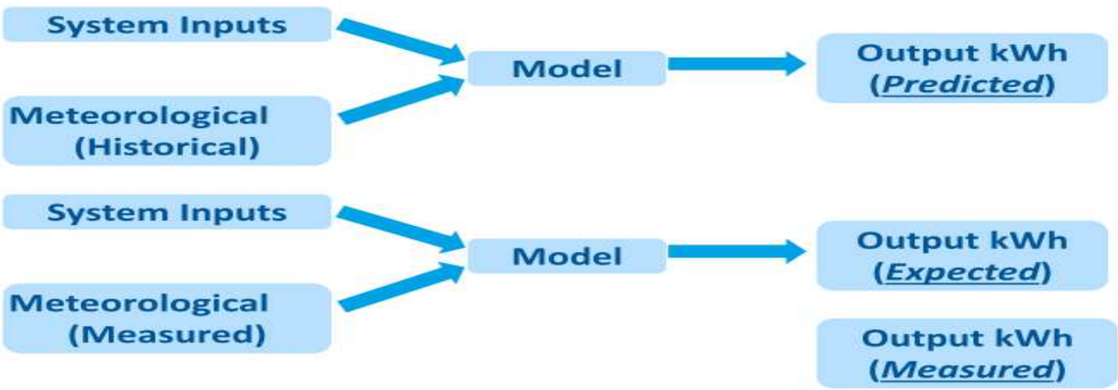
From electrical measurements to final acceptance tests, services should include:

- Design review
- Local code compliance
- Assistance in commissioning
- Definition of tests protocols regarding measurement, data treatment and necessary corrections according to standards
- Acceptance tests for Photovoltaic (PV) installations, including calculations of energy yield, efficiency, performance index, power rating, inverter efficiency, module temperature, array yield, system losses, etc.
- Complete inspection of the facility for final acceptance
- Permitting documentation review
- Witnessing of commissioning

Acceptance / performance test

The fundamental differences between acceptance of a solar power plant and a conventional fossil-fired plant are the inherently transient nature of the energy source and the necessity to use a performance projection model in the acceptance process. IEC standards are the most used (ASTM also in EEUU)

- **Provisional Acceptance Test.** After commissioning this test will be performed. It durations are typically run in the period over a few days (2 – 7).
- **Final Acceptance Test.** Is a continuous multi-day energy test that gathers multiple detailed daily energy outputs and compares the results to projections from a PR. Availability is also reviewed. Between these tests is the guarantee period (1 – 2 years).



Black&Veatch, 2013

How are the risks managed in a PV project?

Financing

Fitch Ratings – Rating Criteria for Solar Power Projects (February 2011)

"Fitch looks for a minimum of one year, hourly, well-maintained, onsite data for a complete solar resource supply assessment. Shorter data periods than one year will not capture the full seasonal and diurnal characteristics of solar irradiance at a particular site, and would be considered either midrange or weaker. Confirmation that the instruments used to collect the data were appropriate and properly calibrated and maintained is also expected."

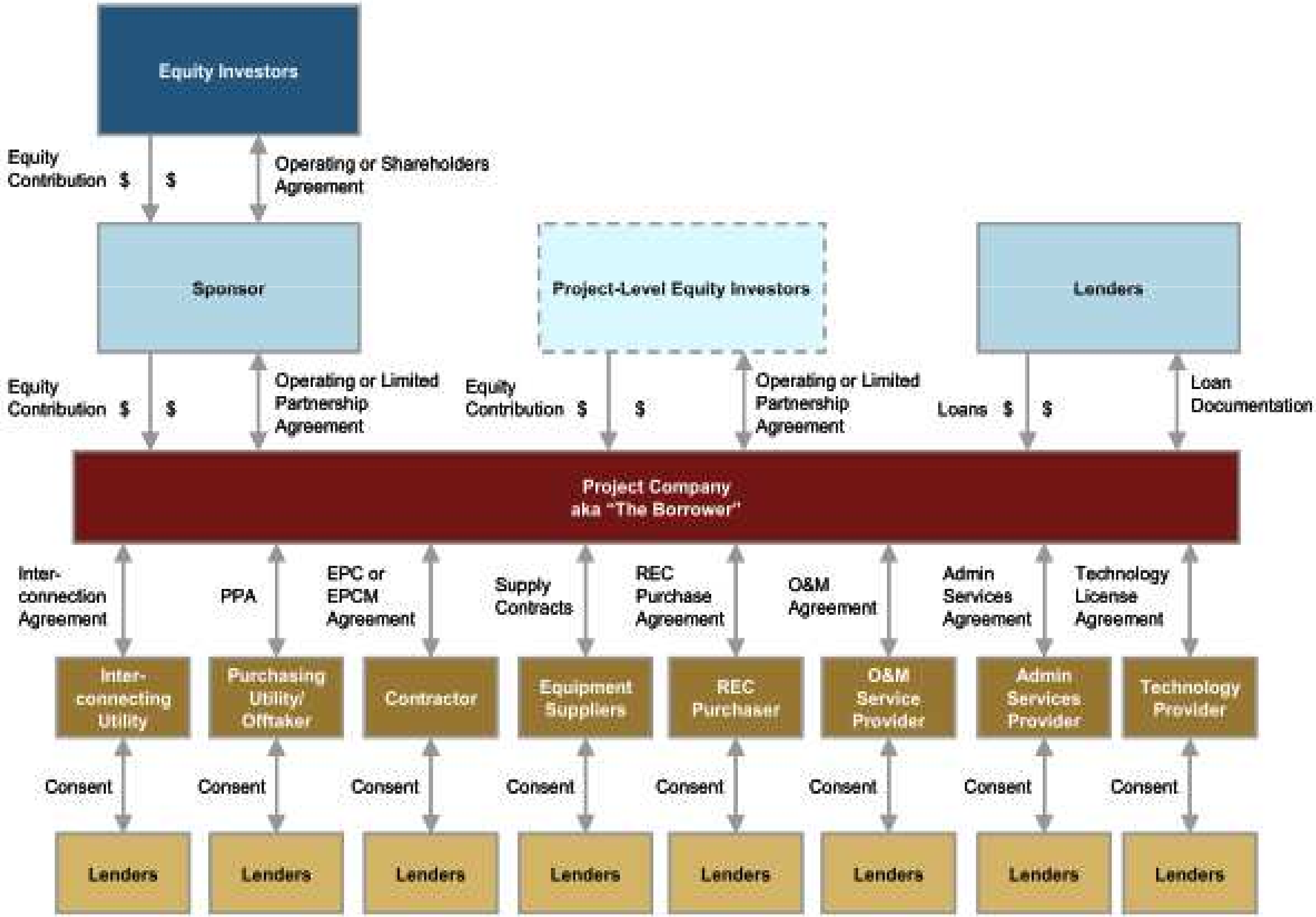
"Fitch considers a solar resource assessment that provides three output probability scenarios, a P50, a one-year P90, and a one-year P99, to be stronger…may not rate a solar debt issue that provides as P50 alone."

Moody's Investors Service – PV Solar Power Generation Projects (July 2010)

"…there has to be high degree of confidence that solar irradiation will meet or exceed certain minimum levels. For PV solar projects, Moody's will likely use a P90 forecast in calculating base case financial ratios…"

Project finance structure

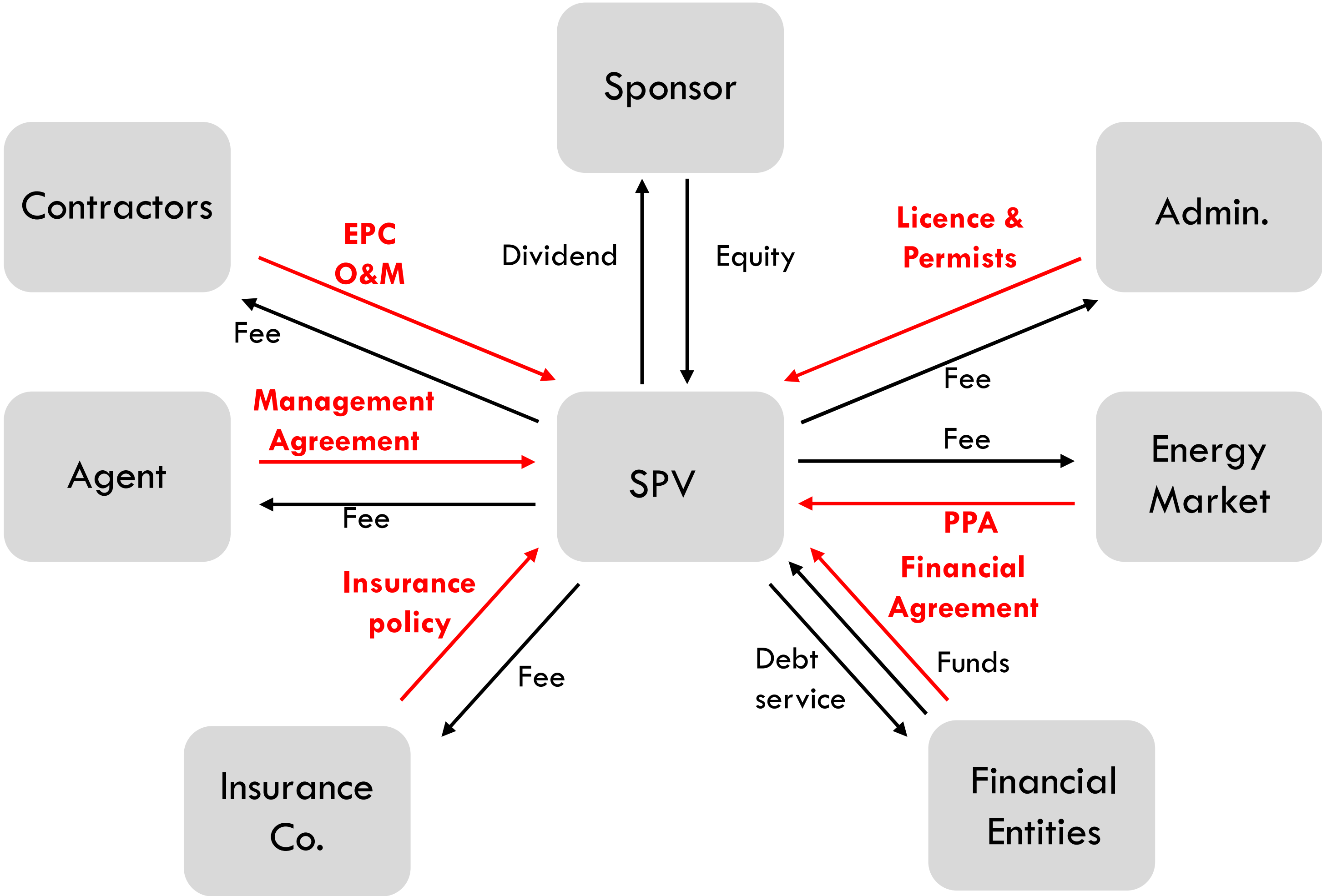
Investments in the PV sector often combine capital intensity with new technologies



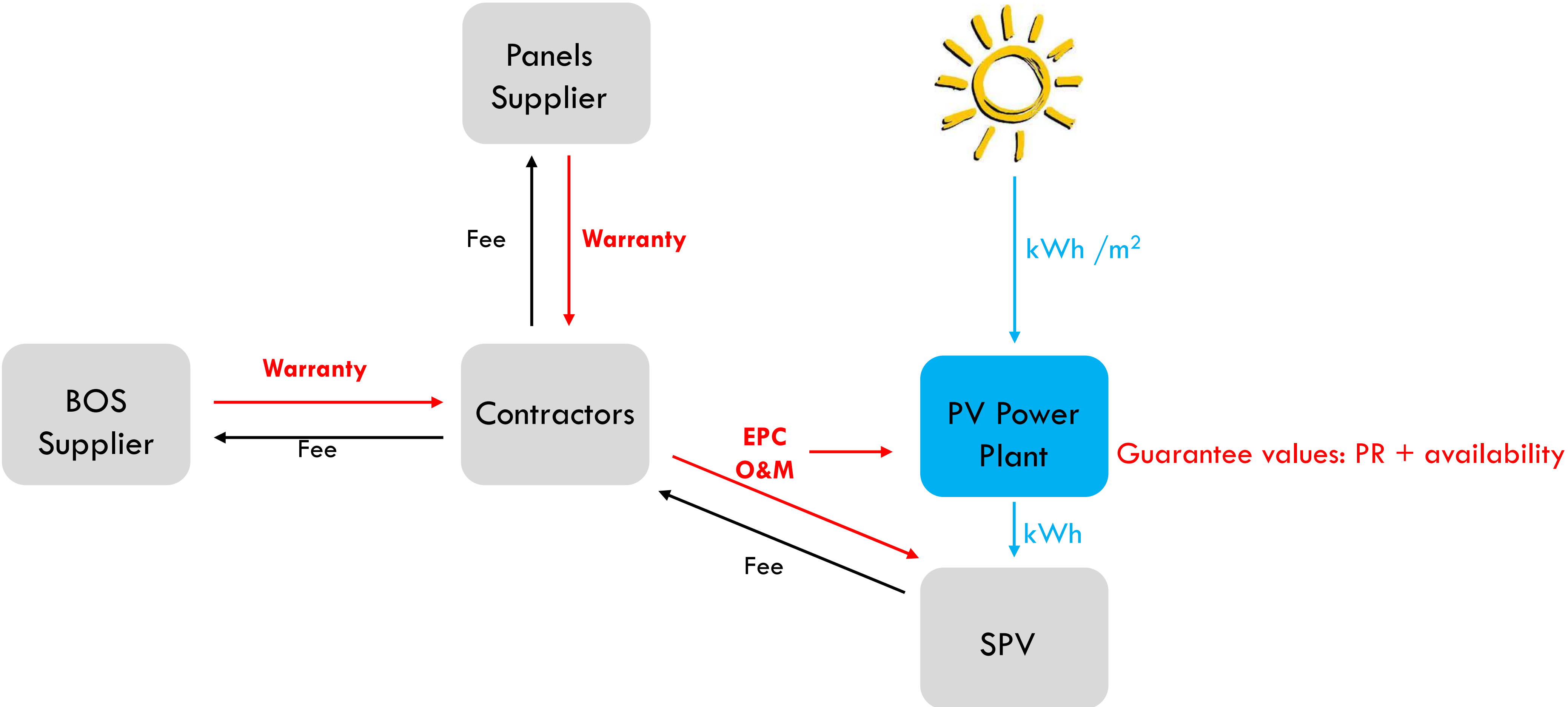
- Securing project finance can prove to be a critical step in the path to commercialization.
- Project finance succeeds best when you have long-term off-take agreements with quality-credit counterparties (such as power purchase agreements).

WSG&R Corporation, 2013

Project finance structure



Project finance structure



Risks

RISK	Probability	Take	Mitigation
Construction	Medium	Contractor	EPC
Performance	High	Contractor	EPC – O&M
Availability	Medium	Contractor	EPC – O&M
Revenues	Low	SPV	PPA
O&M extra cost	Low	Contractor	O&M
EPC extra cost	Medium	Contractor	EPC
Start up delay	Medium	Contractor	EPC
Management extra cost	Low	Agent	Agreement
Force majeure	Very low	Insurance Co,	Policy
Interest rate	High	SPV	Financial agreement
Licenses & Permits	Medium	SPV	L&P contracts
Unrealistic guarantee values	Medium	SPV	DD Technical
Solar resource	High	SPV	DD Technical
Technology life time	Medium	SPV - Contractor	EPC – DD Tech.