CENER | CENTRO NACIONAL DE ENERGÍAS RENOVABLES

ADItech

SESSION 3. PV PLANT PROJECT DEVELOPMENT: DESIGN, SOLAR RESOURCE, EPC-O&M CONTRACTS AND WARRANTIES

GOBIERNO DE ESPAÑA
VICEPRESIDENCIA CUARTA DEL GOBIERNO
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO
MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat

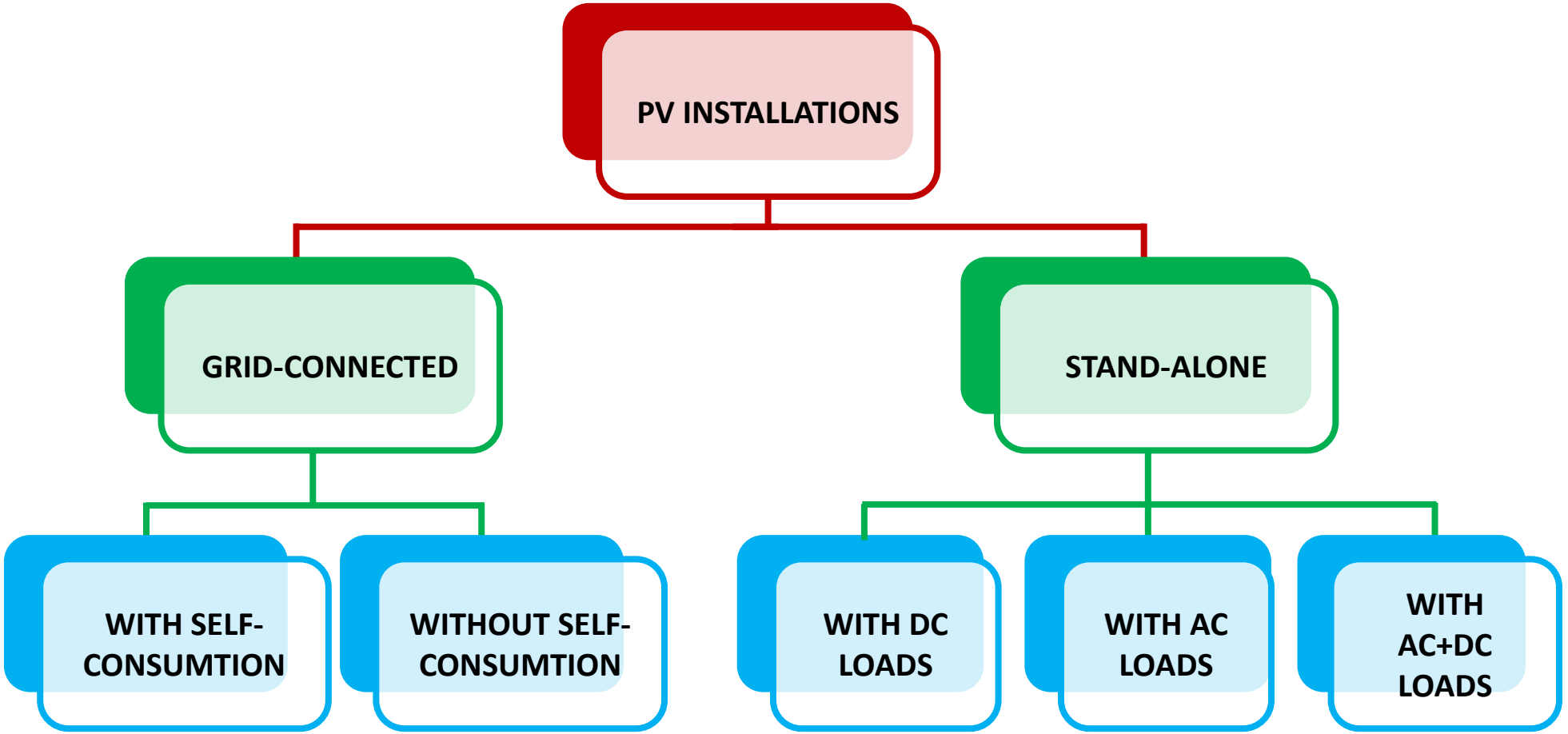
Gobierno de Navarra
Nafarroako Gobernua

INDEX

1. INTRODUCTION TO PV PLANTS
2. REVIEW OF STEPS IN A PV PLANT PROJECT
3. PV PROJECT CONTRACTS STRUCTURE
4. SOLAR RESOURCE & ENERGY PRODUCTION
5. POINT OF INTEREST

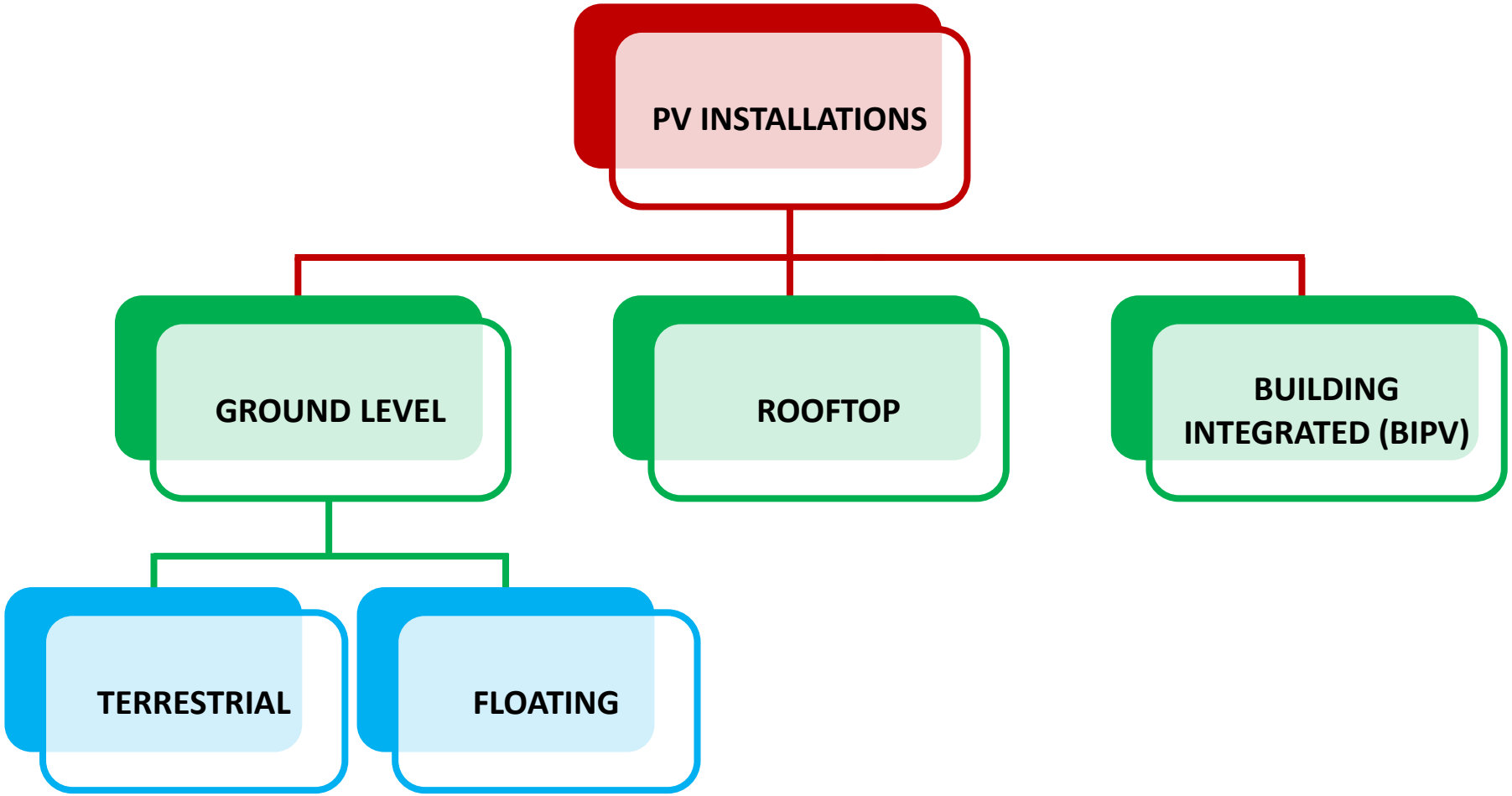
1. INTRODUCTION TO PV PLANTS - CLASSIFICATION

GENERAL CLASSIFICATION OF PV PLANTS

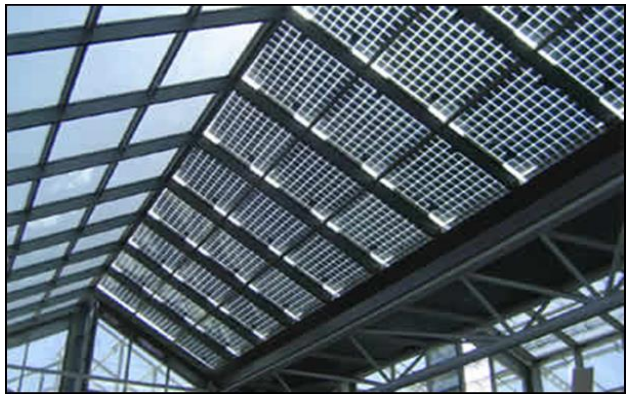


1. INTRODUCTION TO PV PLANTS - CLASSIFICATION

CLASSIFICATION OF PV PLANTS ACCORDING TO LOCATION

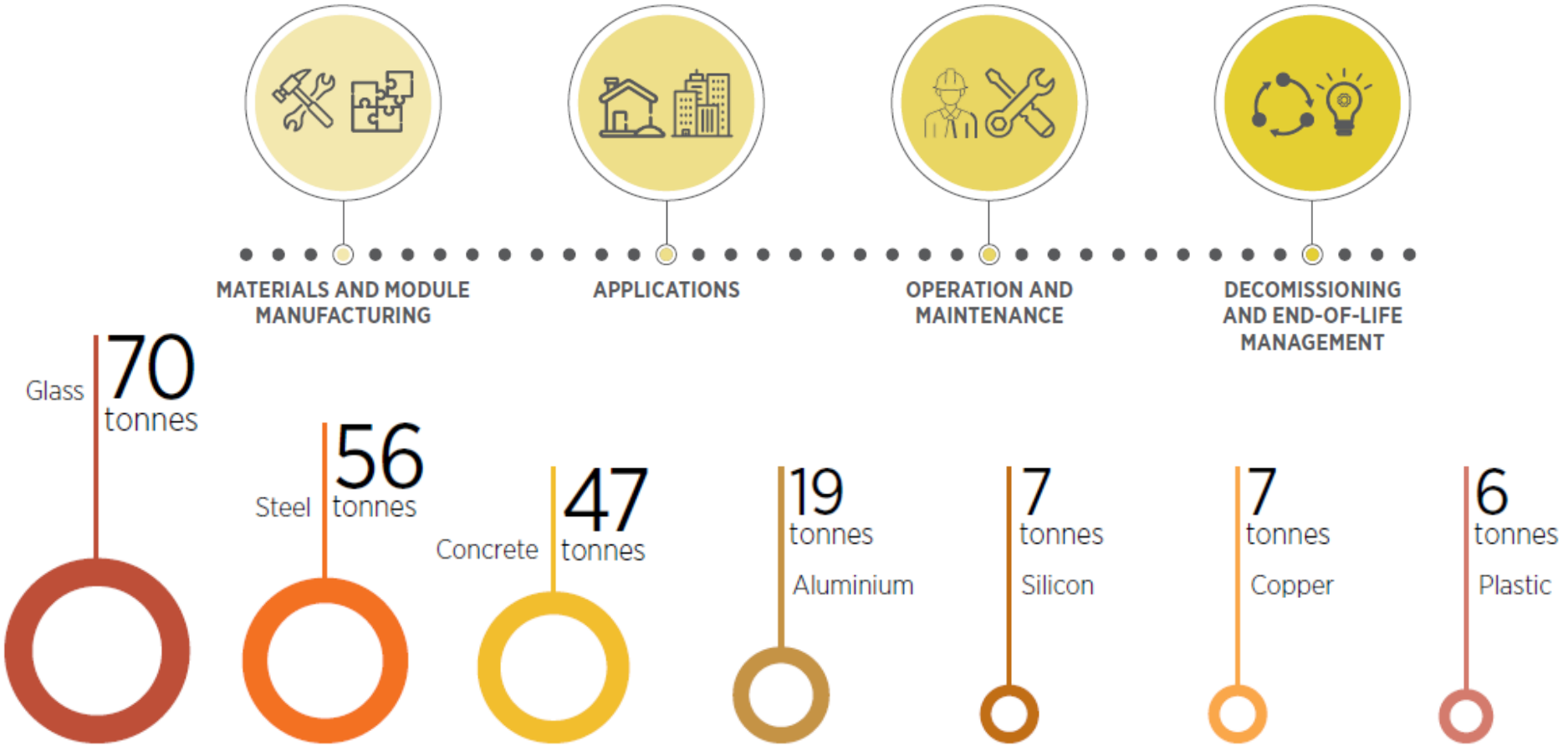


1. INTRODUCTION TO PV PLANTS - CLASSIFICATION



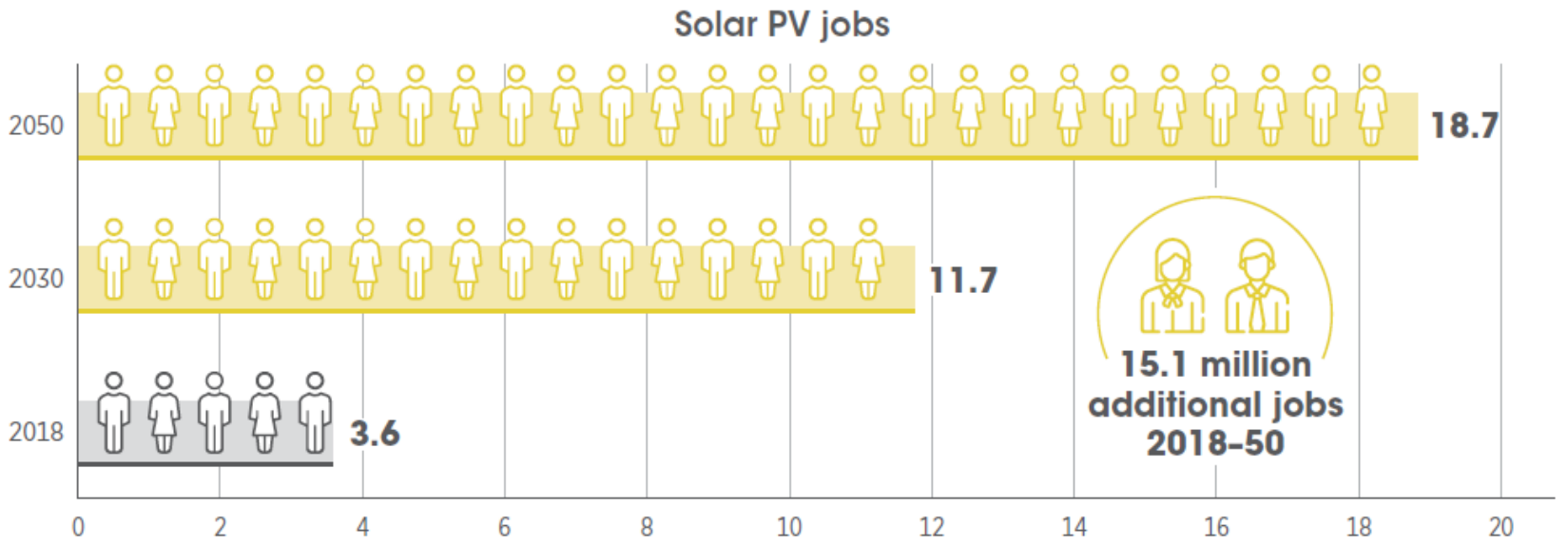
Source: Acciona, Prodiel, Winvestco Martifer, AyudasEnergia.com, energiasrenovables.com.ar

1. INTRODUCTION TO PV PLANTS – GENERAL FACTS



Source: IRENA (2017b).

1. INTRODUCTION TO PV PLANTS – GENERAL FACTS



Sources: IRENA (2019a, 2019j).

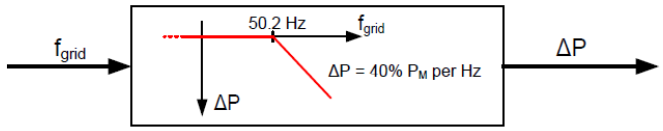
50 MW solar PV: 229 055 person-days

Source: IRENA (2017b).

1. INTRODUCTION TO PV PLANTS – CAPABILITIES

Active Power Control

Active power reduction P(f)

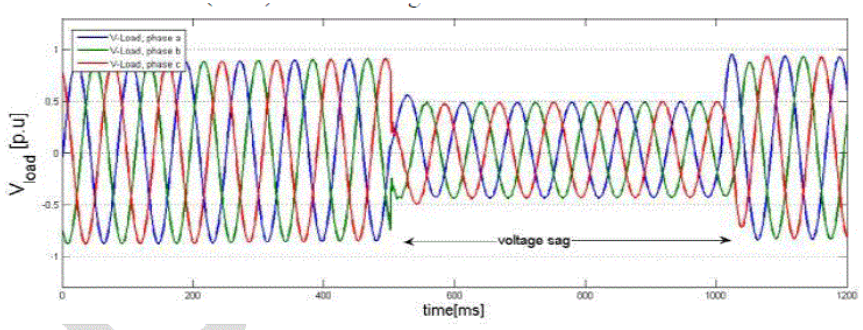


Active power reduction – feed in management

Reactive Power Control

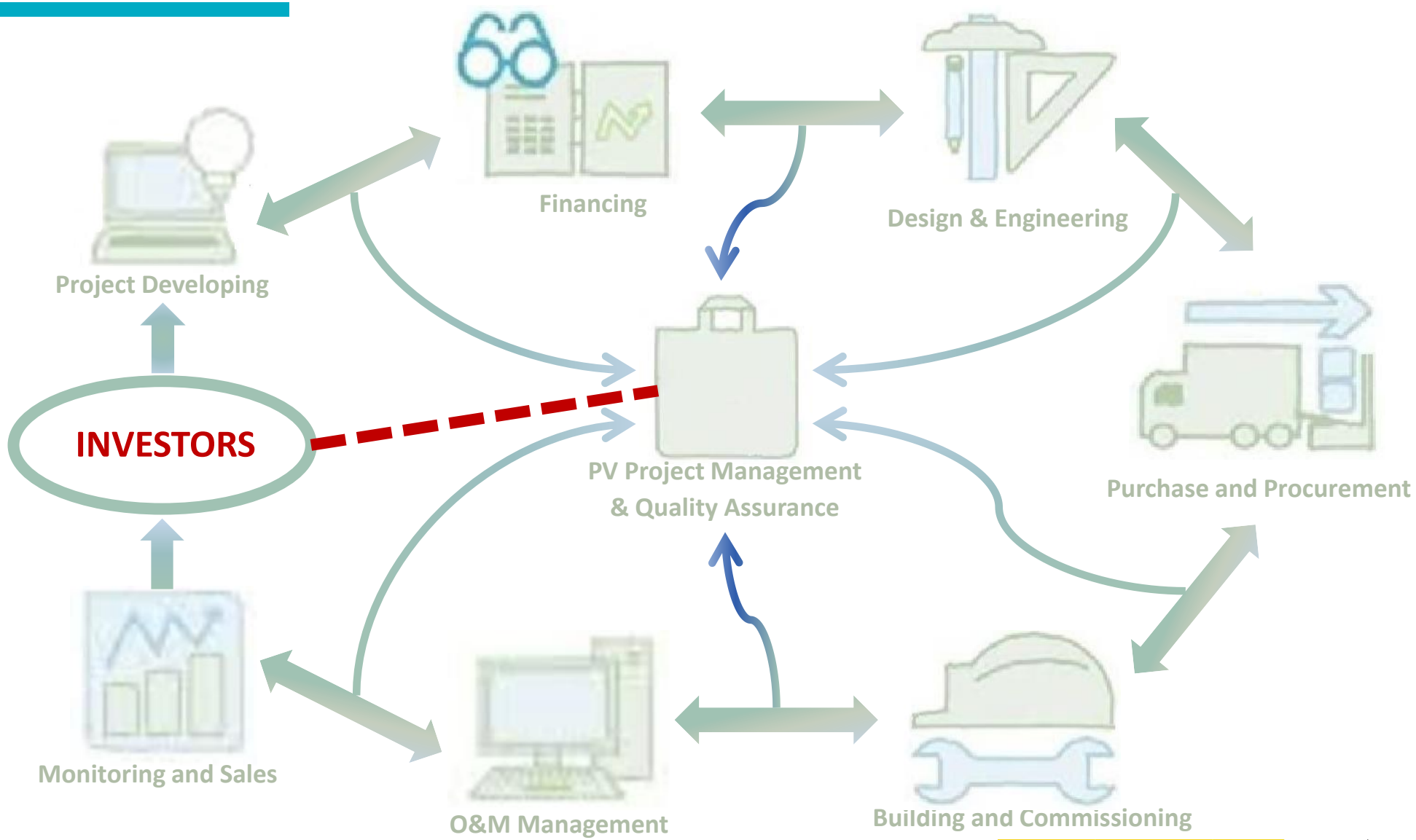
Static voltage support

Dynamic voltage support
LVRT – low voltage ride through



		Power Plant	Old PV Plant	Current PV Plant
P	Ready reserve, Primary control…	✓	✗	✓
	Demand side management	✗	✗	✓
	Feed in management	✓	✓	✓
Q	Dynamic voltage support	✓	✓	✓
	Static voltage support	✓	✓	✓

2. STEPS IN A PV PLANT PROJECT - OVERVIEW



2. STEPS IN A PV PLANT PROJECT

STAGE 1 – SITE IDENTIFICATION

- ✓ Identification of Potential sites(s)
- ✓ Funding of project development
- ✓ Development of rough technical concept

STAGE 2 – PRE FEASIBILITY STUDY

- ✓ Assessment of different technical options
- ✓ Approximate cost/benefits estimation
- ✓ Permitting needs
- ✓ Market assesment

STAGE 3 – FEASIBILITY STUDY/PRELIMINARY PV PROJECT

- ✓ Technical and financial evaluation of preferred option
- ✓ Assesmet of financing options
- ✓ Start of permitting process

2. STEPS IN A PV PLANT PROJECT

STAGE 4 – FINANCING/CONTRACTS

- ✓ Permitting
- ✓ Contracting strategy
- ✓ Supplier selection & contract negotiation
- ✓ Financing of project

STAGE 5 – DETAILED DESIGN/PV PROJECT

- ✓ Preparation of detailed design for all relevant lots
- ✓ Preparation of project implementation schedule
- ✓ Finalization of permitting process

STAGE 6 – CONSTRUCTION

- ✓ Quality Assessment testing
- ✓ Construction supervision

2. STEPS IN A PV PLANT PROJECT

STAGE 7 – COMMISSIONING

- ✓ Performance Testing
- ✓ Preparation of as built design (if required)

STAGE 8 – OPERATION & MAINTENANCE

- ✓ Developing of tasks according to O&M procedures
- ✓ Spare parts & suppliers management
- ✓ Monitoring

STAGE 9 – DISMANTLING

- ✓ Management of old & out-of-service equipment
- ✓ Land restoration

3. PV PROJECT CONTRACTS STRUCTURE

EQUIPMENT PROCUREMENT CONTRACT

SCOPE OF CONTRACT

- Equipment models
- Equipment techical specs
- Product Audit
- Factory/Process Audit
- Acceptance criteria
- Logistics, incoterms and delivery time
- Conditions of use
- Compliance with regulations & standards
- Documentation
- Price and payment method

TECHNICAL SPECS

- Factory quality system
- Certifications
- Traceability

TESTING

- Factory testing
- Pre-shipment testing
- On-site at plant reception testing
- On-site mounted testing
- Commissioning testing

WARRANTIES

- Product Warranty
- Performance Warranty

3. PV PROJECT CONTRACTS STRUCTURE

EQUIPMENT PROCUREMENT CONTRACT – POSSIBLE RISKS

- Indefinition or insufficient technical specifications to ensure the choice of suitable components.
- Inadequate testing of components to verify manufacturing deviations of the product (PV modules).
- Absence or non-definition of component acceptance criteria.

3. PV PROJECT CONTRACTS STRUCTURE

EPC CONTRACT

SCOPE OF CONTRACT

- Solar Resource & Energy Production Estimation
- Design & Engineering
- Landing Preparation
- Construction & Mounting
- Definition of monitoring
- Definition of O&M procedures
- Definition of Commissioning procedures
- Safety and surveillance of PV plants
- Spare part list

TECHNICAL SPECS

- Design & technology of PV plant
- Selection and quality specs of the equipments
- Product guarantees
- Product certifications

TESTING

- Technical inspections
- Quality assurance product testing
- Commissioning

WARRANTIES

- PV plant Performance
- Product operating
- Availability
- O&M warranty

3. PV PROJECT CONTRACTS STRUCTURE

EPC CONTRACT – POSSIBLE RISKS (Design)

- No consideration of the evaluation of the solar resource in the long term (solar resource based on one year).
- No consideration of statistical studies in the estimation of PV plant electricity generation (probability of exceedance PXX)
- Underestimation of the degradation of PV modules and its effect on the estimation of their long-term behavior.
- No consideration of the PV plant availability when evaluating the estimation of the energy production.

3. PV PROJECT CONTRACTS STRUCTURE

EPC CONTRACT – POSSIBLE RISKS (Construction)

- Indefinition of tasks and responsibilities in the contract, agreement with the rest of the contracts (equipment procurement and O&M)
- Indefinition of transport and assembly guidelines for PV modules.
- Unsuitable procedures when unpacking components and incorrect handling during construction or installation.
- Lack of supervision during the construction or installation stage that ensures quality criteria (external technical evaluator).

3. PV PROJECT CONTRACTS STRUCTURE

EPC CONTRACT – POSSIBLE RISKS (Commissioning)

- Inadequate visual inspection process during the provisional or final acceptance stage of the PV plant.
- Incorrect definition of the Performance Ratio value of the PV plant.
- Indefinition of the Performance Ratio measured and guaranteed at the final acceptance of the PV plant.
- Absence of equipment specifications and data collection for the calculation of the Performance Ratio during provisional and final acceptance of the PV plant.
- Absence of documentation of the PV plant after starting operation (as built)

3. PV PROJECT CONTRACTS STRUCTURE

O&M CONTRACT

SCOPE OF CONTRACT

- Predictive maintenance
- Preventive maintenance
- Corrective maintenance
- Warranty claim management
- Spare part management
- PV module cleaning
- Vegetation control
- Safety & surveillance
- Monitoring
- Production and O&M reports

TECHNICAL SPECS

- Instructions and user's manual of equipment
- O&M procedures

TESTING

- O&M procedures (after maintenance action)

WARRANTIES

- PV plant Performance
- Product operating
- Availability
- O&M warranty

3. PV PROJECT CONTRACTS STRUCTURE

O&M CONTRACT – POSSIBLE RISKS

- Inadequate monitoring system for the detection and identification of faults in the PV plant.
- Unavailability of devices for detecting defects not visible to the human eye during preventive maintenance tasks (thermography).
- Indefinition of PV plant performance indicators guaranteed in the O&M contract.
- Absence of equipment specifications and data collection for the calculation of the Performance Ratio during the O&M stage.
- Absence of a maintenance clause for the sensors and monitoring system.
- Absence of specification of cleaning frequency of PV modules or low frequency.

3. PV PROJECT CONTRACTS STRUCTURE

PPA CONTRACT (Power Purchase Agreement)

SCOPE OF CONTRACT

- Estimation of energy production (interconnection with grid)
- Prediction of energy production
- Feed-in Tariff
- Payment
- Energy measurement

TECHNICAL SPECS

- Electric Market Regulations
- Certificate of origin of energy

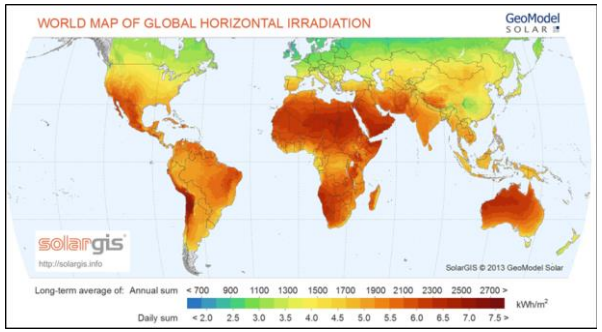
TESTING

WARRANTIES

- Supply energy
- Origin of the energy (renewables)

4. SOLAR RESOURCE & ENERGY PRODUCTION

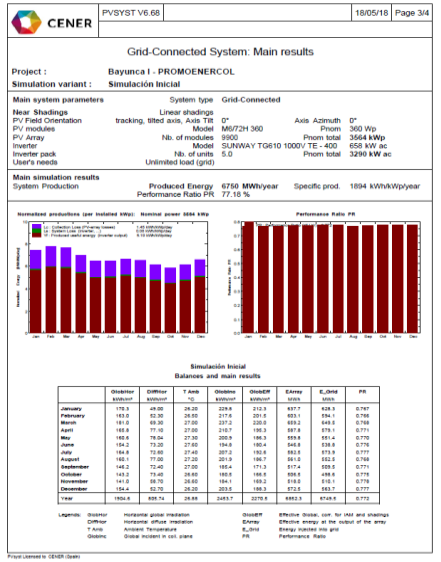
Data Bases
- Necessary Data: G, T
- Recommended Data: D, v
- TMY



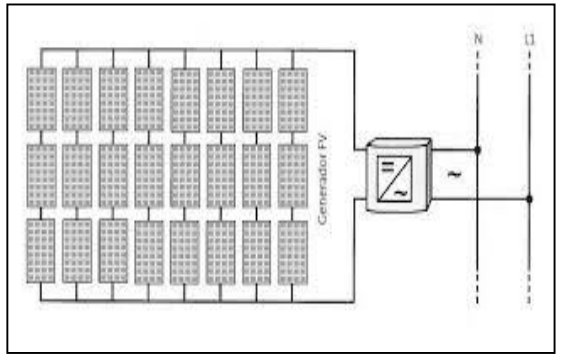
Source: SolarGIS

PV SYSTEM SOFTWARE SIMULATION

ENERGY PRODUCTION ESTIMATION



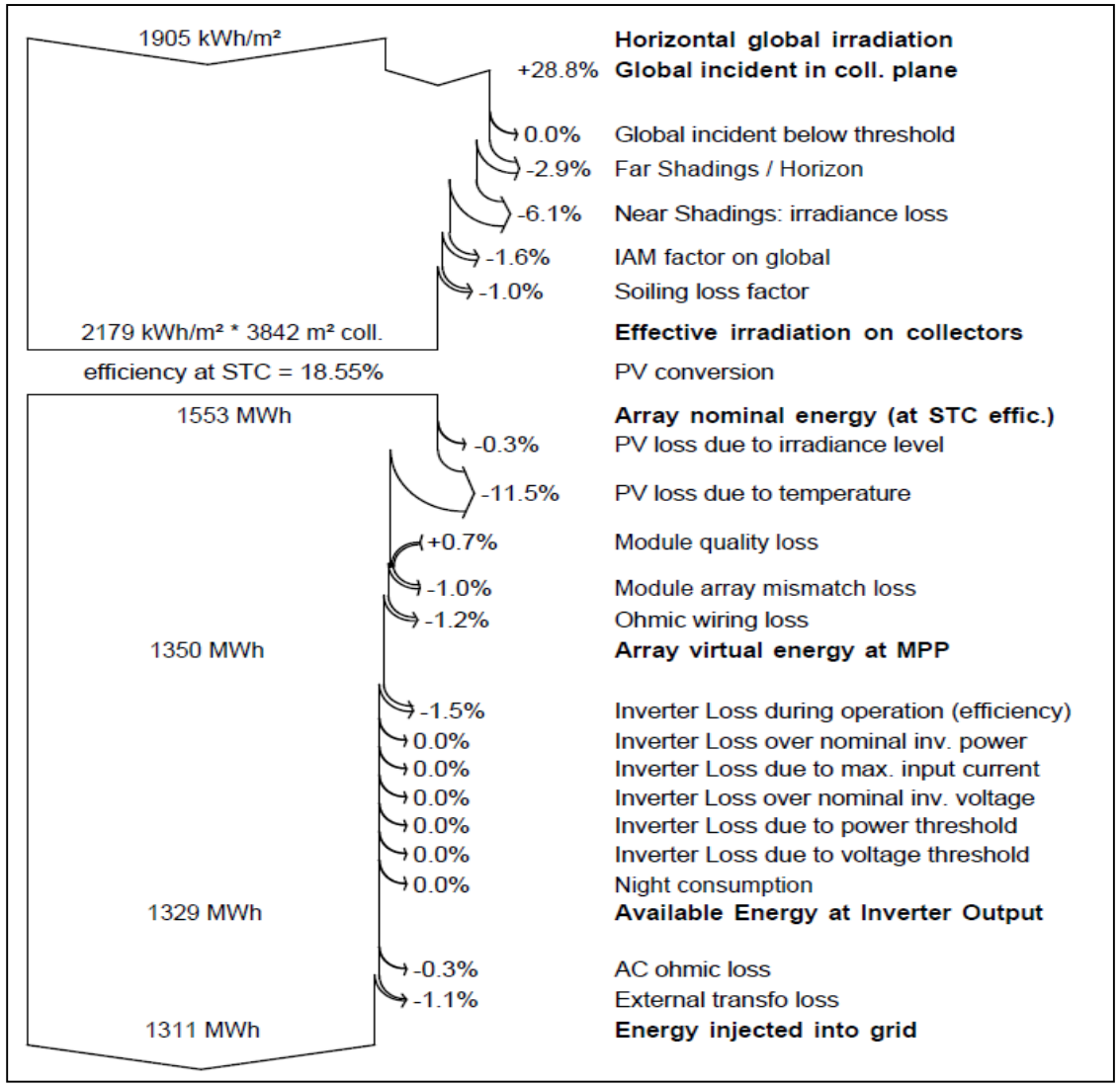
Technical Specs of PV Plant
- Equipment
- Tilt/Orientation/Tracking
- Electrical configuration
- Layout and wiring



4. SOLAR RESOURCE & ENERGY PRODUCTION

DESIGN OF A PV PROJECT
LOSS FACTOR ANALYSIS

- Radiation Loss Factors
- DC-side Loss Factors
- AC-side Loss Factors

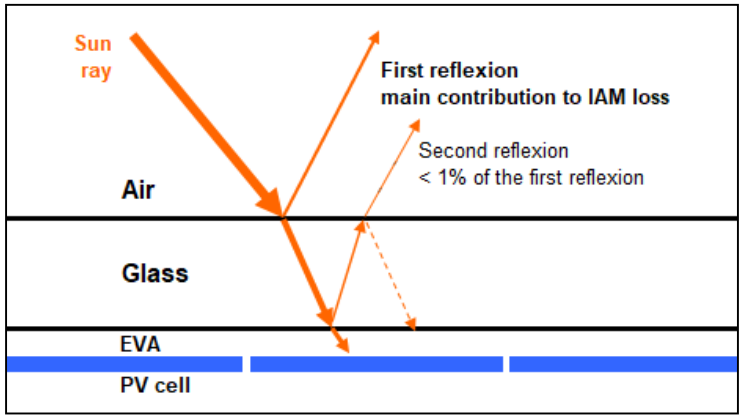


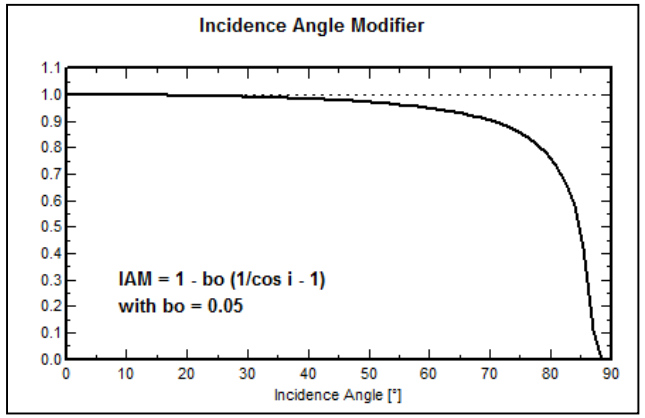
Source: CENER/`PVSYST

4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – RADIATION LOSS FACTORS

- Incident Angle





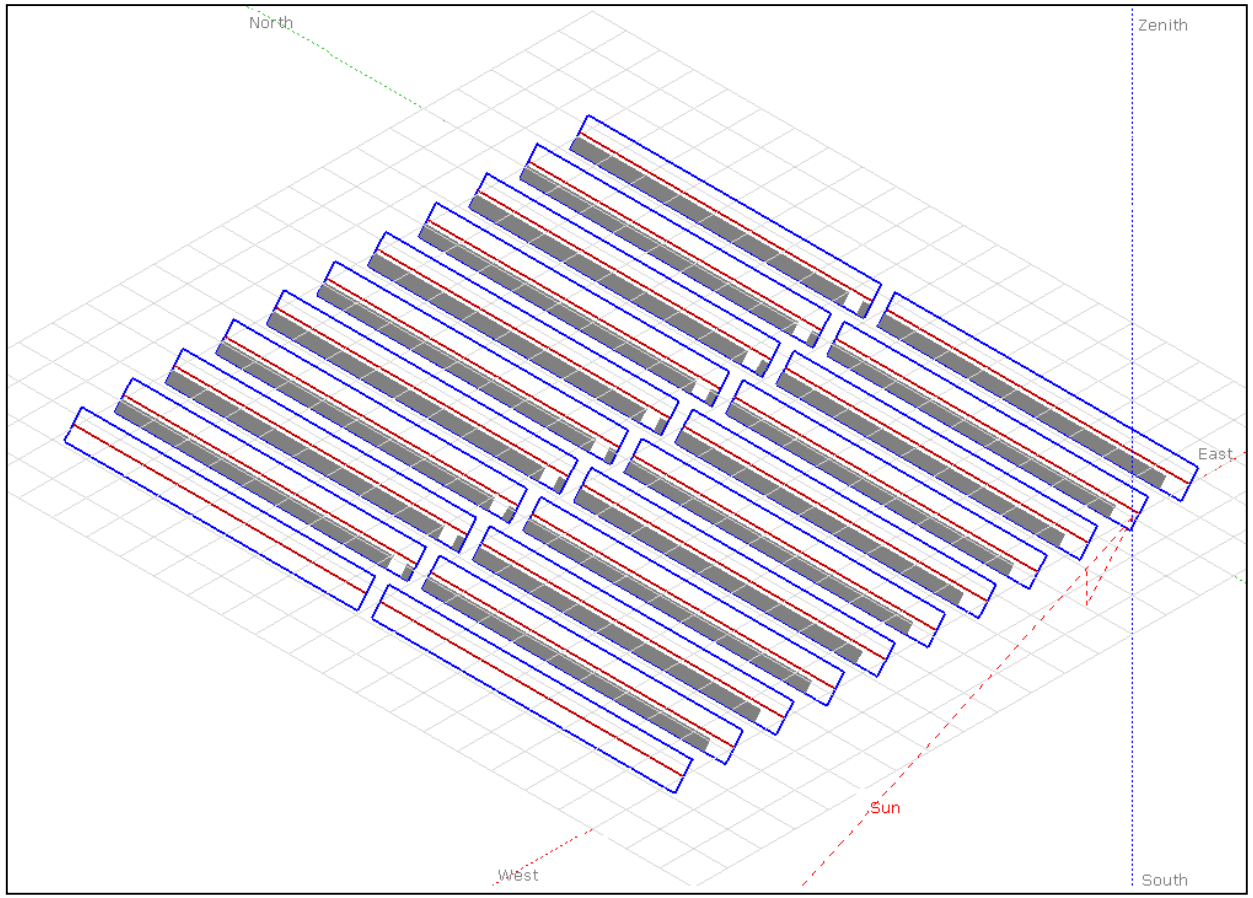
- Soiling

Climate classification (Köppen-Geiger)		Module tilt angle below 5°	5° to 15°	above 15°
		Overall annual soiling loss [%]		
Tropics	A	1.0	0.5	0.5
Arid	B	4.0	4.0	4.0
Warm moderate	Cf	2.0	1.0	0.5
	Cs	2.5	1.5	1.0
	Cw	2.5	1.5	1.0
Snow	Df	2.0	1.0	0.5
	Ds	3.0	2.0	1.5
	Dw	3.0	2.0	1.5
Polar	E	–	–	–
Exceptional soiling sources		Decision on a by-case basis		

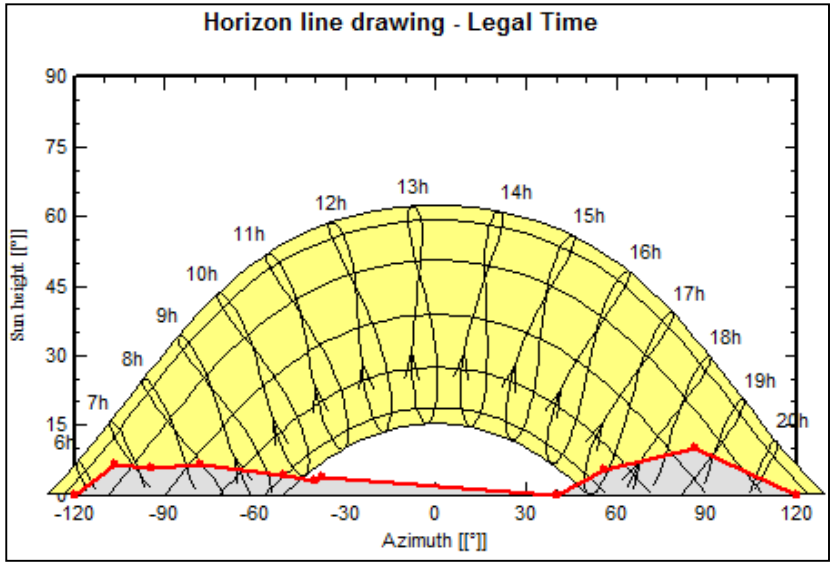
4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – RADIATION LOSS FACTORS

- Near Shading



- Far Shading (Horizon Line)



Source: CENER/`PVSYST

4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – DC-SIDE LOSS FACTORS

- Temperature Loss Factor

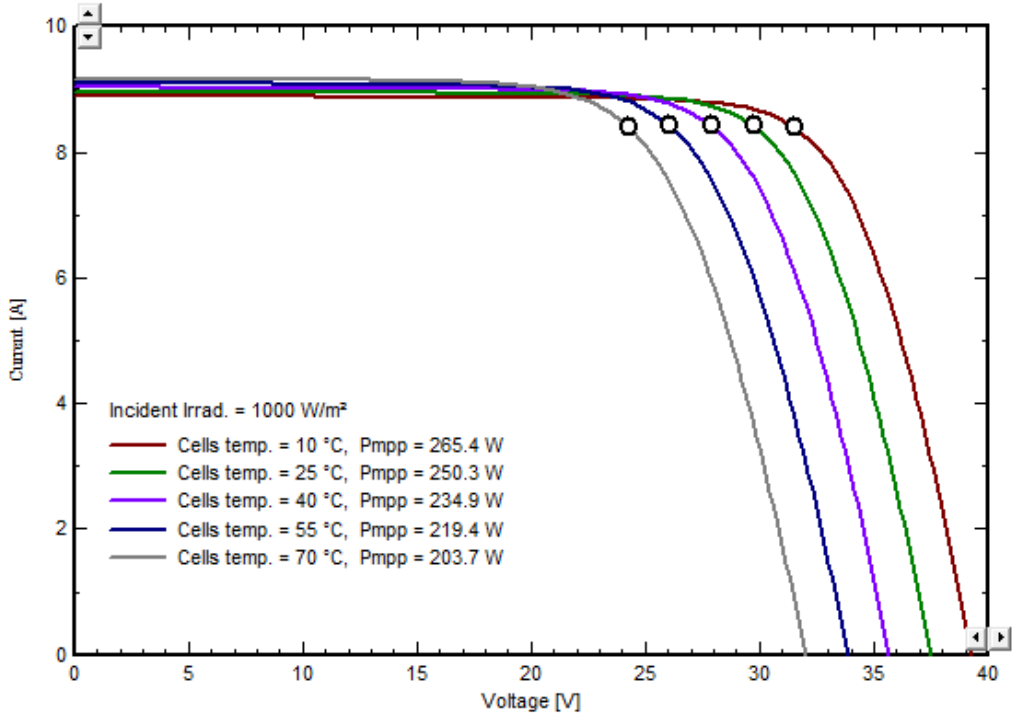
$$T_c = T_a + \frac{\alpha E_{POA}(1 - eta_m)}{U_0 + U_1 * WS}$$

where

- T_c is cell temperature (°C)
- T_a is ambient air temperature (°C)
- α is the adsorption coefficient of the module (PVsyst default value is 0.9)
- E_{POA} is the irradiance incident on the plane of the module or array (W/m^2)
- eta_m is the efficiency of the PV module (PVsyst default is 0.1)
- U_0 is the constant heat transfer component (W/m^2K)
- $U_1$is the convective heat transfer component (W/m^3sK)
- WS is wind speed (m/s)

PVsyst says little about what values to use for U_0 and U_1. Note that the current default values assume no dependance on wind speed ($U_1 = 0$)

- For free-standing arrays the current default is : $U_0 = 29\ W/m^2K; U_1 = 0\ W/m^3sK$
- For fully insulated arrays (close roof mount) the current default is: $U_0 = 15\ W/m^2K; U_1 = 0\ W/m^3sK$

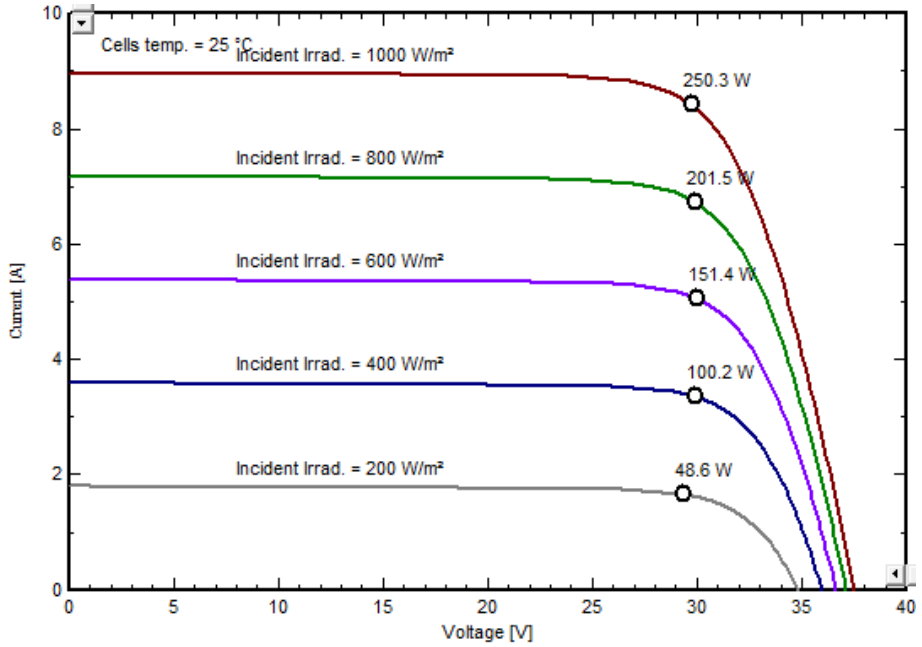


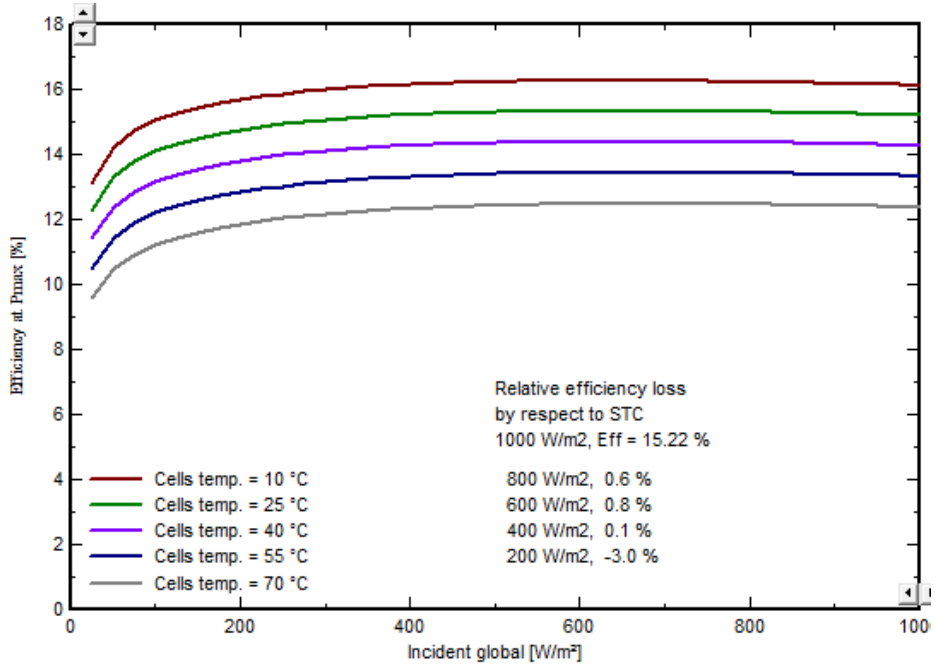
Source: CENER/`PVSYST

4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – DC-SIDE LOSS FACTORS

- Irradiance Loss Factor





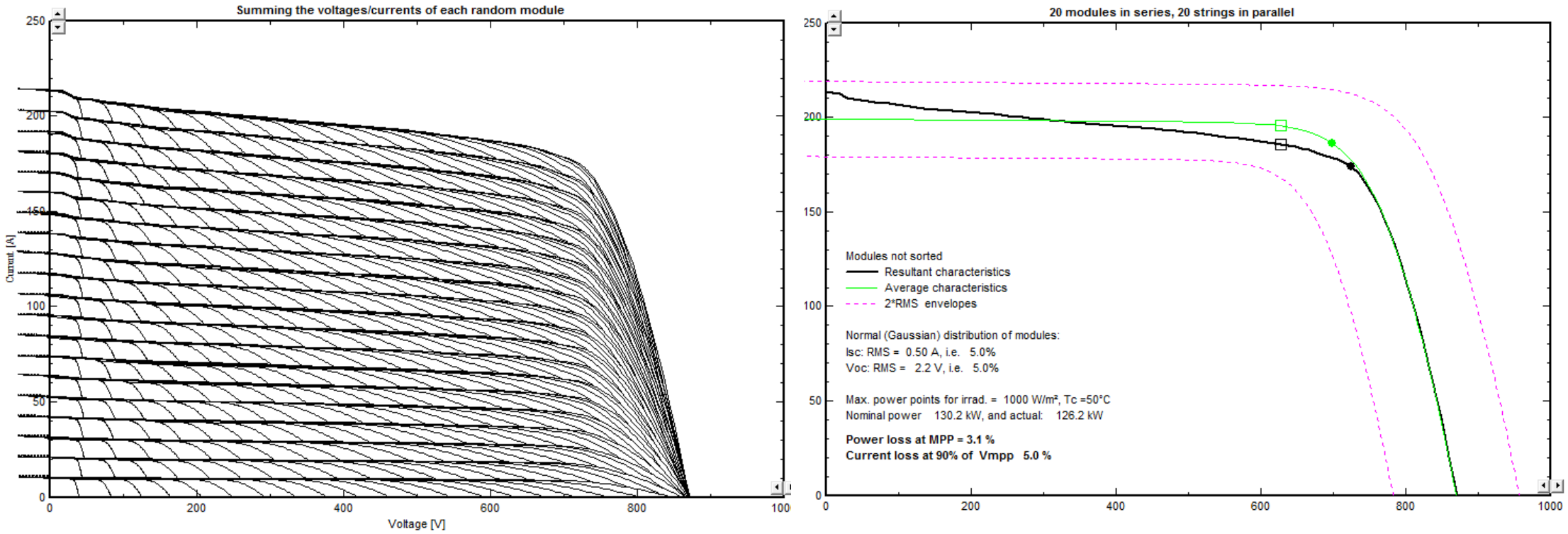
Behaviour of the photovoltaic modules is not the same to their behaviour in STC at all levels of irradiance (loss or gain)

Source: CENER/`PVSYST

4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – DC-SIDE LOSS FACTORS

- Mismatch Loss Factor

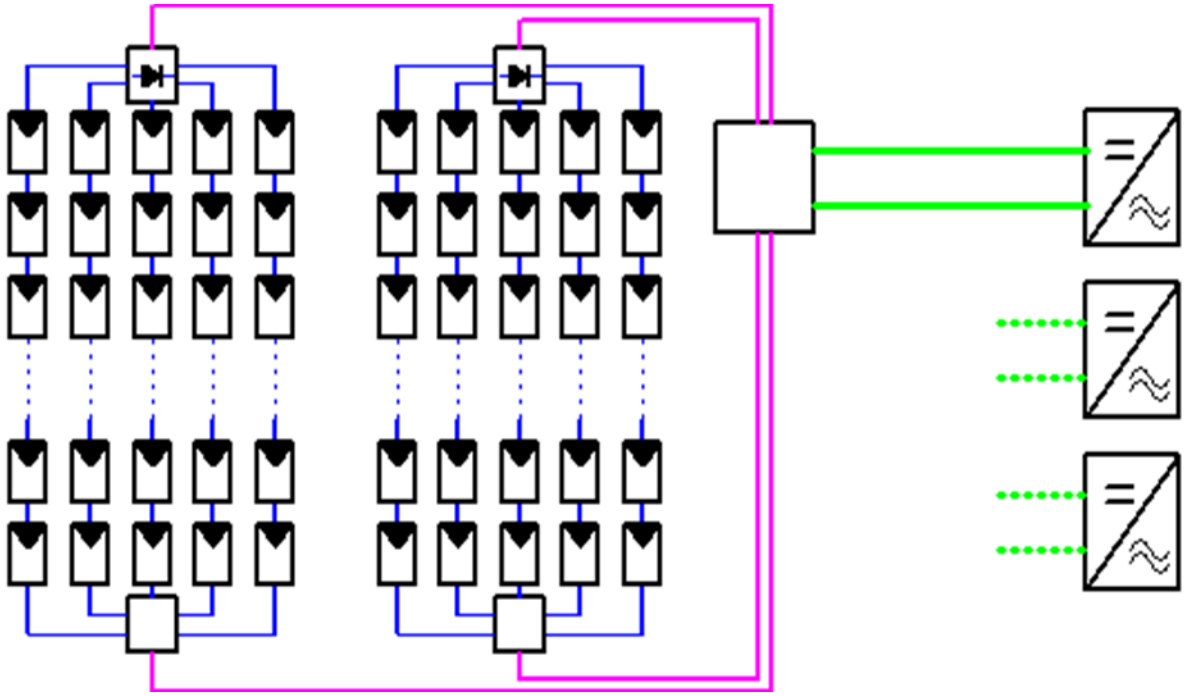


The difference in the characteristics of the interconnected PV modules produces an overall loss

Source: CENER/`PVSYST

LOSS FACTOR ANALYSIS – DC-SIDE LOSS FACTORS

- Ohmic Loss Factor



Source: CENER/`PVSYST

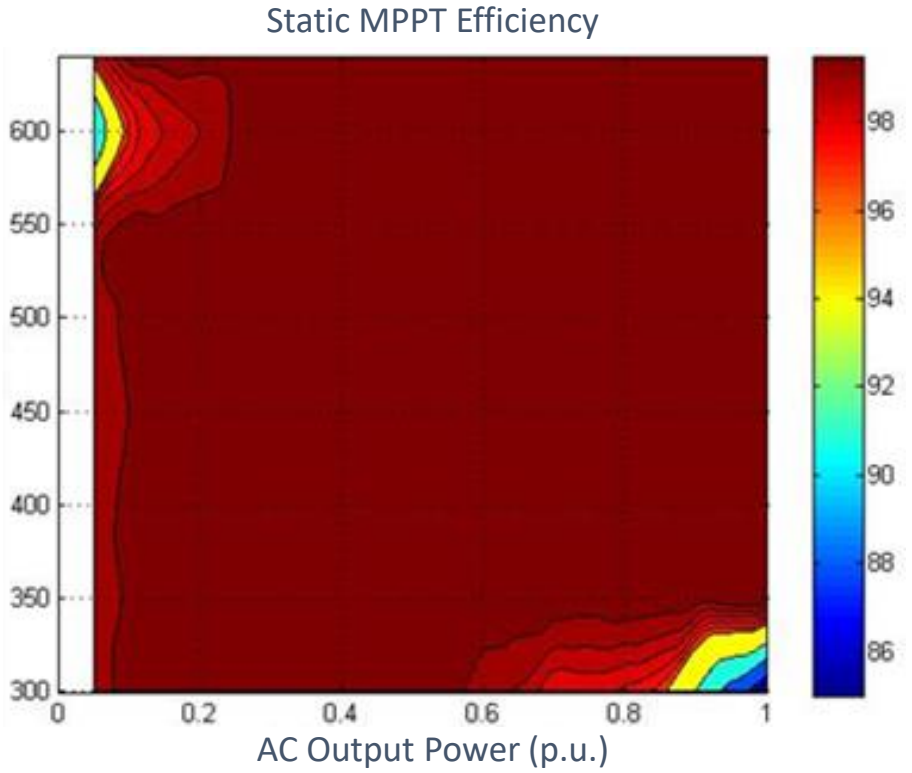
$$R_{DC} = \frac{1}{\sum_{k=1}^{n} \frac{1}{R_k}}$$

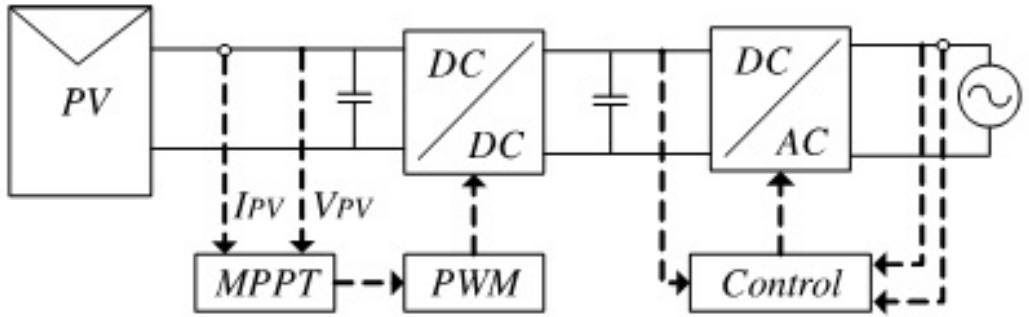
PV plant wiring can be assumed as a equivalent resistance, with an associated ohmic loss factor

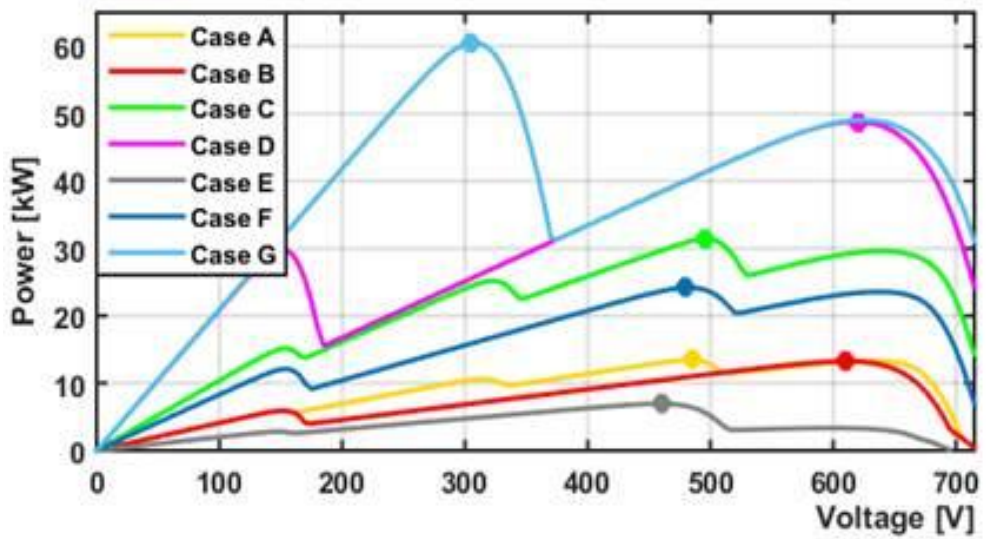
4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – DC-SIDE LOSS FACTORS

- MPPT System Loss Factor



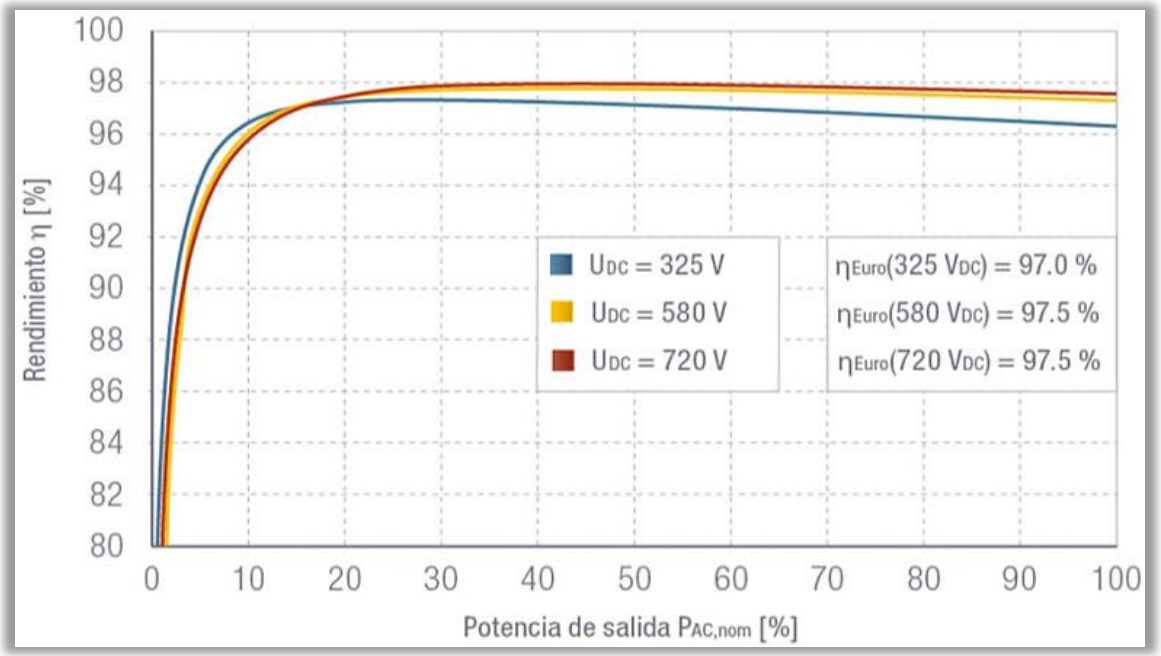




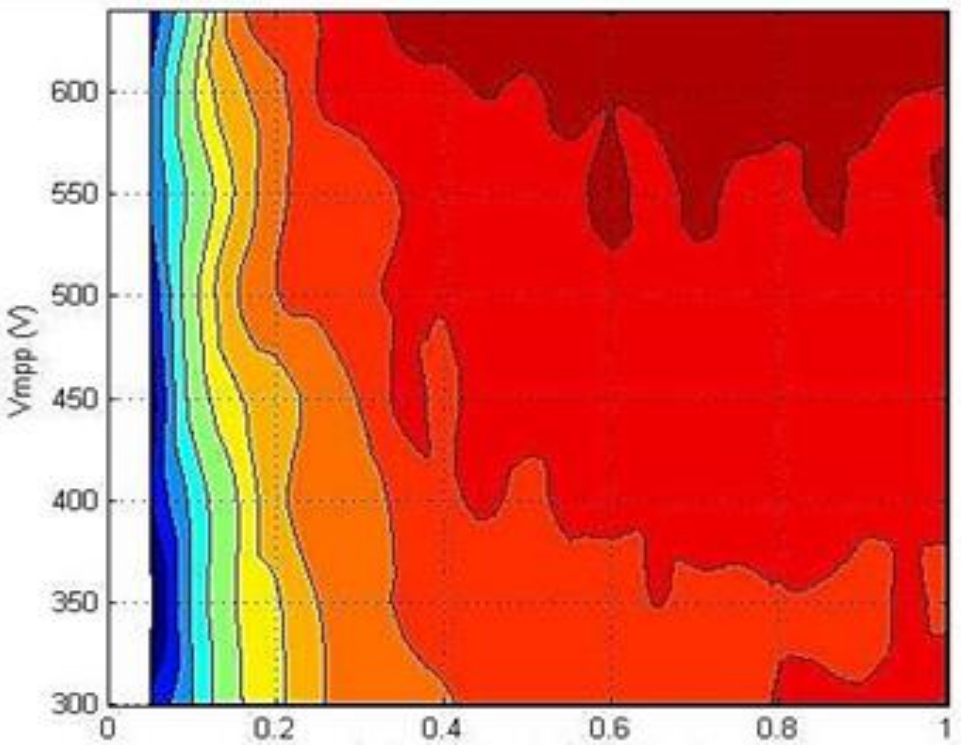
4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – AC-SIDE LOSS FACTORS

- DC/AC Conversion Loss Factor



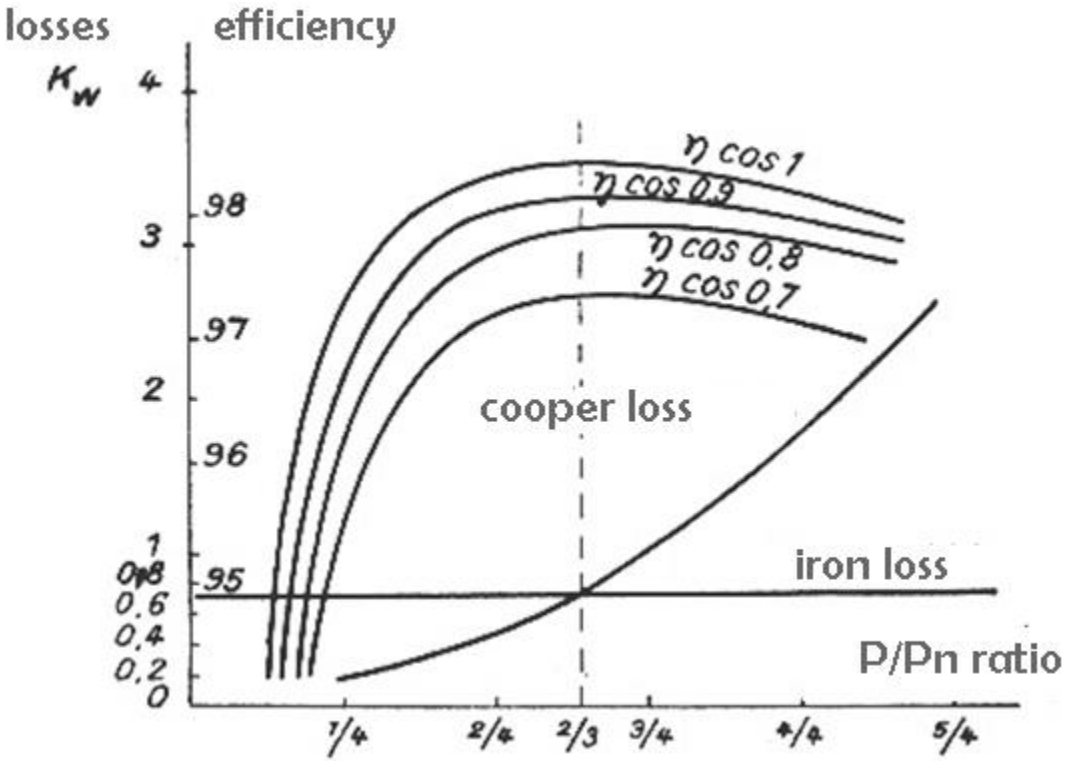
DC/AC Efficiency



4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – AC-SIDE LOSS FACTORS

- LV/MV Transformer Loss Factor



Source: electroaldesa.com

4. SOLAR RESOURCE & ENERGY PRODUCTION

LOSS FACTOR ANALYSIS – AC-SIDE LOSS FACTORS

- Transmission line Loss Factor

In the case that the transformation centre is in a distant substation, transmission line losses may be borne by the PV plant (depending on the applicable legislation, PPA, etc.)

Source: EnergyBusiness.mx

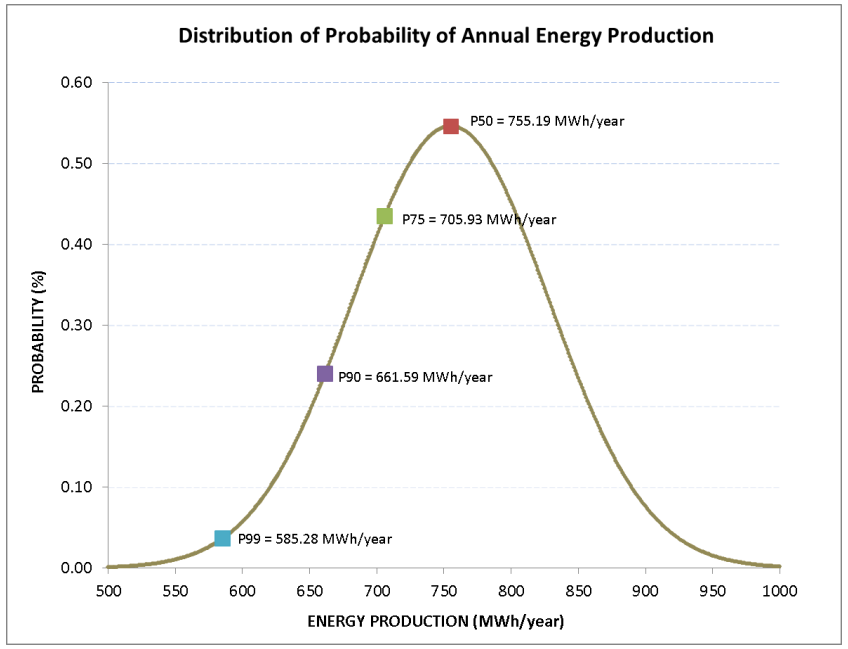
GOBIERNO DE ESPAÑA
VICEPRESIDENCIA CUARTA DEL GOBIERNO
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Gobierno de Navarra
Nafarroako Gobernua

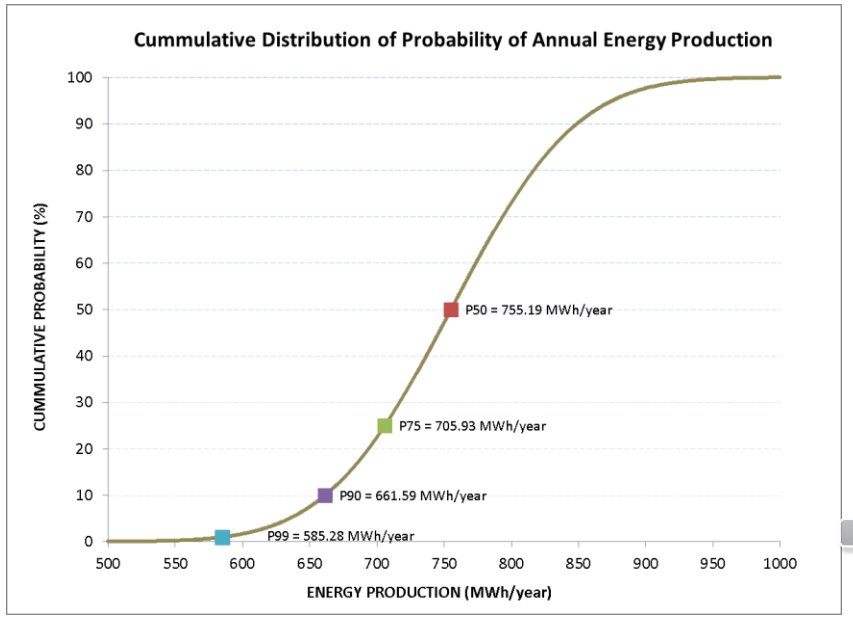
4. SOLAR RESOURCE & ENERGY PRODUCTION

ENERGY ESTIMATION - PROBABILITY

PRODUCTION VARIABILITY CALCULATION	
Concept	**Variability (%)**
Global Horz. Irradiance	1.76
PVSYST Calculation	3.00
PV Module tolerance	3.00
PV Module mismatch	0.22
PV inverter efficiency	0.50
Soiling	1.00
Tracking	0.00
Unabailavility	1.00
ANNUAL PRODUCTION VARIABILITY (STANDARD DEVIATION) (%)	**4.84**

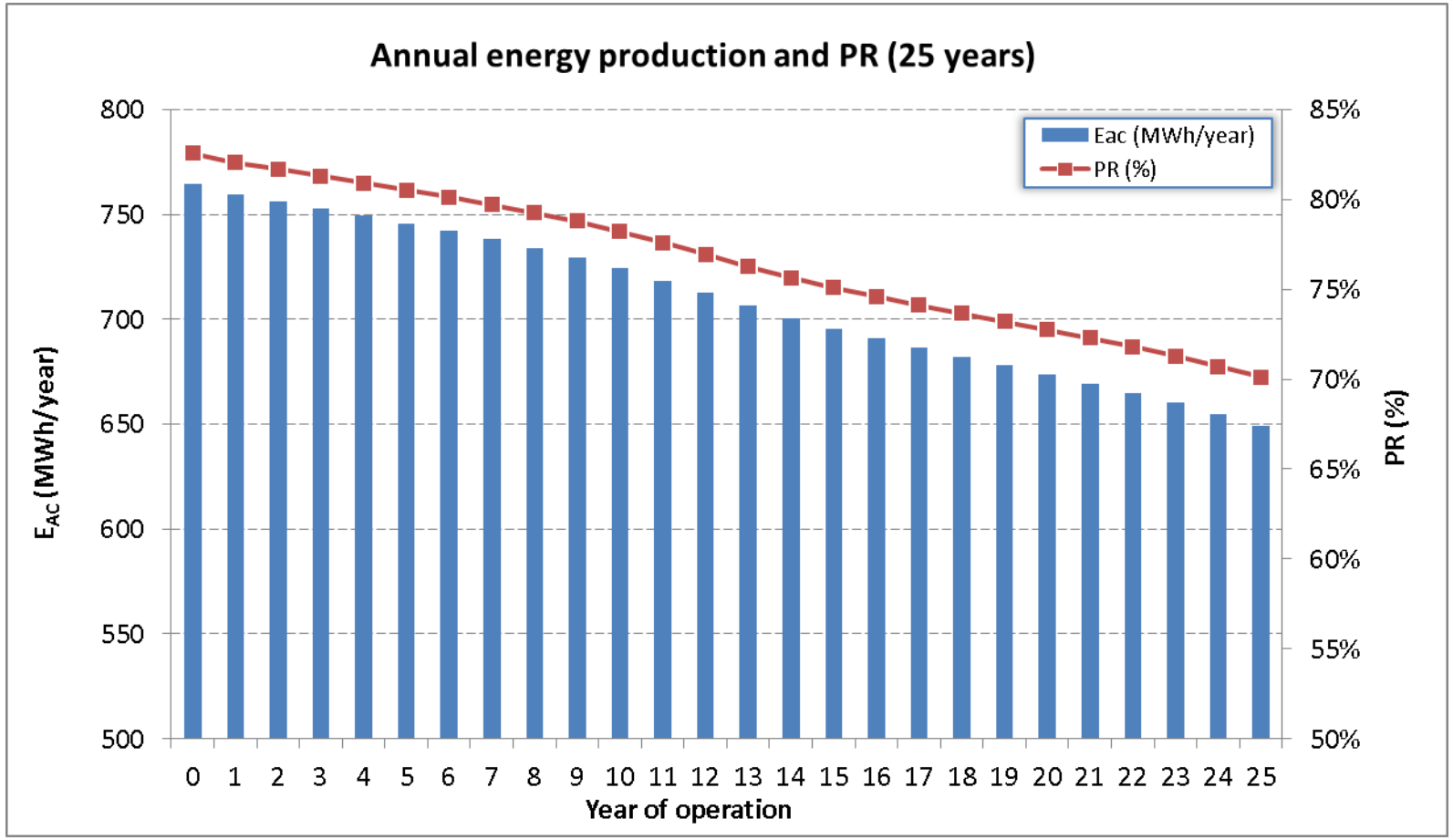
Source: CENER





4. SOLAR RESOURCE & ENERGY PRODUCTION

ENERGY ESTIMATION – LONG TERM



Source: CENER

5. POINTS OF INTEREST – FEASABILITY STUDY

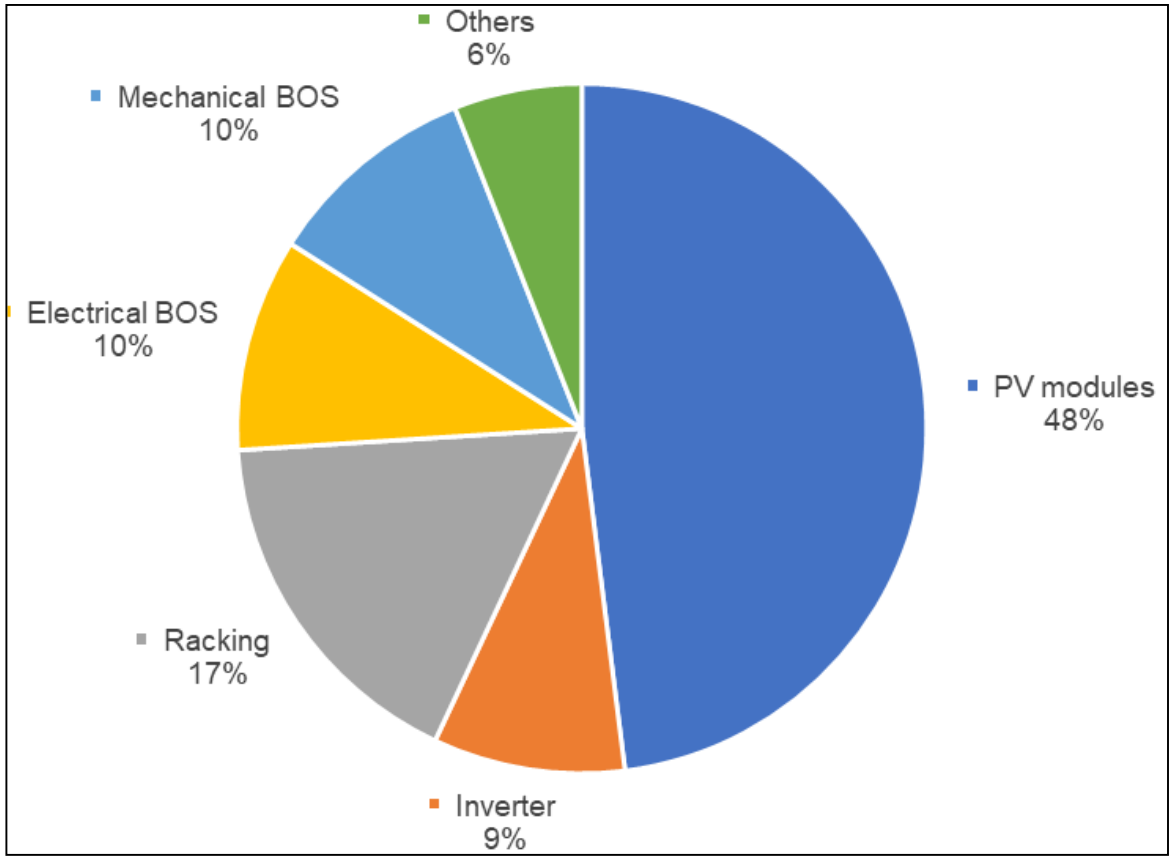
PV PLANT DESIGN STRATEGY

- Lower LCOE
- Higher IIR
- Lower initial investment
- Higher specific production
- Higher GCR
- Other strategies (experimental installations, emblematic projects, etc.)

PV Plant design strategy depends on:

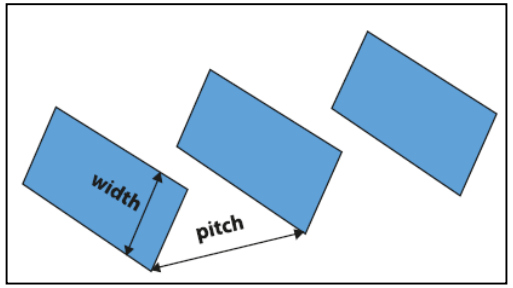
- Fixed costs (not related with energy production)
- Location
- Financing conditions
- Technical or legal limitations

COST OF EQUIPMENTS AND COMPONENTS

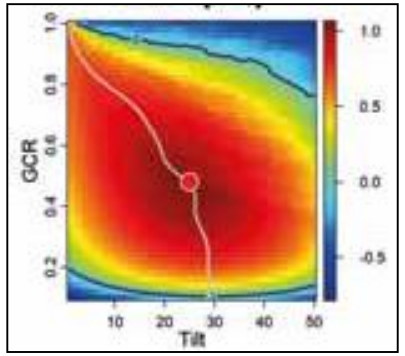


Source: Underwrite Laboratories

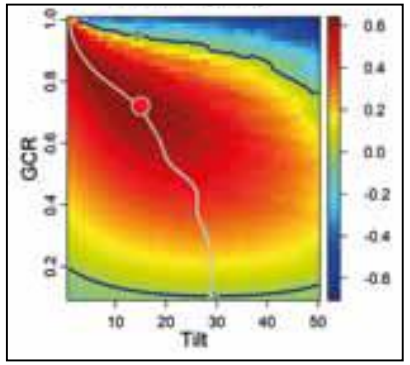
5. POINTS OF INTEREST – PREFEASABILITY STUDY

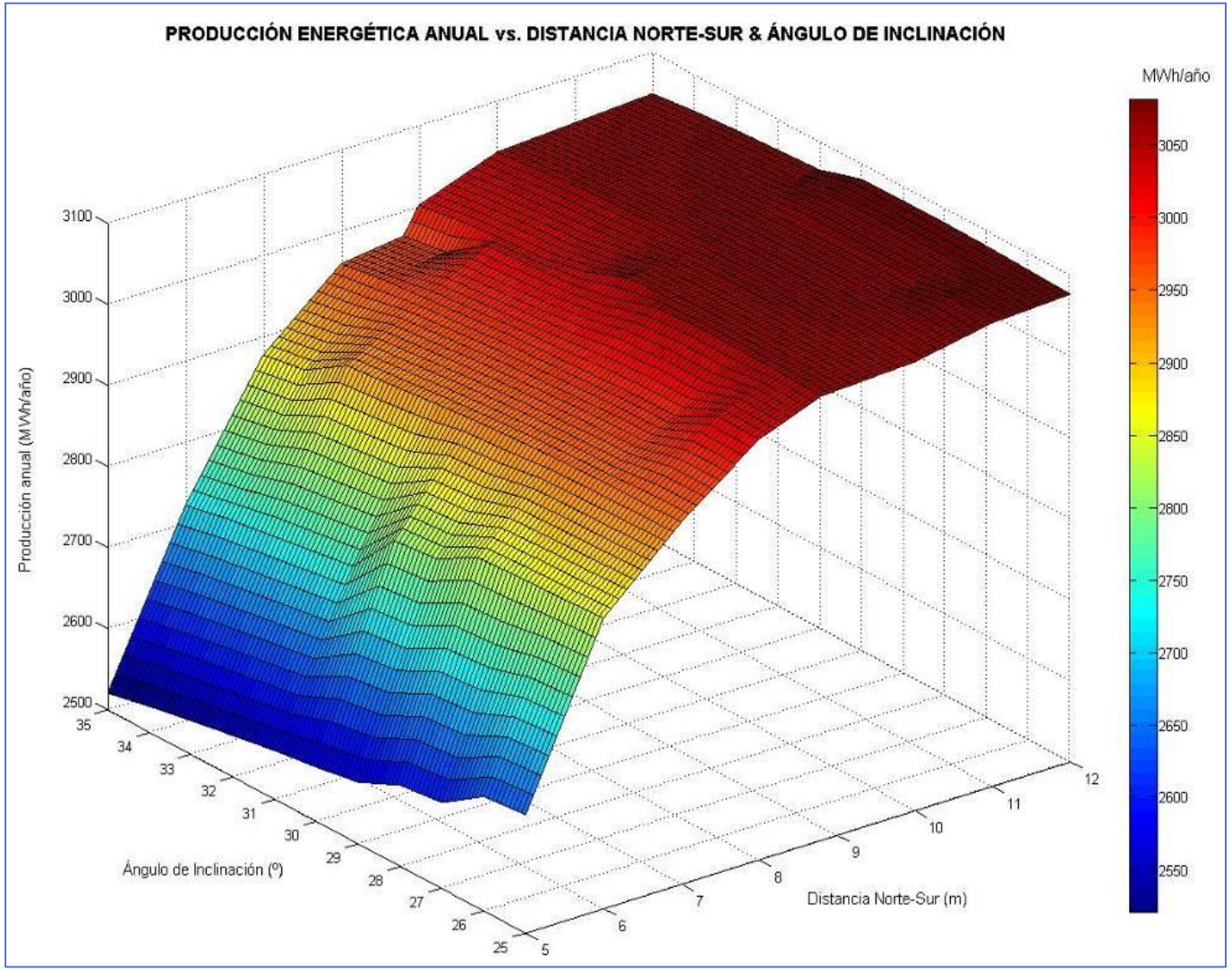


FIXED POWER



FIXED SURFACE

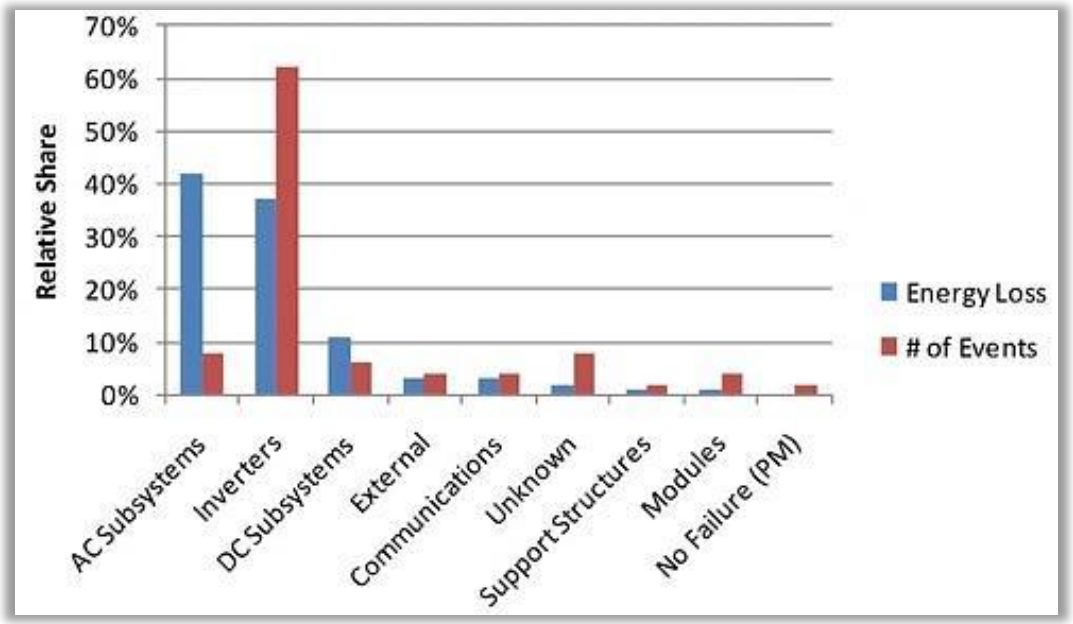


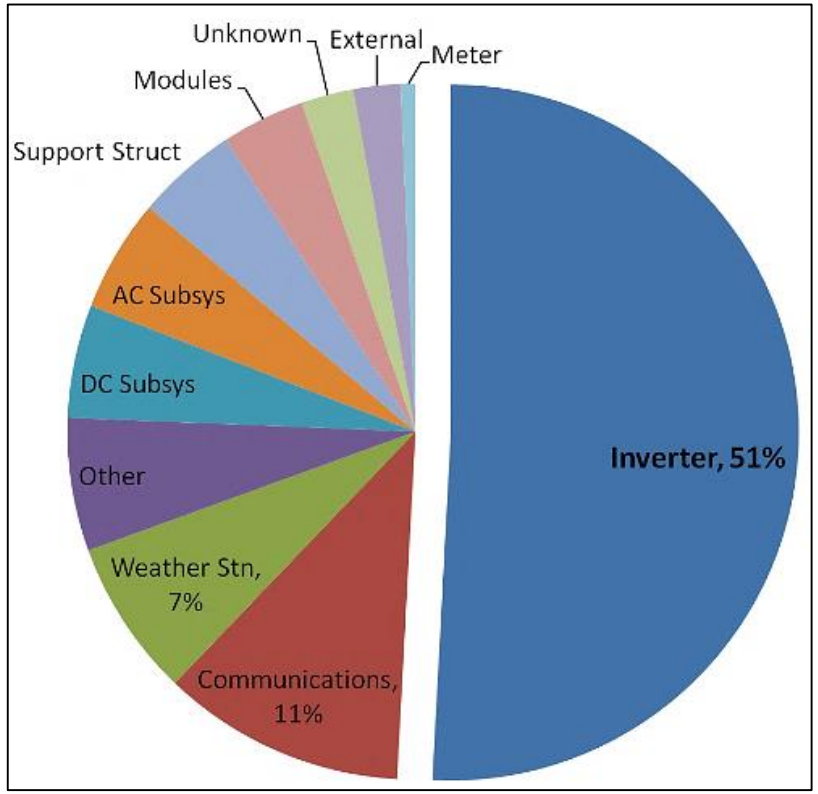


Source: CENER

5. POINTS OF INTEREST – O&M ISSUES

FAILURE EVENTS IN A PV PLANT





Source: SunEdison

Thank you for your attention!

imunoz@cener.com

info@cener.com

www.cener.com

CENER | CENTRO NACIONAL DE ENERGÍAS RENOVABLES
ADItech

GOBIERNO DE ESPAÑA | VICEPRESIDENCIA CUARTA DEL GOBIERNO | MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO | MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat

Gobierno de Navarra
Nafarroako Gobernua