

# SOLPVLAB

## Department of Solar Energy Technologies & Storage - PV area



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ENERGY CENTRE



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MINISTERIO  
PARA LA TRANSICIÓN ECOLÓGICA  
Y EL RETO DEMOGRÁFICO

MINISTERIO  
DE CIENCIA  
E INNOVACIÓN

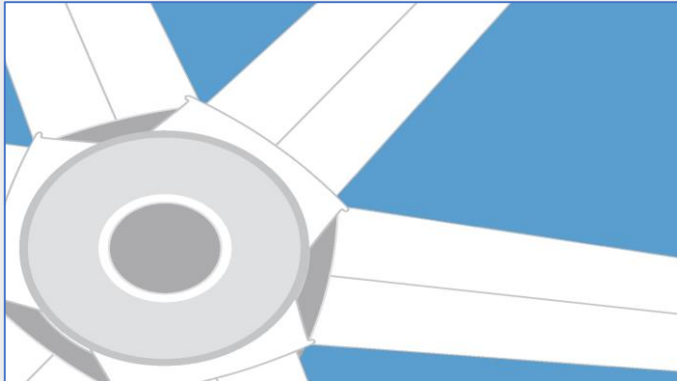
**Ciemat**



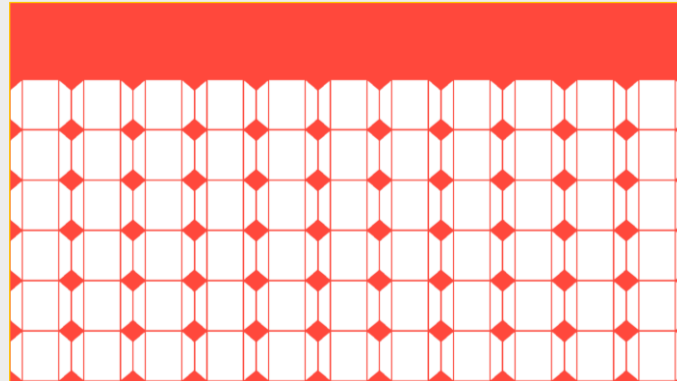
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# CENER RESEARCH AREAS

## SOLAR ENERGY TECHNOLOGIES AND STORAGE



Wind Energy



Photovoltaic Solar Energy



Solar Thermal Energy



Biomass



Energy in Buildings



Grid Integration of Renewable Energy

# Department of Solar Energy Technologies and Storage



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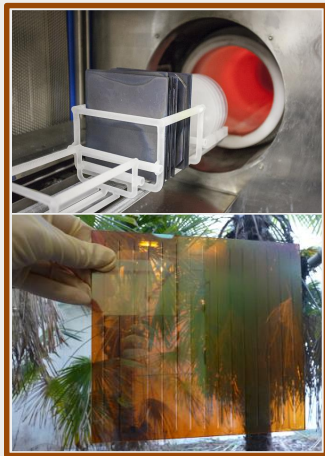
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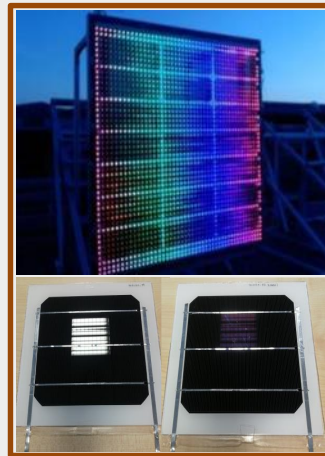


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# SUMMARY OF SERVICES PROVIDED OVER PV VALUE CHAIN



**Solar cell design and manufacturing**  
 Characterization of processes and full solar cell



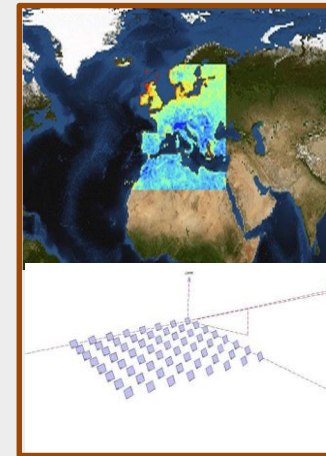
**PV and BIPV element design and prototyping**  
 Glass functionalization



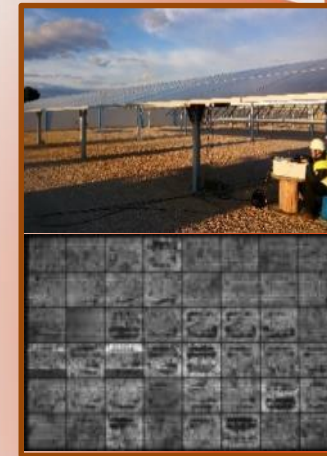
**PV modules accredited testing laboratory**  
 IEC certification laboratory  
 Outdoor testing



**Solar Tracker accredited testing laboratory**  
 PV inverter testing, quality & FAT audits



**Solar resource & energy estimation**  
 Preliminary & PV project finance  
 Technical advisor



**Commissioning**  
 Full PV plant inspection & diagnosis (aerial EL, IRT, IV curve)  
 O&M analysis



**1. SOLAR CELLS, MATERIALS AND COATINGS**

**2. ADVANCED PV MODULE**

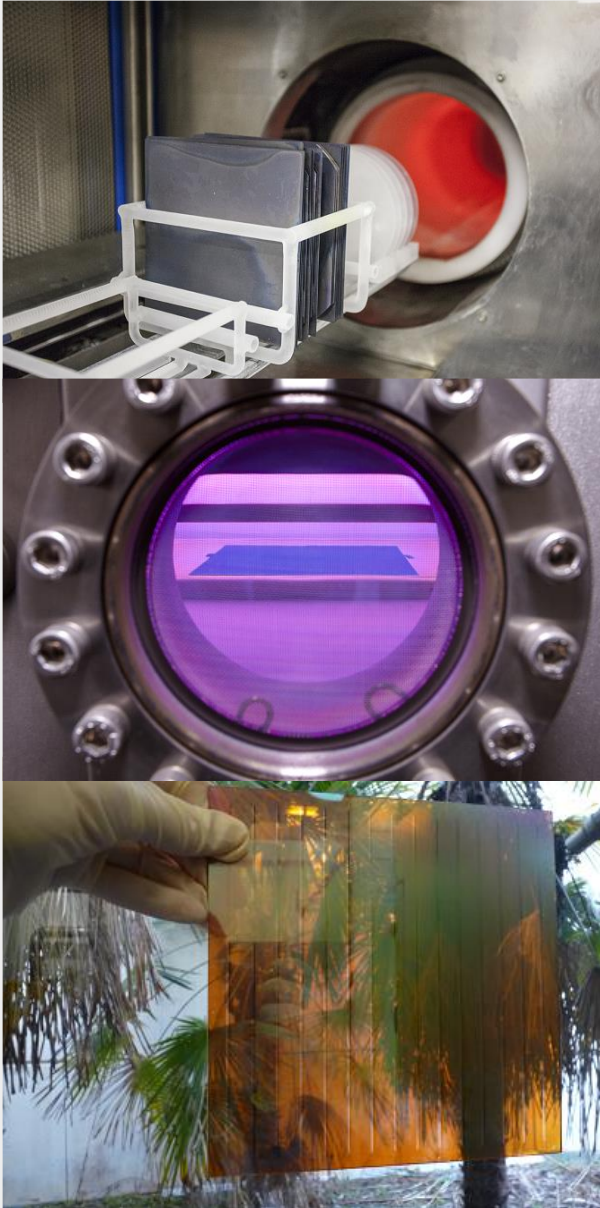
**3. PV MODULES AND MATERIALS TESTING**

**4. BOS TESTING**

**5. PV PLANT DESIGN**

**6. PV PLANT BUILDING AND O&M**

# 1. SOLAR CELLS, MATERIALS AND COATINGS



- ✓ **Integration of c-Si wafer based PV cells**
  - Route from Si wafers to complete solar cells. Expertise in Si micro and nano-structuring.
  - Chemical bench, diffusion furnace, ARC deposition, contacts printing and edge isolation.
  - **Moving forward to novel deposition techniques (LIFT)**
  
- ✓ **Thin film technology: Integration of amorphous silicon minimodules**
  - Minimodules integrated on glass.
  - Sputtering (ITO, AZO, metallization...), PECVD (p-i-n silicon), RIE, pulsed Lasers.
  
- ✓ **Characterization of individual processes and full solar cell**
  - Continuous sun simulator, spectral response, electroluminescence, lock-in thermography.
  - SEM with EDX, AFM, Profilometer, Spectroradiometer, Ellipsometer, SINTON,  $\mu$ -PCD, 4 probe resistance.
  
- ✓ **Silvaco TCAD-based design of solar cells – CENER MODELAB**
  - c-Si solar cell, heterojunction and **perovskite** tandem.
  - Design and optimization of architectures.

Recent related projects: VIPERLAB, TITAN-PV, DESAFIO

# 1. SOLAR CELLS, MATERIALS AND COATINGS

## Laboratory capacities



2 Cathodes Sputtering



PECVD & RIE



Glovebox with e-beam &  
Thermal Evaporation



Nanosecond Pulsed Lasers

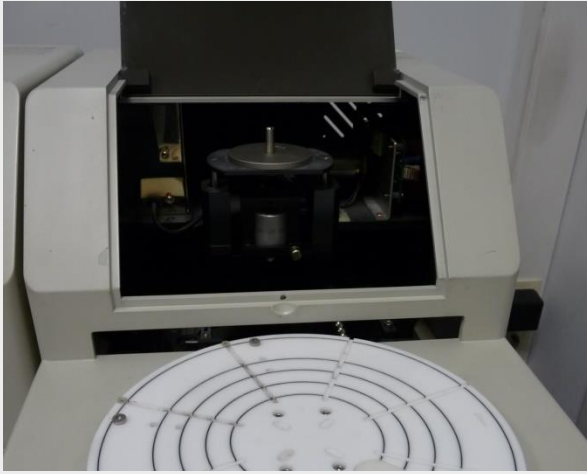


Photolithography &  
Chemical Bench



# 1. SOLAR CELLS, MATERIALS AND COATINGS

Four Probe technique



Photoconducance Lifetime Tester



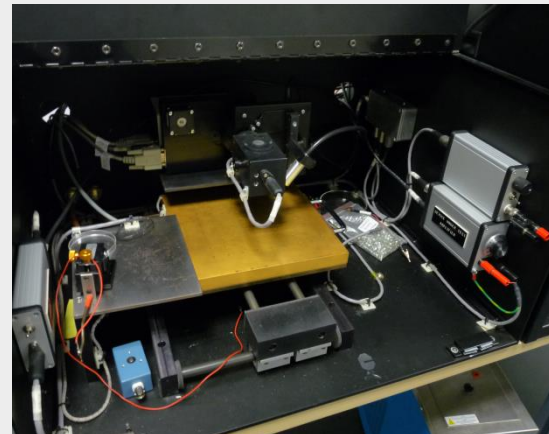
SEM with EDX



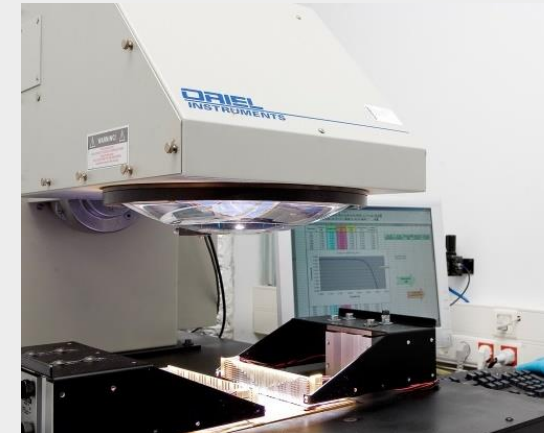
$\mu$ PCD – Microwave Photoconductivity Decay



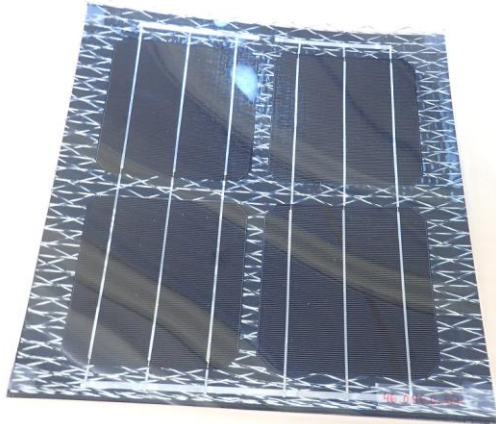
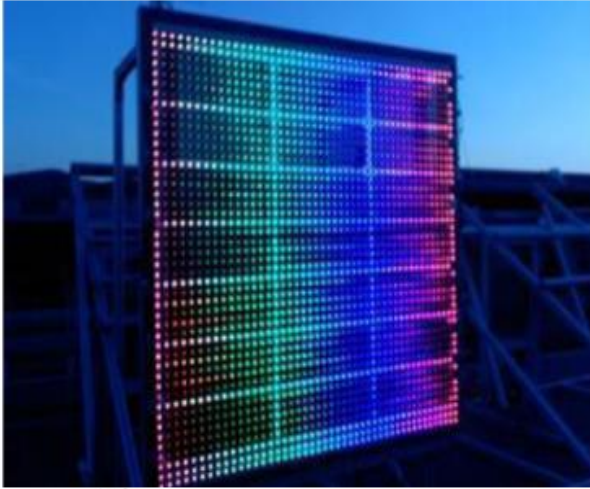
Spectral Response



Sun Simulator



## 2. ADVANCED PV MODULES



- ✓ **Prototyping of lightweight modules**
  - Fabrication and testing of lightweight modules using innovative alternative materials.
- ✓ **Design and fabrication of hybridized modules for BIPV**
  - Design, fabrication and testing of PV modules with thermal management.
- ✓ **Support to the development of functionalized coatings**
- ✓ **Glass surface functionalization**
  - Simple process providing multiple advantages to glass, such as anti-reflective, anti-soiling, IAM factor improvement, and passive cooling.
  - **Moving forward to upscale and transfer this technology.**
- ✓ **Moving forward to passive cooling strategies.**
- ✓ **Moving forward to flexible concepts.**
- ✓ **Moving forward to Eco-design and Energy Label of PV modules.**

Recent related projects: DESAFIO, OPENLAB, AISOVOL1, AISOVOL2, ETFE-MFM



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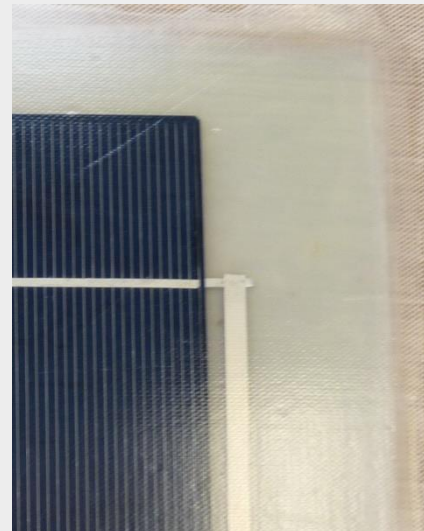
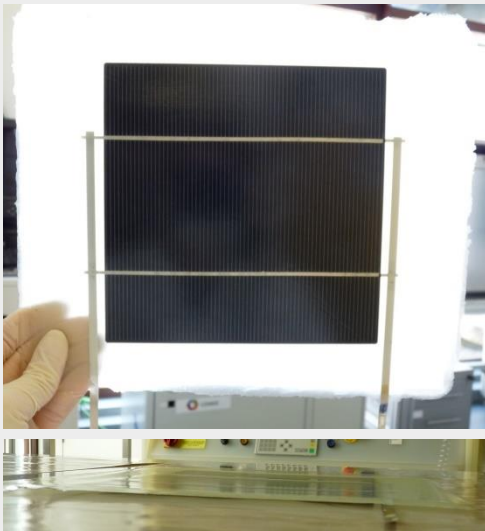
## 2. ADVANCED PV MODULES

### Laminator

**Process:** manufacture photovoltaic modules from individual components: photovoltaic cell, encapsulating material, glass and rear protective layer

The process is based on the polymerization of a thermoplastic, consisting of two or more components, that melts by the effect of temperature and "thermo-seal" the photovoltaic module to protect it from the environment.

- Experienced laminating up to 2 x 2 cells minimodules



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## 2. ADVANCED PV MODULES

### Spectroradiometric measurement equipment

**Characterization:** two spectrometers clustered together to cover spectral range from 250nm to 1650nm.

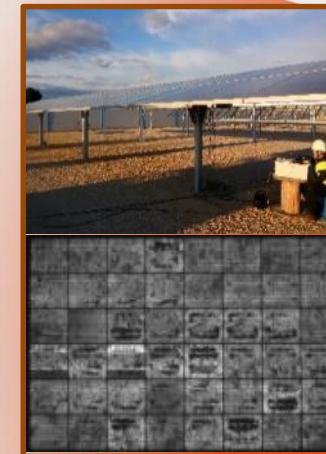
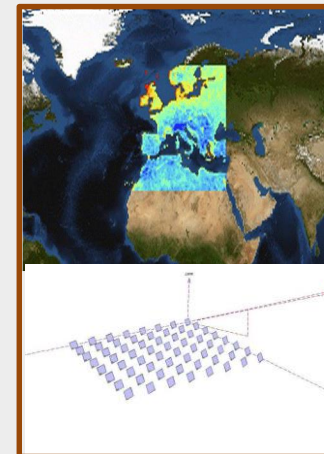
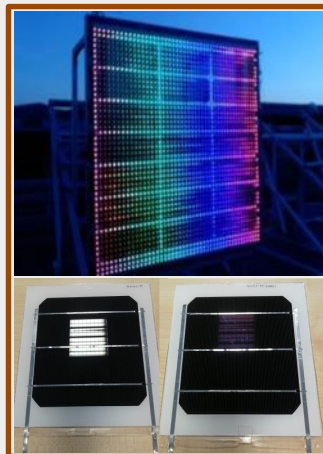
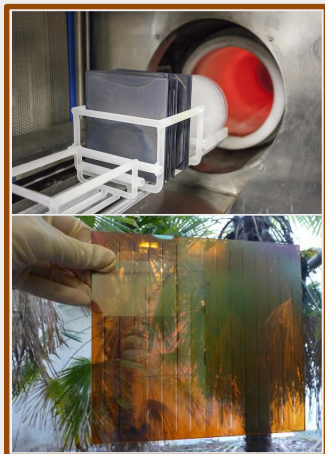
In combination with an integrating sphere it is able to determine the diffuse transmission and reflection (global and diffuse) of scattering samples.

It has, basically, no limitation in sample size

Experienced measuring transmittance and reflectance of silicon solar cells and glasses with and without coatings, laminated glasses.



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2. ADVANCED PV MODULE

3. PV MODULES AND MATERIALS TESTING

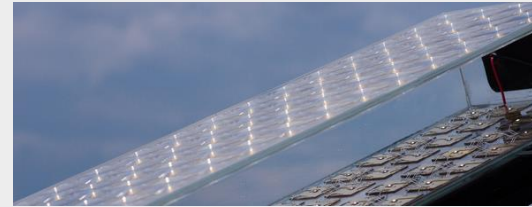
4. BOS TESTING

5. PV PLANT DESIGN

6. PV PLANT BUILDING AND O&M

# 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

CENER is accredited for the following standards:



## IEC 61215-1 & IEC 61215-2



Design qualification and type approval  
Year: 2021



## IEC 62108

CPV modules and assemblies, Design qualification and type approval



## IEC 62817

Design qualification of solar trackers  
Edition 1  
Year: 2015



IEC 61215-1-1 (c-Si)  
Year: 2021

IEC 61215-1-2 (CdTe)



IEC 61215-1-3 (a-Si & μc-Si)



IEC 61215-1-4 (CIS & CIGS)



Year: 2021

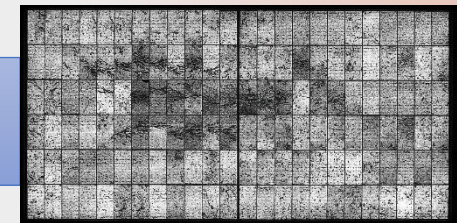
IEC TS 62804-1 (c-Si)

PID detection  
Year: 2015



## IEC 60904-13

Electroluminescence



## IEC 61730-1 & IEC 61730-2

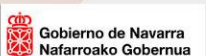


PV module safety qualification  
Edition 2 - Year 2016 Crystalline Silicon and Thin Film

Related projects: mostly commercial projects and supports activities in every R&D project



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### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

- ✓ + 1000 listed equipment
- ✓ + 82 DIFFERENT TEST METHODS



### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

#### ☐ SUN SIMULATORS

##### ✓ Pulsed sun-simulator

###### A. Tunnel type:

- Test area: 2m x 1,6m
- Lamp Type: Xenon with filters
- Class: AAA
- Pulse: 10 ms
- Thermal Chamber

###### B. “Desktop” sun simulator

- Test area: 2,4m x 1,4m
- Lamp Type: Halogens + LED
- Class: AAA+
- Pulse: 200 ms
- **Spectrum: Variable**
- Thermal chamber



### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

#### ENVIRONMENTAL CHAMBERS

##### ✓ Climatic Chambers

###### A. CW-40/6 from CTS x 2

- Volume: 6 m<sup>3</sup>. 2m x 1,3m x 2,3m (H x L x W)
- Range: Temperature → -40°C to 180°C  
Humidity → 10 to 95%HR

###### B. CCK-40/3900 from Dycometal

- Volume: 3 m<sup>3</sup>. 1m x 1,3m x 2,3 (H x L x W)
- Range: Temperature → -40°C to 100°C  
Humidity → 10 to 95%HR
- Utility: Damp heat test

###### C. C-70/200 from CTS

- Volume: 0,2 m<sup>3</sup>. 0,65m x 0,4 m x 0,75m (H x L x W)
- Range: Temperature → -70°C to 180°C  
Humidity → 10 to 95%HR



### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

#### ENVIRONMENTAL CHAMBERS

##### ✓ Climatic Chamber

##### D. CW-45/9/PV from CTS

- Volume: 9 m<sup>3</sup>. 3m x 2m x 1,5m (H x L x W)
- Range: Temperature → -45°C to 100°C  
Humidity → 10 to 95%HR
- Steady-state sun simulator included
  - Class: BBB
  - Test Plane: 2,4m x 1,5 m
  - Irradiance Level: 500 to 1200 W/m<sup>2</sup>
- Year: 2022





### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

#### ENVIRONMENTAL CHAMBERS

##### ✓ UV Chamber

###### A. CW+60/19 from CTS

- Test plane: 6,25 m<sup>2</sup>. 2,5m x 2,5m (H x W)
- Range: Temperature → 15°C to 70°C  
With temperature controls
- Exchanged lamps: Two different doses.

##### ✓ Salt Mist Corrosion Chamber

###### A. S 2500 M-TR from Liebisch

- Volume: 2,5 m<sup>3</sup>. 2,1m x 1m x 2,5 (H x L x W)
- Range: Temperature → 25°C to 50°C

##### ✓ Thermal Chambers

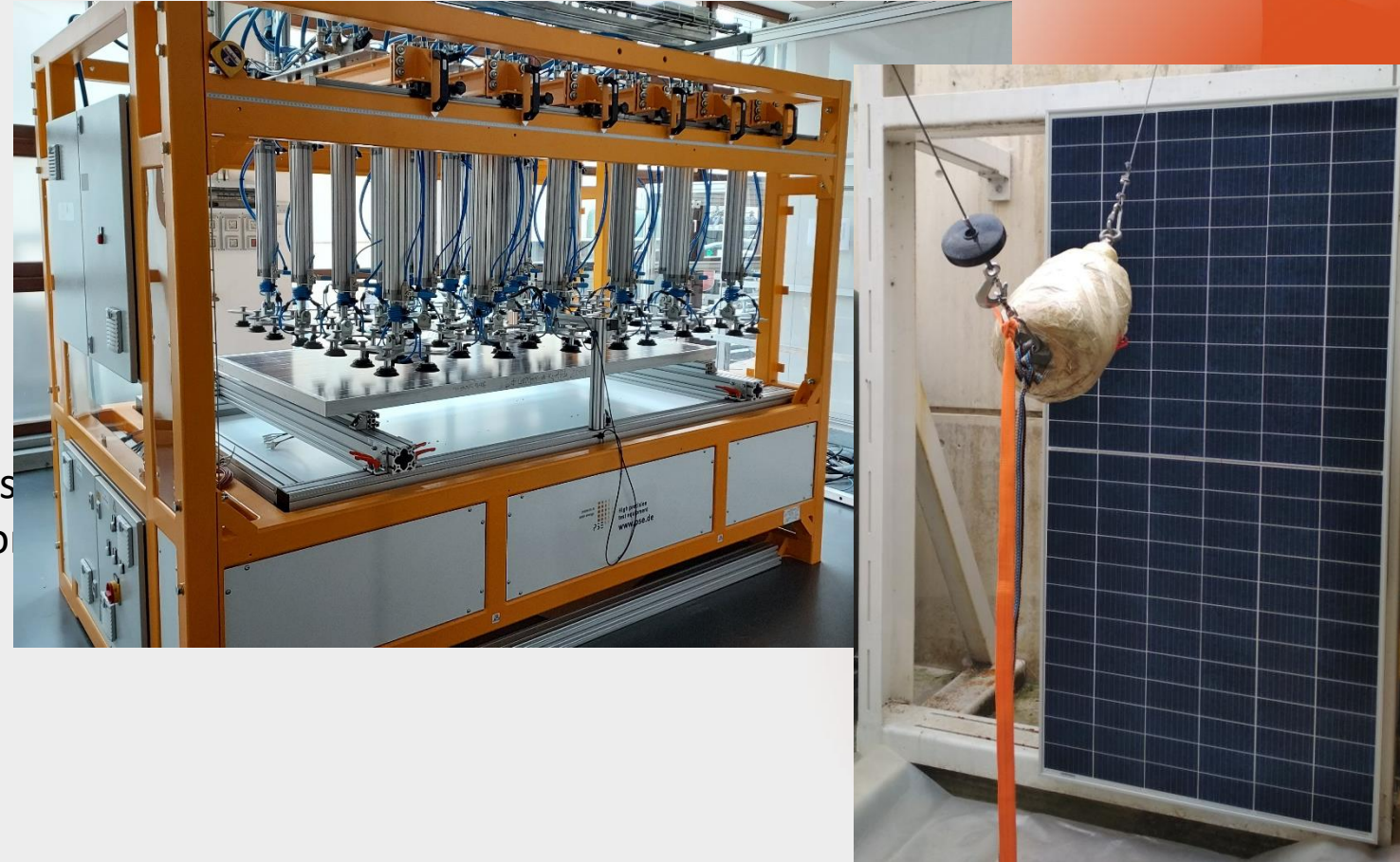
###### A. AFA-85/6000 from Dycometal

###### B. Walk-In modulo T9



## MECHANICAL TEST

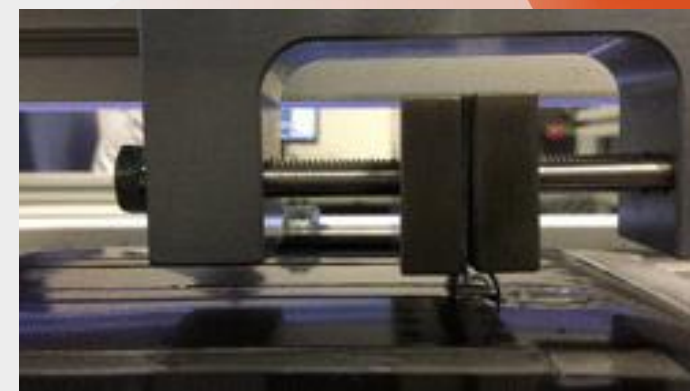
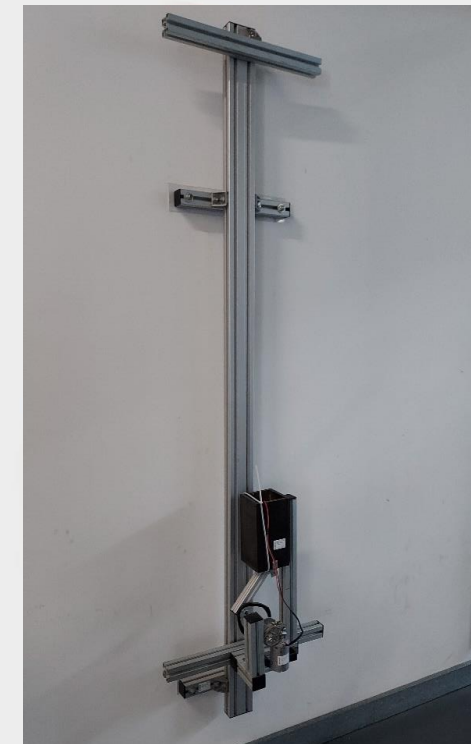
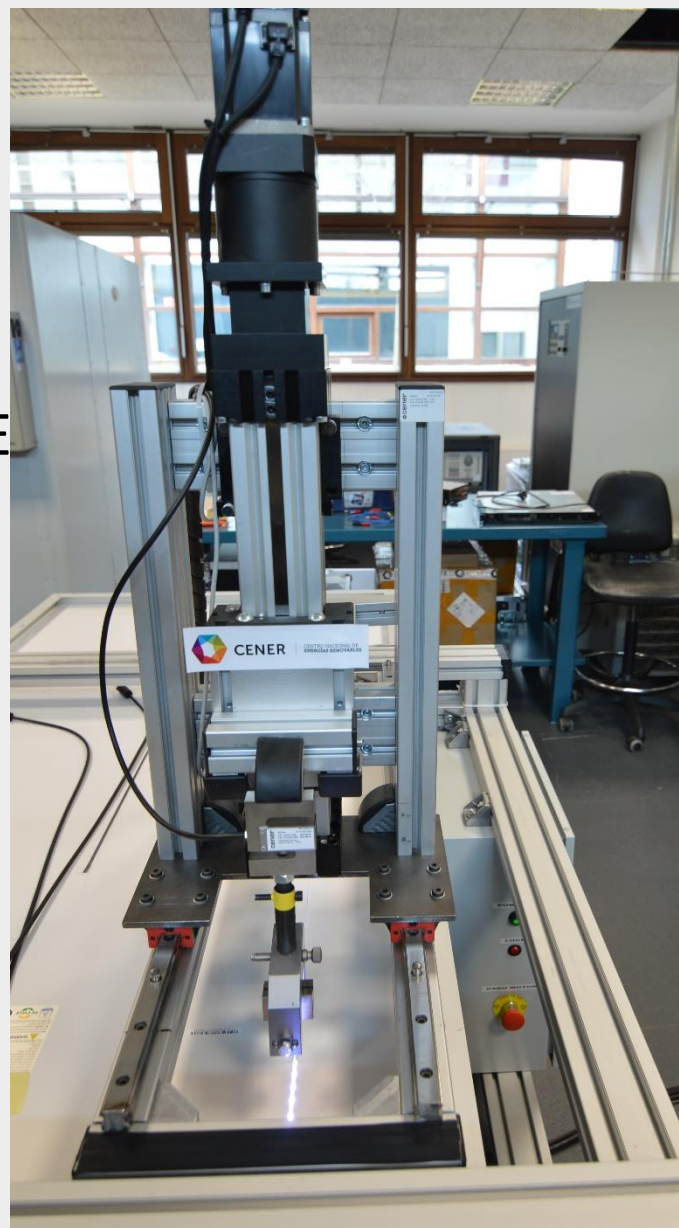
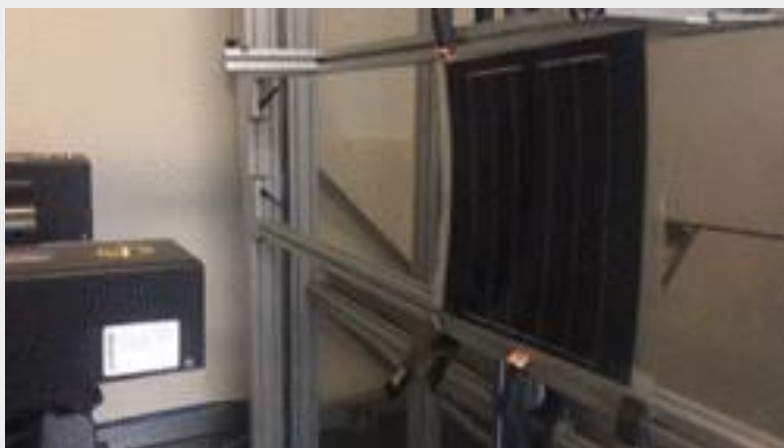
- ✓ BREAKAGE TEST BENCH
- ✓ MECHANICAL LOAD TEST BENCH
  - Replacement of the current bench
  - Test Surface: 2,4 x 1,5 m
  - Static & dynamic test (until 6 cycles)
  - 24 Pneumatic Cylinders – 96 suction
  - Range: 16.300 Pa (push)  
12.940 Pa (pull)



### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

#### ☐ MECHANICAL TEST

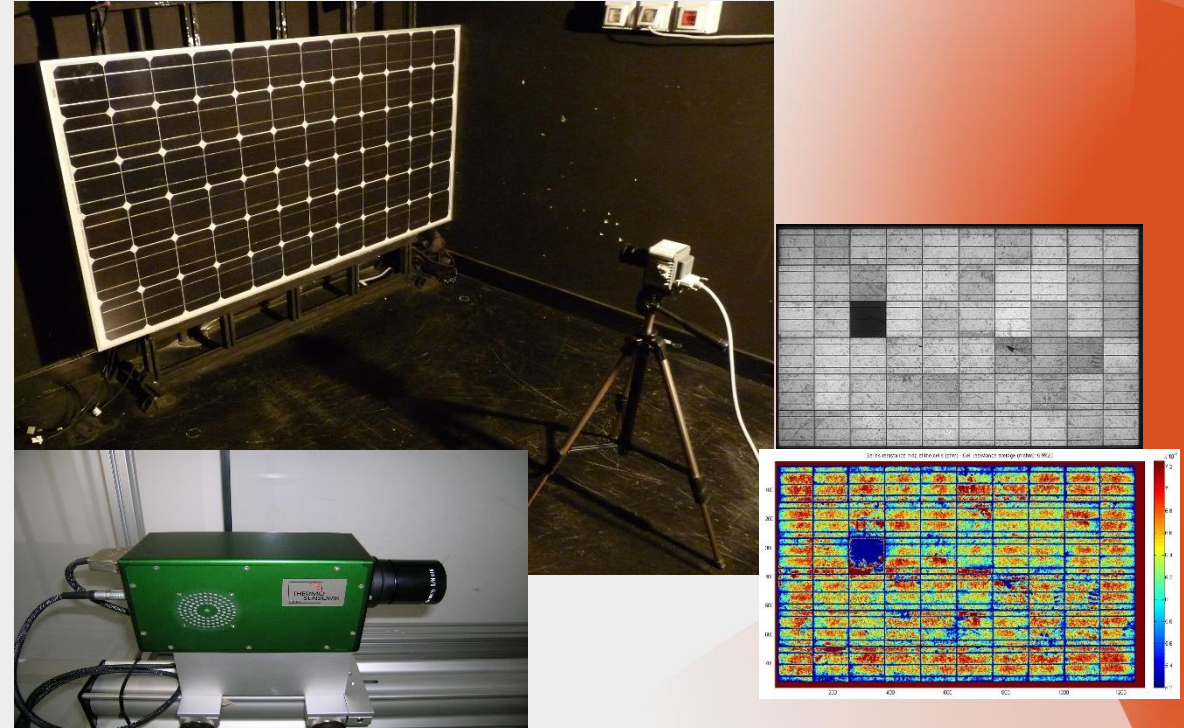
- ✓ HAIL STORM LAUNCHER
- ✓ ROBUSTNESS OF TERMINATIONS TEST BENCH
- ✓ PEEL-OFF TEST BENCH



# 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

## OTHER ELECTRICAL & CHARACTERIZATION EQUIPMENT

- ✓ ELECTROLUMINESCENCE
- ✓ LOCK-IN THERMOGRAPHY CHARACTERIZATION
  - PV Modules & Cells



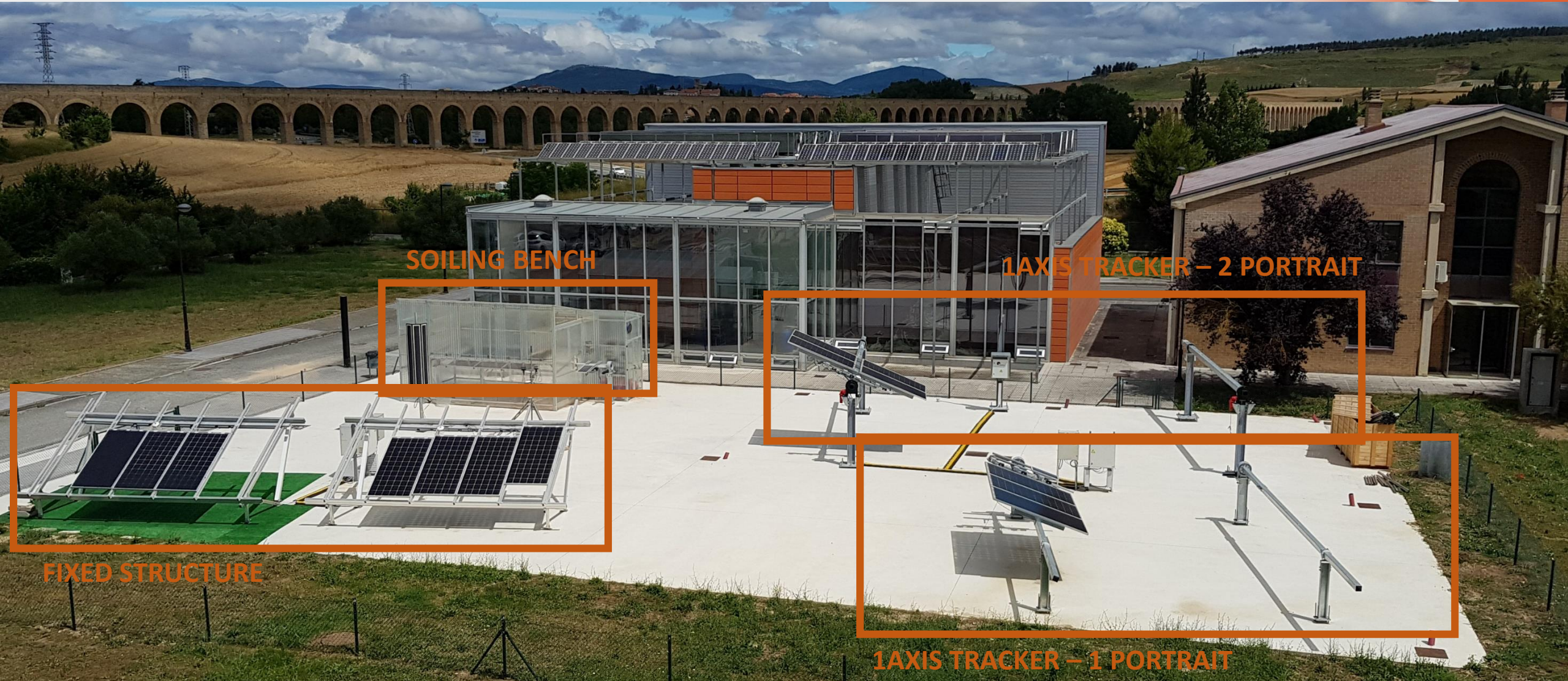
### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

#### □ OTHER ELECTRICAL & CHARACTERIZATION EQUIPMENT

- ✓ LABORATORY ELECTROLUMINESCENCE
- ✓ LOCK-IN THERMOGRAPHY CHARACTERIZATION
  - PV Modules & Cells
- ✓ POWER SUPPLIES
  - PV Modules Biased
  - Different ranges of V & I
- ✓ ELECTRICAL INSULATION MEASUREMENT
- ✓ DATA ACQUISITION SYSTEMS
- ✓ TEMPERATURE PROBES, IRRADIANCE SENSORS



### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB



SOILING BENCH

1AXIS TRACKER – 2 PORTRAIT

FIXED STRUCTURE

1AXIS TRACKER – 1 PORTRAIT



### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

#### ☐ CAPACITIES OUTDOOR EXPOSURE

- ✓ 15 Positions in Fixed Structure
- ✓ 12 Positions in 1-axis Tracker – 2 P
- ✓ 6 Positions in 1-axis Tracker – 1 P
  
- ✓ POSITION:
  - I, V, T measurements
  - Monitoring and recording
  - Test Plane Irradiance measurement
  - Individual MPPT
  
- ✓ METEROLOGICAL STATION
  - Global and Albedo Irradiance
  - Ambient temperature
  - 3 Sonic anemometers in the installation



### 3. PV MODULES AND MATERIALS TESTING -SOLPVLAB

#### ☐ CAPACITIES OUTDOOR EXPOUSURE

- ✓ 15 Positions in Fixed Structure
- ✓ 12 Positions in 1-axis Tracker – 2 P
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## SOILING BENCH

- ✓ Test Area: 8 m<sup>2</sup>
- ✓ Up to 4 PV modules
- ✓ Full-size test
- ✓ Interchangeable support structures
  - Fixed structure
  - Tracker



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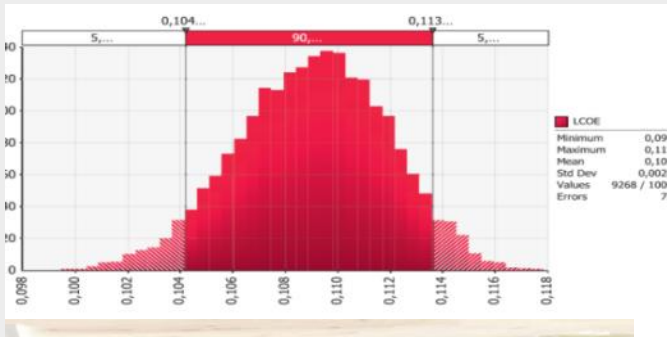
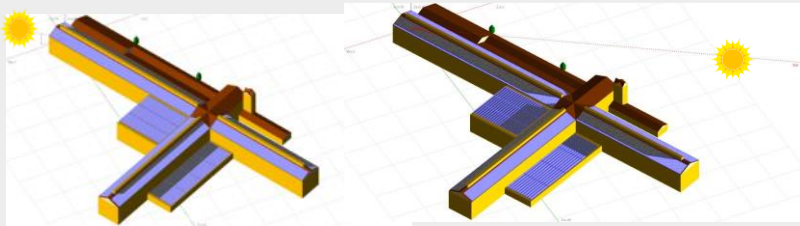
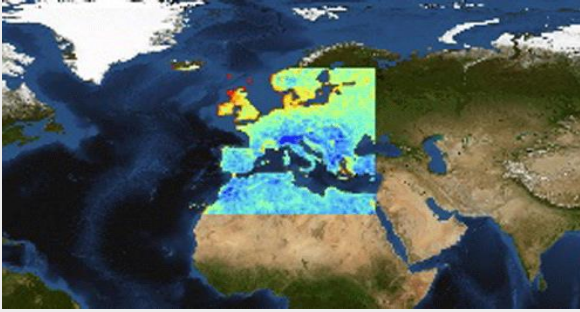
## 4. BOS TESTING



- ✓ **Accredited testing laboratory for:**
  - IEC 62817 Design qualification of **SOLAR TRACKERS**
    - Functioning & Performance tests
    - Characterization tests
    - Mechanical test
    - Environmental test
    - Specific Tracker Control Unit (TCU) test
- ✓ **Solar Trackers and PV inverters indoor & outdoor testing**
  - Testing laboratory of PV inverters up to 30 kW
  - On-site PV inverter characterization. Quality & FAT audits
  - Experimental Outdoor PV field for solar tracker, including different parts of the tracker separately (drive train, TCU)
- ✓ **Cleaning Systems testing**
  - Test bench developed by CENER to test and evaluate cleaning systems and effects produced along PV module lifetime
- ✓ **Moving forward to new tracking algorithms design, evaluation & validation**

*Related projects: mostly commercial projects and supports activities in every R&D project*

# 5. PV PLANT DESIGN



- ✓ **Solar resource characterization**  
TMY, Plausible MY, Forecasting, Site adaptation
- ✓ **Detailed optical modeling (Tonatiuh Ray Tracer)**  
PV and STE solar field optimized layouts
- ✓ **High temporal resolution PV simulation models**
- ✓ **Plant performance transient analysis for control and operation strategy**
- ✓ **Hybrid PV-CSP simulation software**
- ✓ **Moving forward to novel PV, CSP and/or hybrid solar applications (e.g. desalination, Agro-PV, floating-PV)**
- ✓ **Conceptual engineering and optimization of PV, CSP and Hybrid plants**
- ✓ **Preliminary PV Design Project**
- ✓ **Tendering, request of proposal and technical selection of offers**
- ✓ **Capacity building and training, training-in-the-job**
- ✓ **Quality system, accreditation processes and quality audits**

Recent related projects: *OPENLAB*, and commercial projects



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## 6. PV PLANT BUILDING AND O&M



- ✓ **Technical advisory in utility scale projects**
  - Contractual evaluation (EPC, Guarantees, O&M contracts)
  - PV project evaluation (including energy estimation, project finance)
- ✓ **Technical Due Diligence**
- ✓ **Commissioning**
- ✓ **Technical assistance “in the field”**
  - Energy production monitoring activities
  - PR evaluation and analysis
  - Troubleshooting of PV plants performance and components
- ✓ **Third Party Laboratory for Quality Control of PV Modules**
  - Characterization test (Visual inspection, I-V Curve, Insulation test, Electroluminescence,...)
  - Environmental tests:
    - PID Test, LeTID test
    - Damp heat, thermal cycling, UV exposure test
- ✓ **Full diagnosis and inspection of PV plants**
  - Quality control by advanced terrestrial and aerial inspections based on EL and AI (CELSOS)
  - IR Thermography & IV Curve Tracer
  - Aerial visual inspection for PV plants with high distributed dispersion or difficult access
- ✓ **Moving forward to innovative encapsulant diagnosis techniques**

*Related projects: INSPECPV and Commercial projects*

# MEMBERSHIPS

- Founding member of European Solar Manufacturing Council (ESMC); participating at PV-IPCEI
- Member of the Executive Committee of the International Energy Agency PVPS (Photovoltaic Power Sources) representing Spain
- Member of EERA-PV
- Member of the executive committee of the Spanish Photovoltaic Technological Platform (Fotoplat)
- Member of Unión Española de Fotovoltaica (UNEF)
- Member of the SC82, national sub-committee, part of the International Electrotechnical Commission (IEC) for discussion and issuance of PV regulations
- Member of WG2, WG3, WG7, WG8, WG9, international working groups of the IEC, specifically dedicated to Concentrated Photovoltaic technology (CPV) and flat PV modules and materials within TC82
- Member of the scientific committee of the European Photovoltaic Solar Energy Conference EUPVSEC

# MAIN REFERENCES (PHOTOVOLTAIC TECHNOLOGIES)



- 30+ Solar Resource Assessments
- 10+ new components, devices and methods.
- 10+ Yield Assessments & Feasibility Studies.
- 10+ specialized training courses.
- 25+ On-site O&M Services
- 100+ Module characterization test projects
- 20 + Module Certification Tests under IEC standards
- 5+ Solar Tracker certification under IEC standards



**THANKS A LOT.**

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