Workshop SOLARX Project
CPV receiver´s implementation

SolarPACES, 25/09/2025

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CPV receiver: Goals

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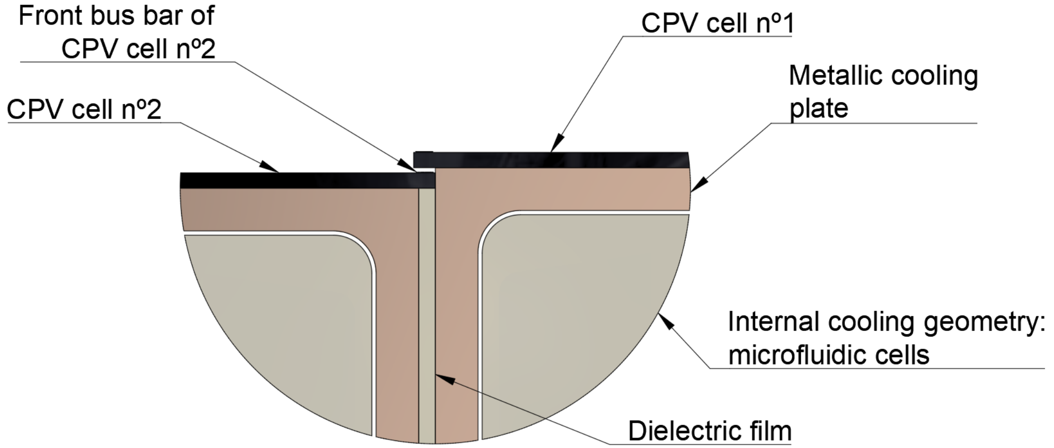
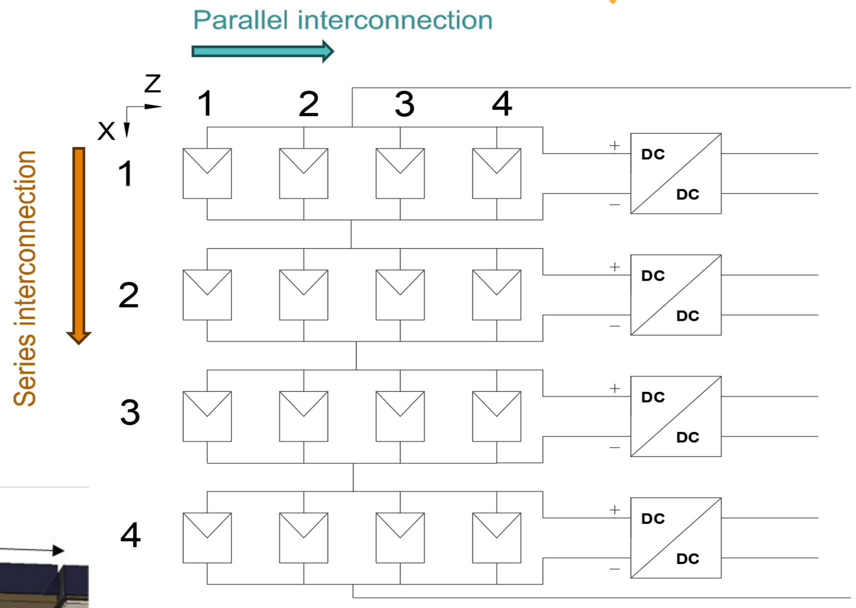
Main goals:

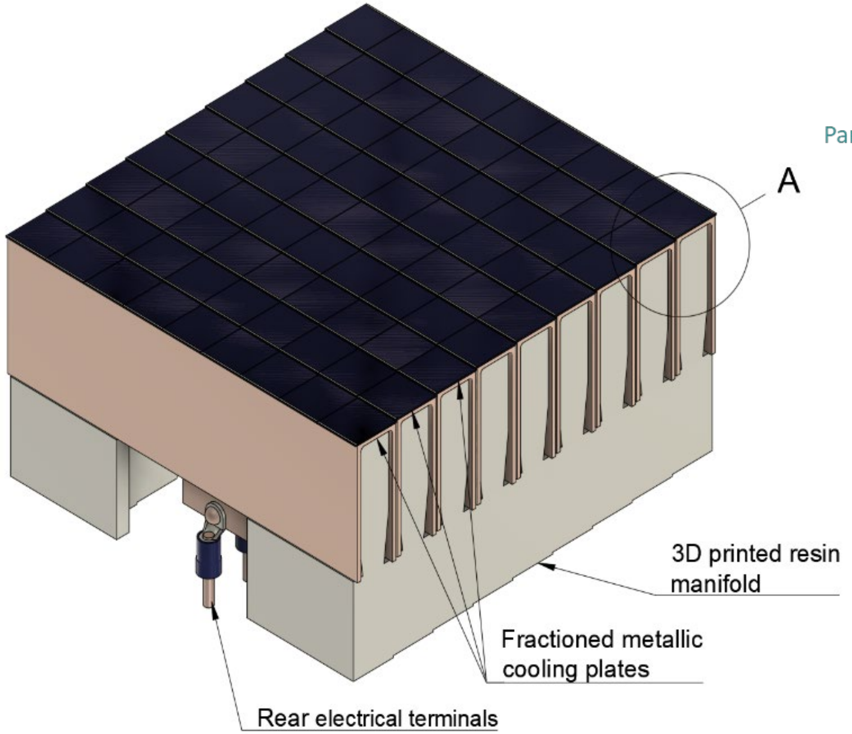
1. Increase the **temperature uniformity** to overcome the **voltage mismatch** losses when the CPV receiver is submitted under **non-uniform solar irradiance**.
   - Maximize the cooling capacity
   - Provide electric interconnection of the CPV cells with the external DC-DC converters without affecting the active surface area of the receiver

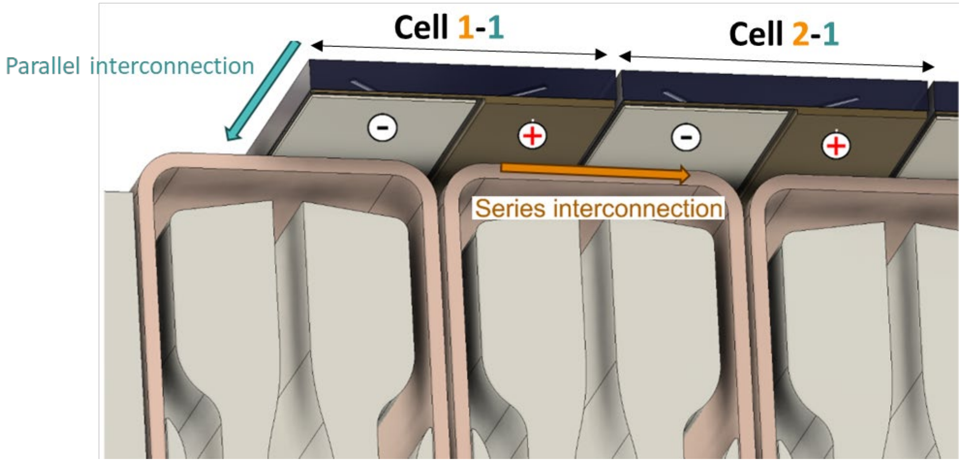
2. Reduce the **current mismatch** losses when the CPV receiver is submitted under non-uniform solar irradiance by using a **DC/DC converters**.

CPV receiver: Global concept



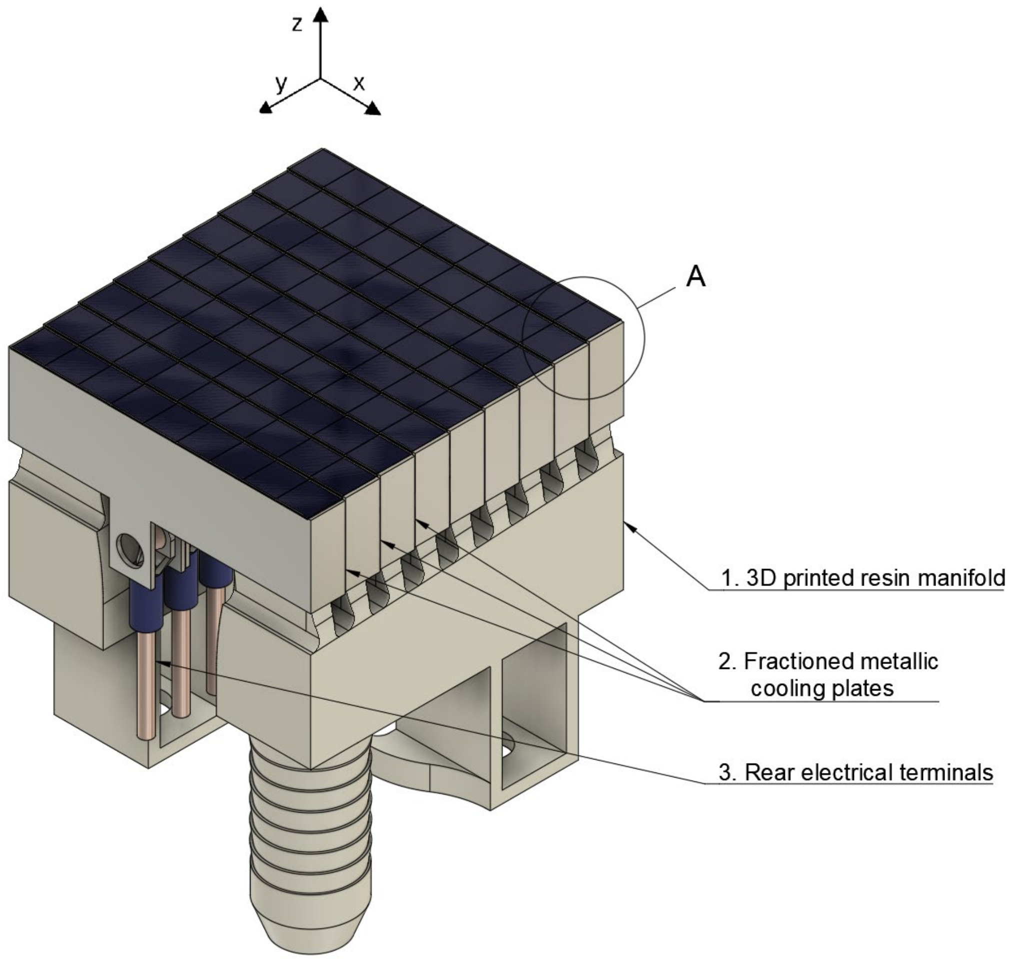


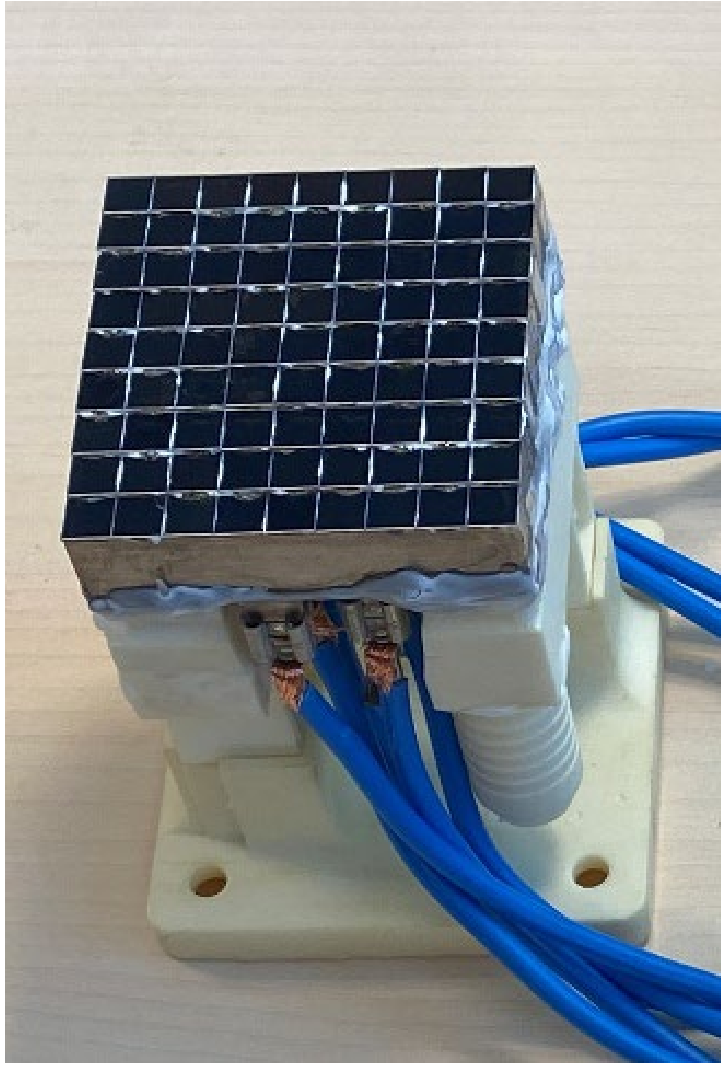




International Application Number: PCT/EP2025/055479, protecting integrated thermo-electrical receiver design.

CPV receiver: From design to outdoor characterization





Design and modelling of the CPV receiver

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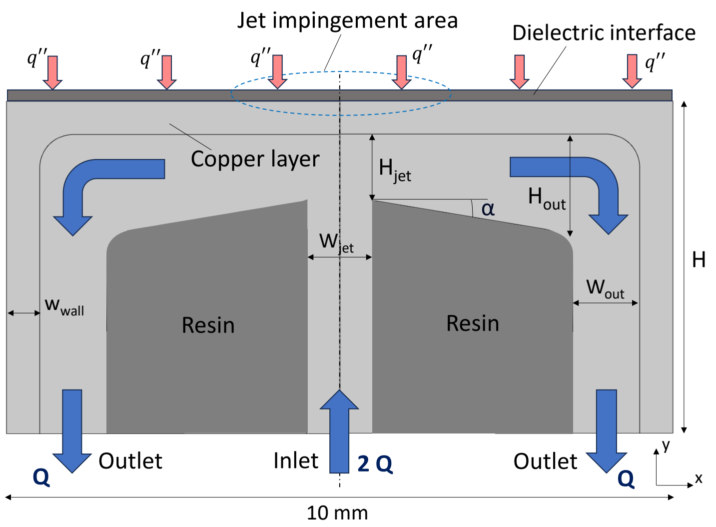
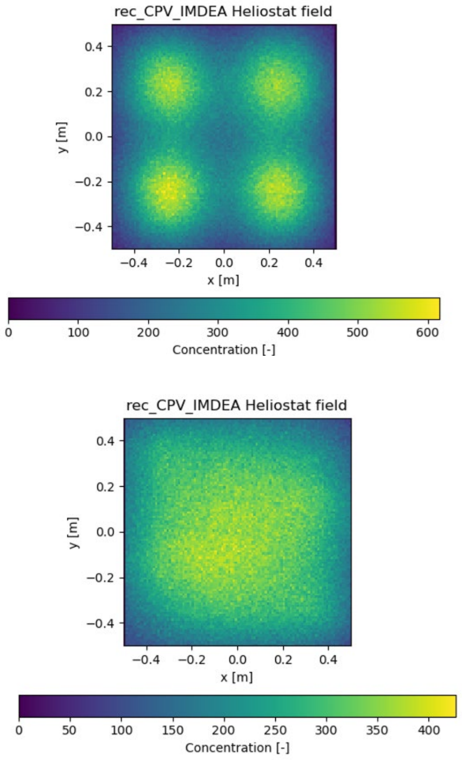
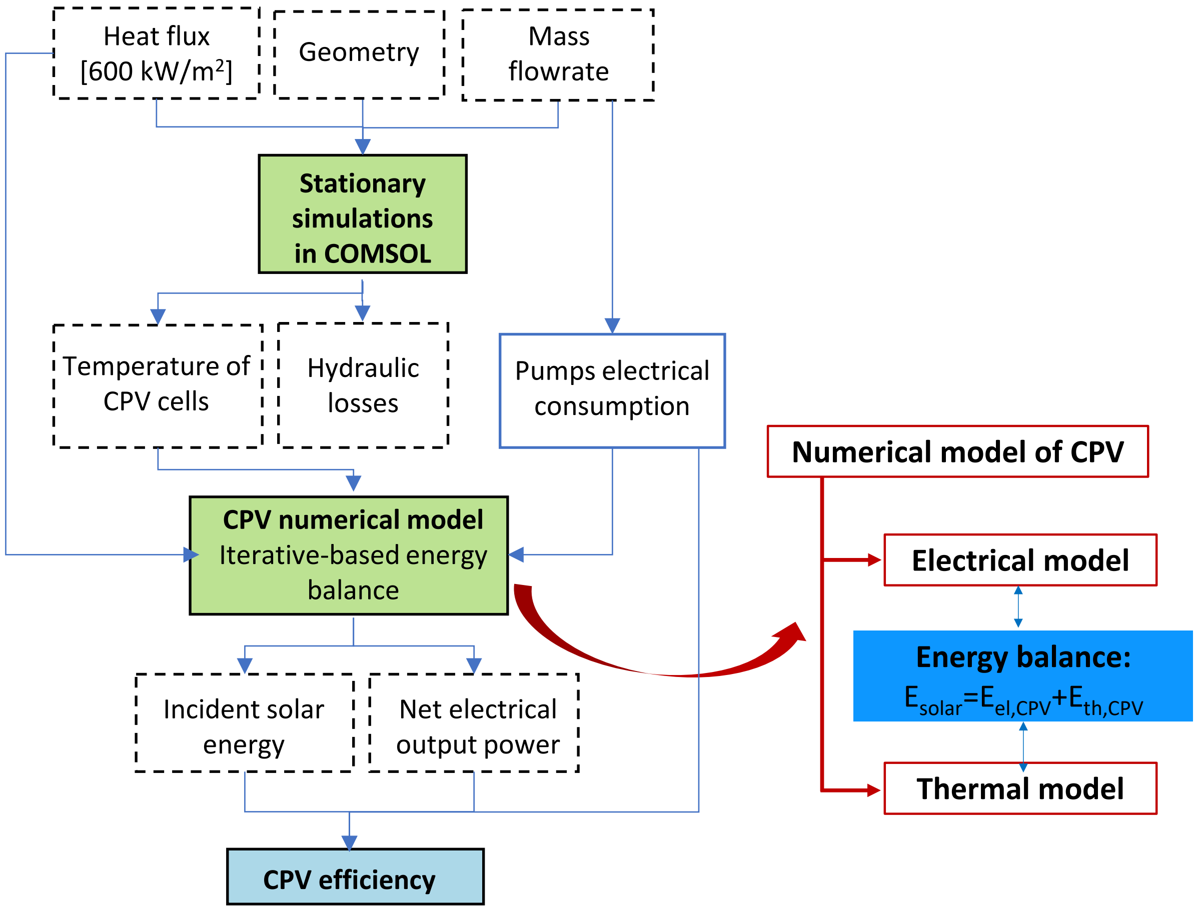
- Optimal design of the cooling device was defined through a numerical optimization







Design and modelling of the CPV receiver

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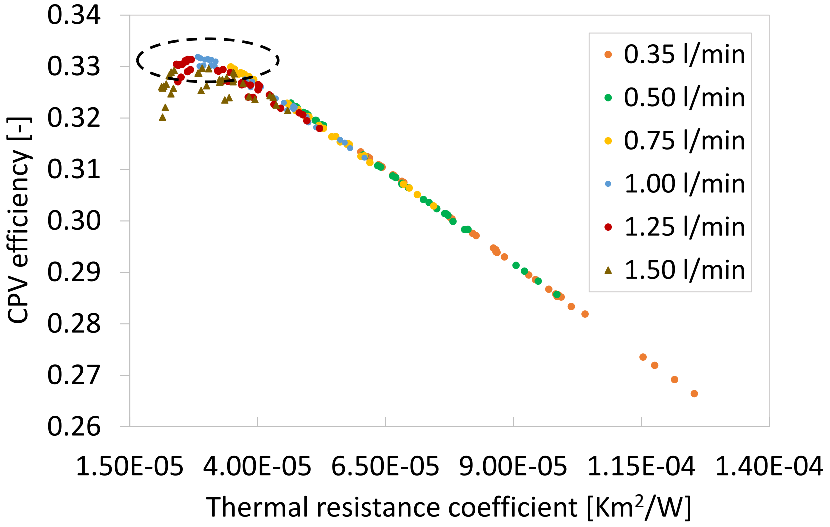
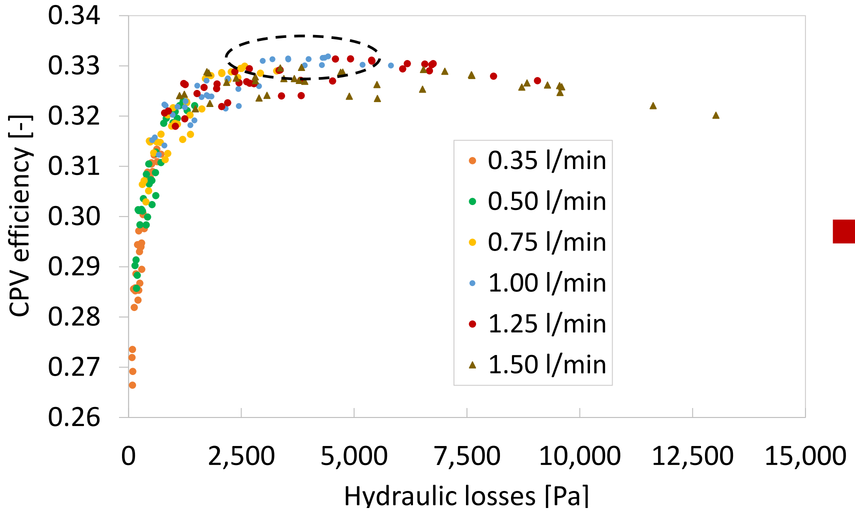
- <u>Optimal design</u> of the cooling device was defined through a numerical optimization

Mismatch losses reduced by >70% using DC-DC converters + jet impingement

CPV efficiency of studied scenarios



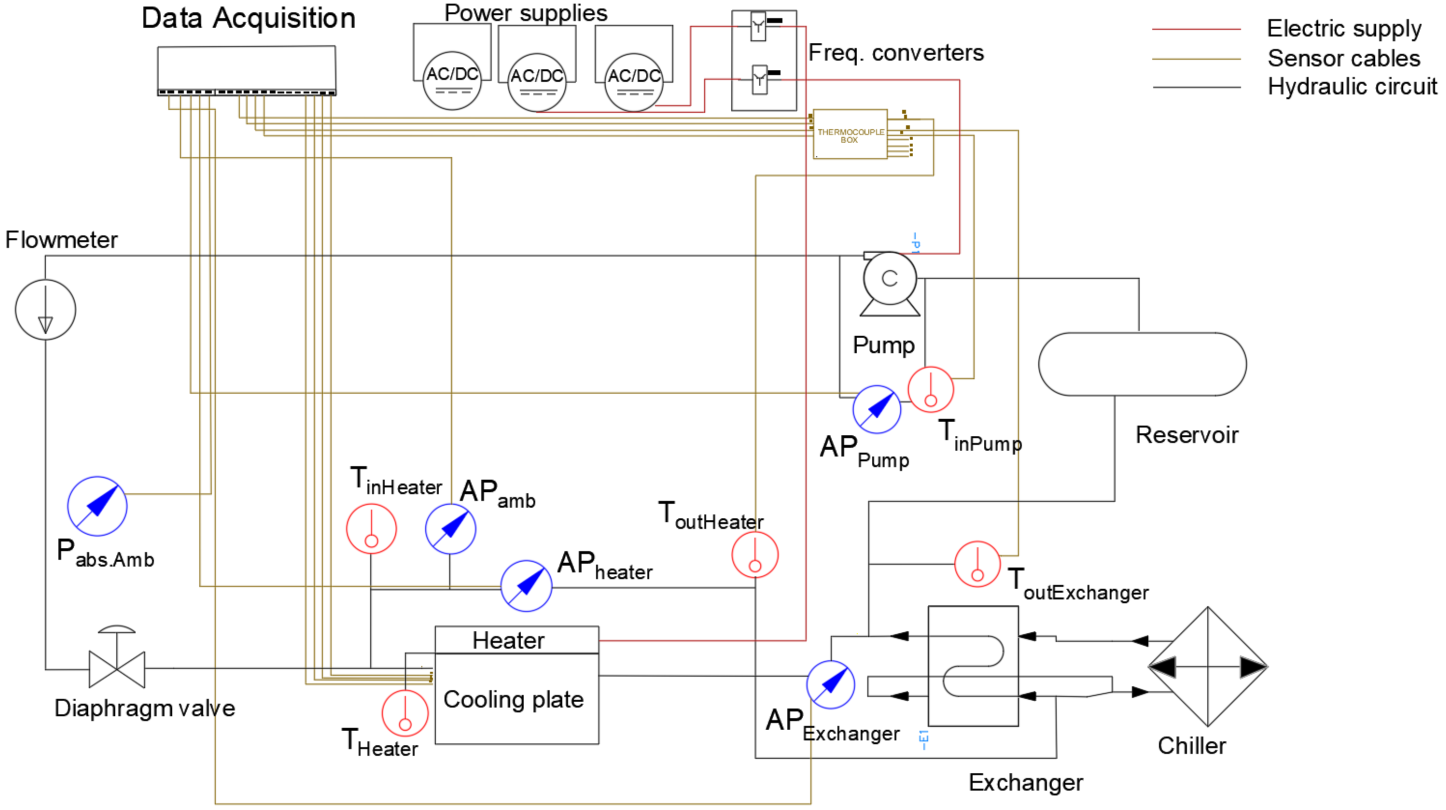


Optimal geometry

Fabrication and testing of the cooling device

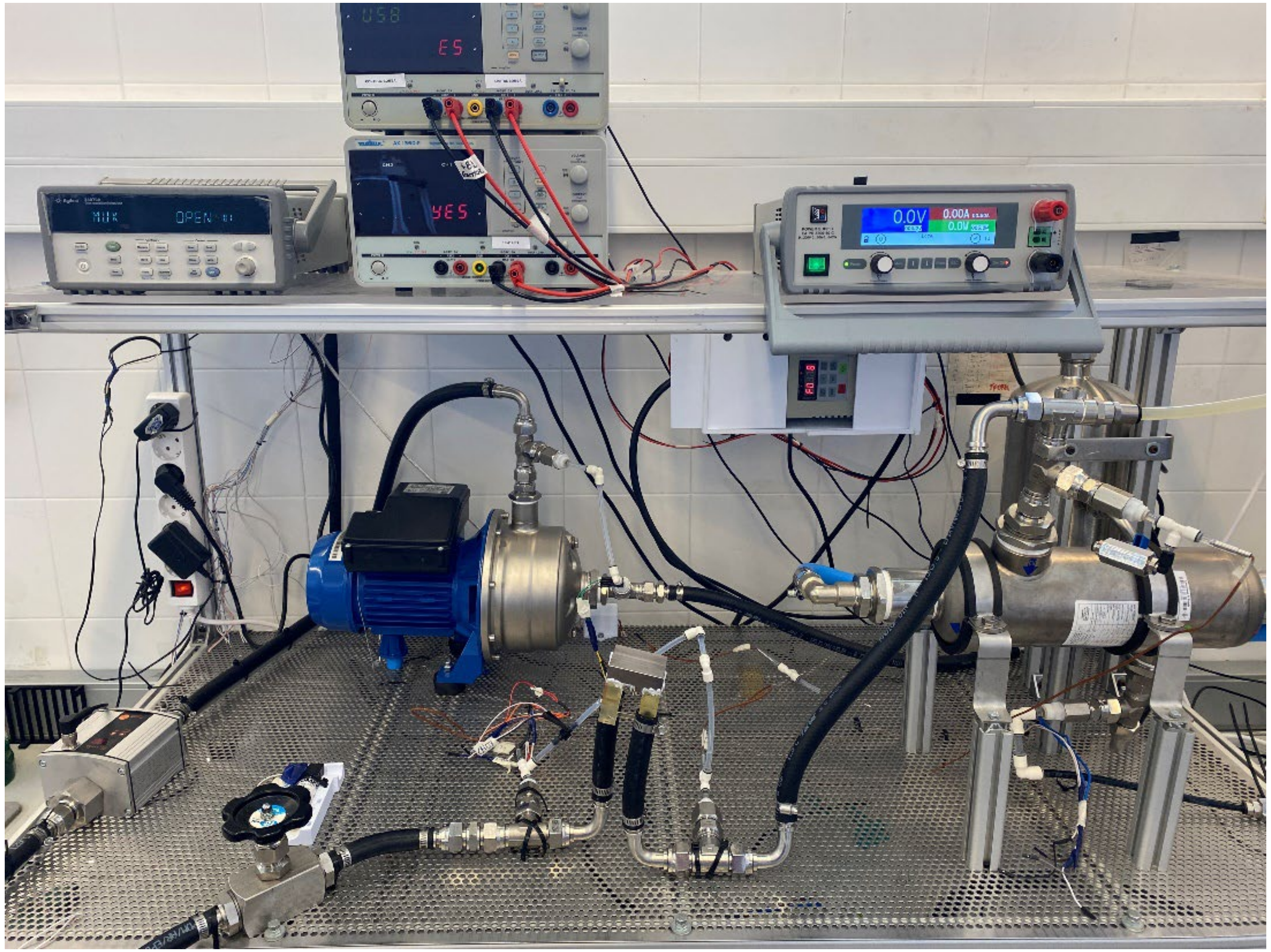
Thermal & hydraulic characterisation

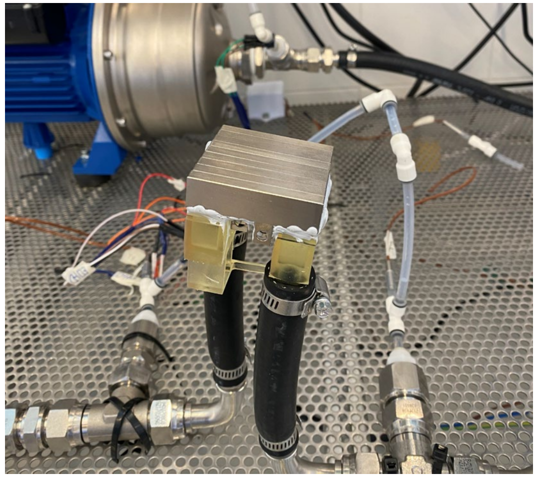
- **Test bench**: centrifugal pump (0–40 L/min), 3 kW chiller, liquid-liquid titanium heat exchanger.
- **Ceramic heater**: 50 × 50 mm^2, 1.86 kW → 74.3 W/cm^2 (≈743 suns).
- **Measured heat transfer coefficient**: $>1 \times 10^4$ $W/m^2 \cdot K$.
- **Stability**: no leakage, >2 h continuous operation validated under 3 bar.

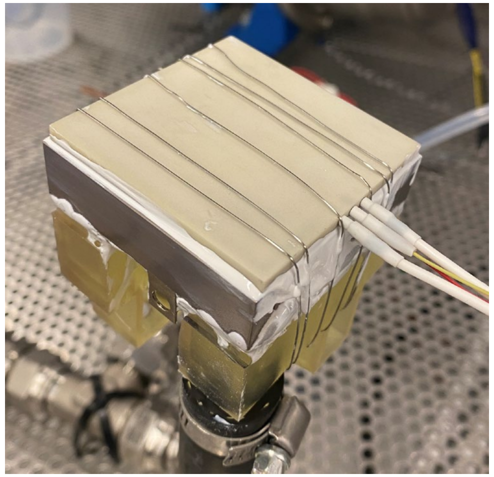


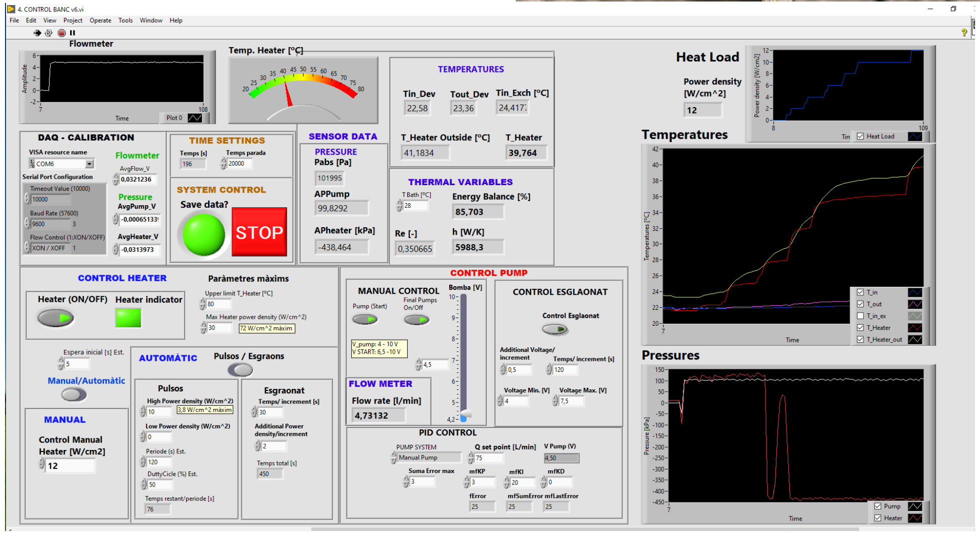
Fabrication and testing of the cooling device

SOLAR X



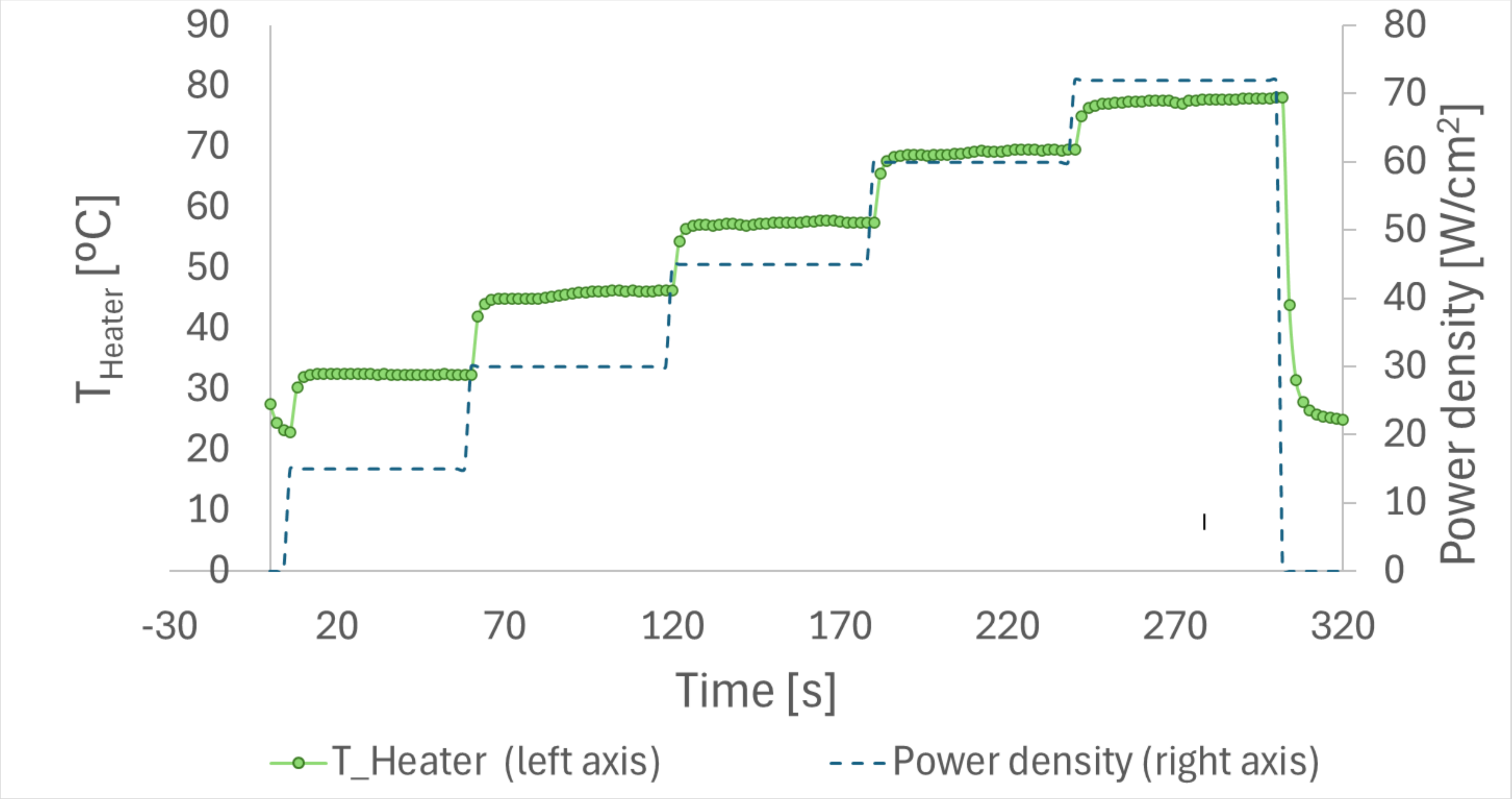






Mobile test bench (same for outdoor tests)

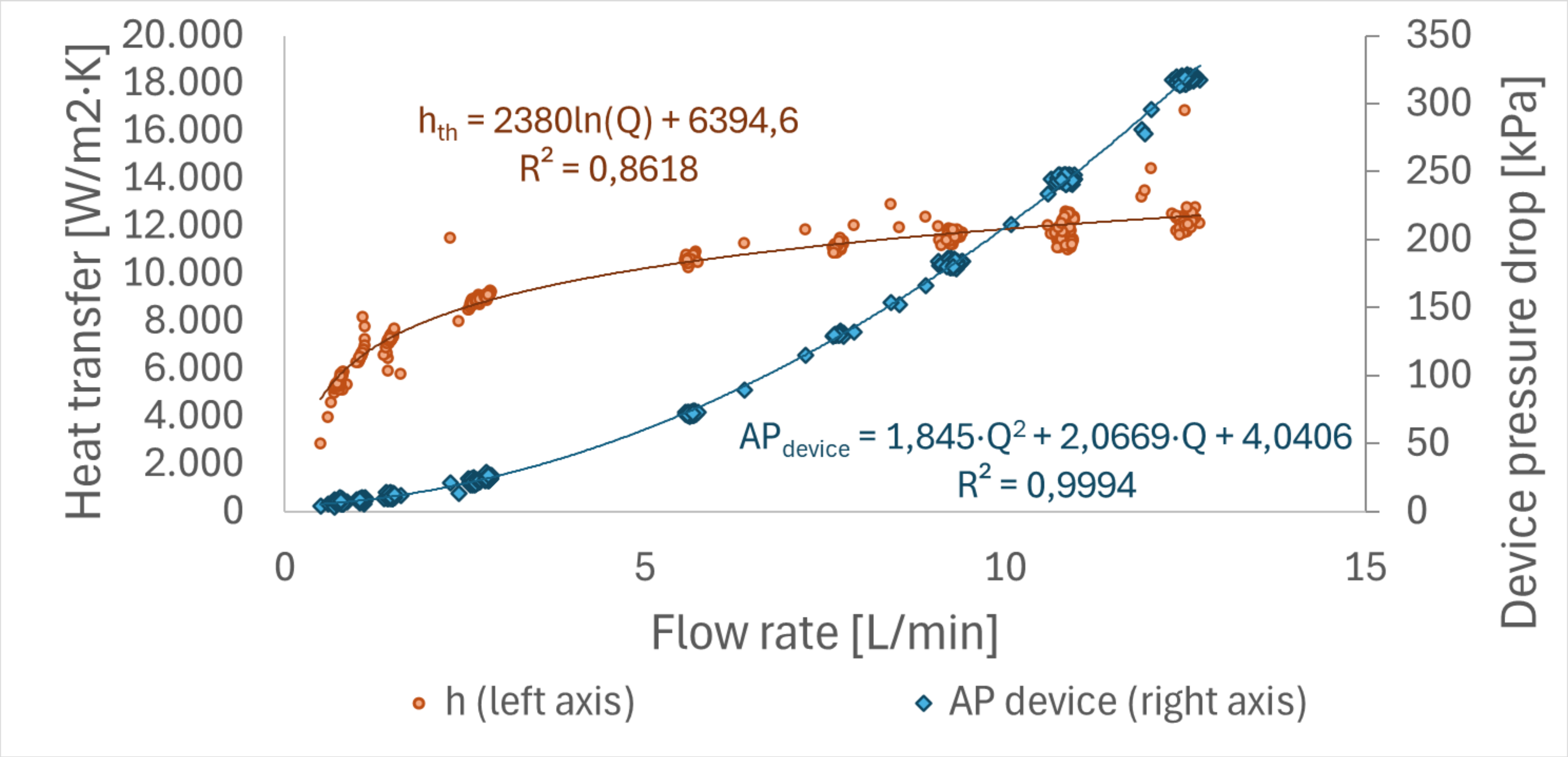
Fabrication and testing of the cooling device



R_{th}=8,7·10^{-5} m²·K/W
(h=11.500 W/K.m²)
@12 L/min (max flow rate)

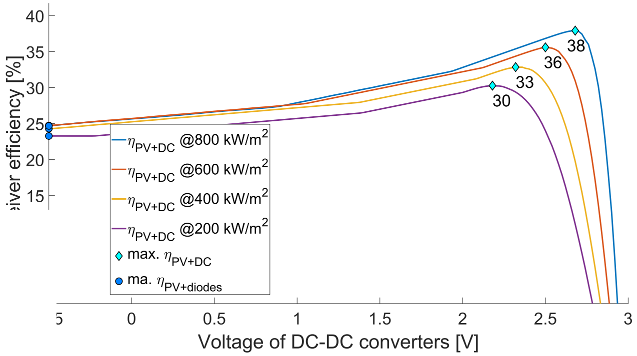
R_{th}=9,1·10^{-5} m²·K/W
@7,7 L/min (energy-optimised flow rate)

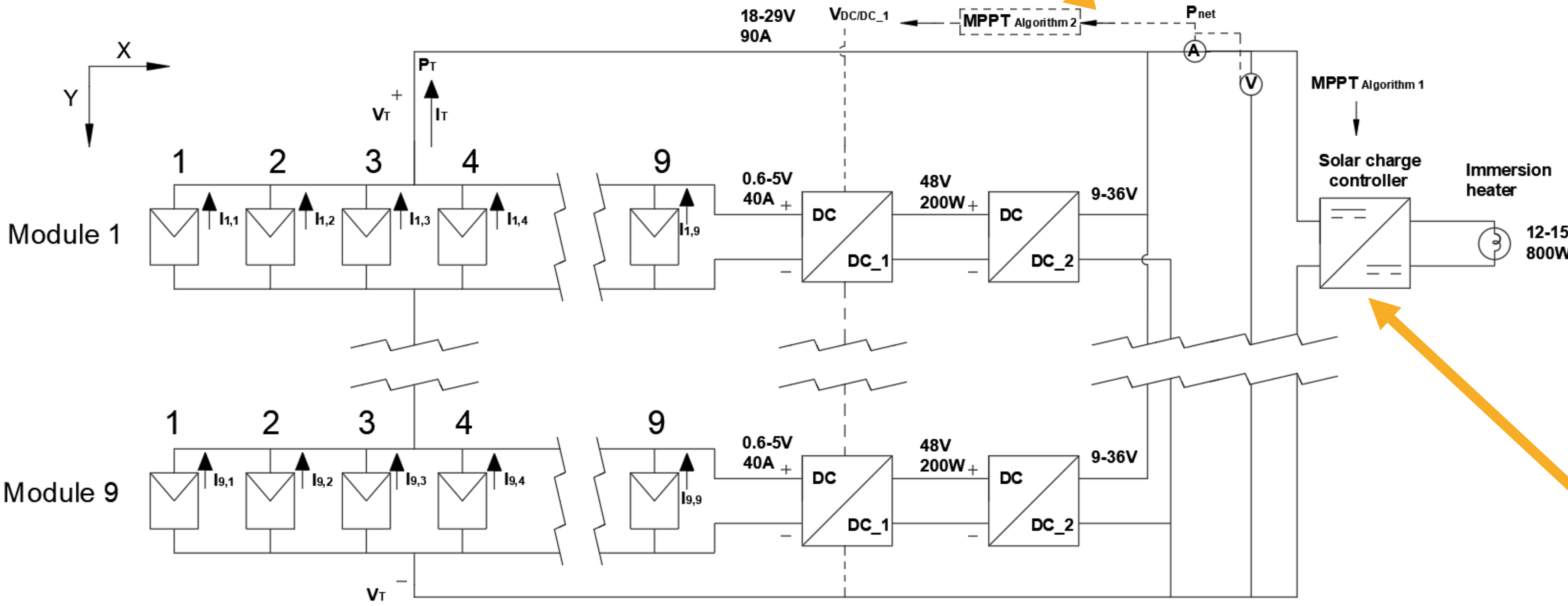
Fabrication and testing of the cooling device

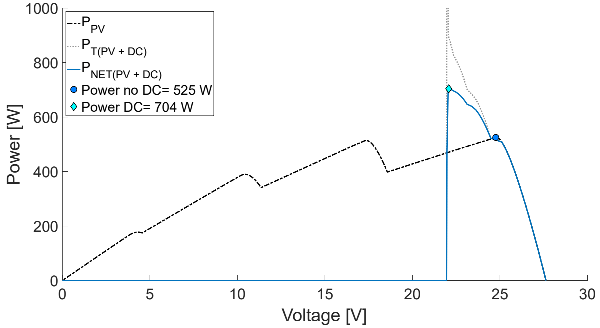


Design of electrical interconnection and control of the DC/DC converters

Main goal: Reduce the **current mismatch** losses when the CPV receiver is submitted under non-uniform solar irradiance by using a DC/DC converters.





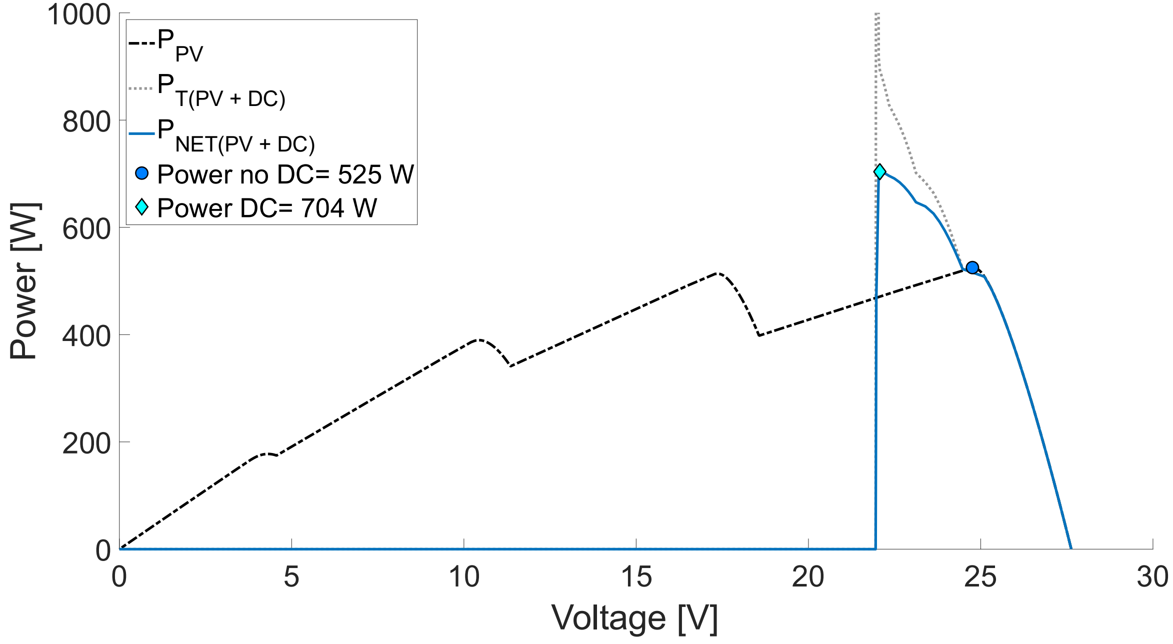


Schematic of the implemented DC-DC control system.

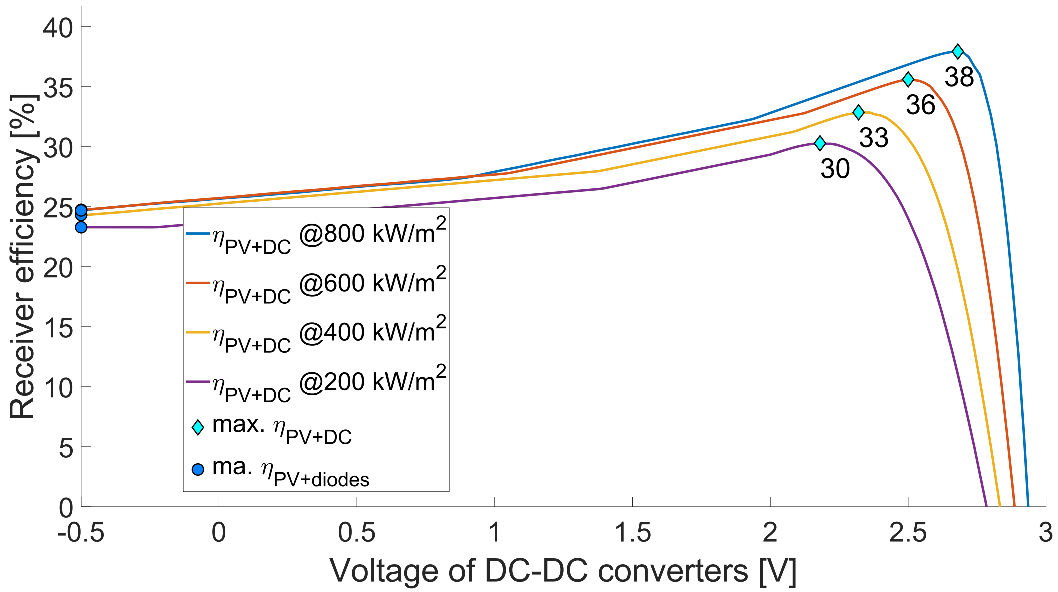
Design of electrical interconnection and control of the DC/DC converters

Results of Receiver Thermal and Electrical Modeling

- Comparison of Power Curves: Analysis of receiver performance with and without DC-DC converters.
- Selected DC-DC Converters and Control System: Details on the chosen converters and the implemented control system.



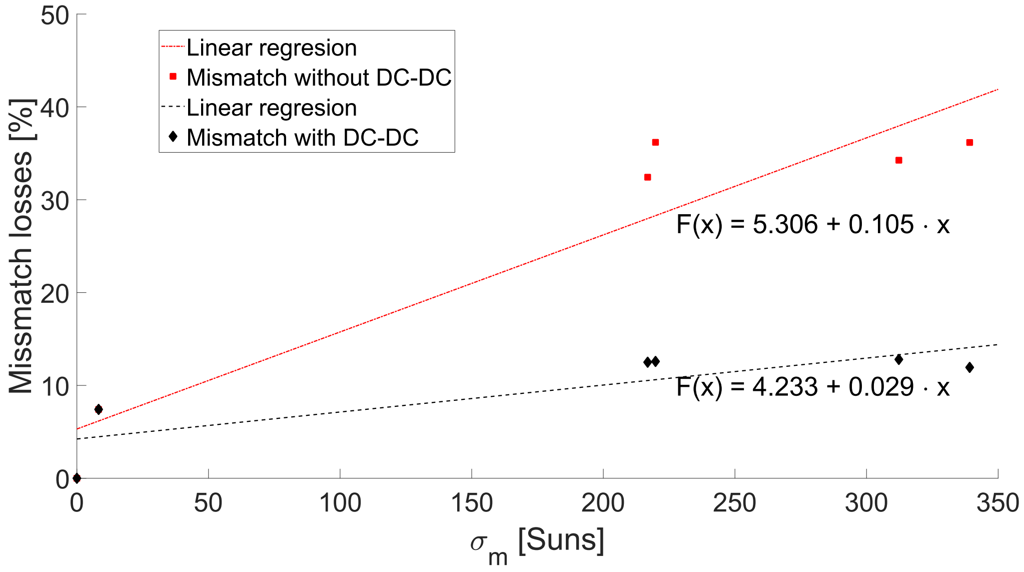
P-V characteristic curve of the CPV receiver under a Gaussian illumination profile



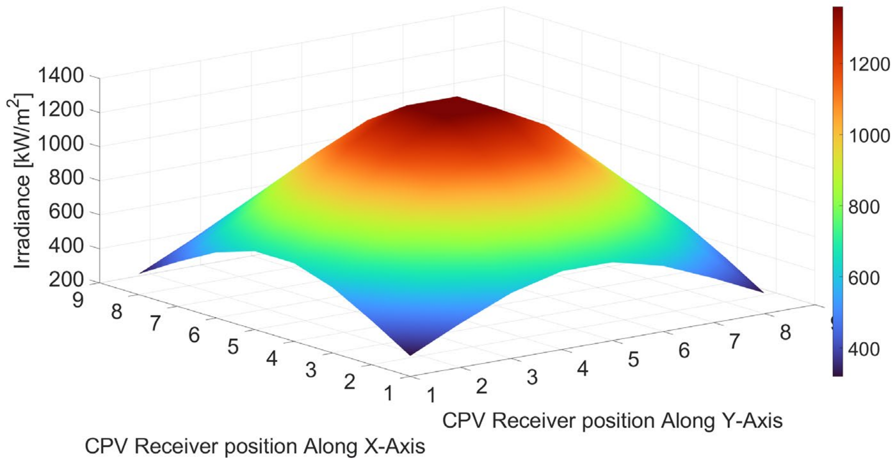
Receiver efficiency plotted against the voltage of DC-DC converters, representing the maximum power point of the receiver using DC-DC converters or diodes at different mean receiver irradiance levels under Gaussian profile P1.

Design of electrical interconnection and control of the DC/DC converters

Power **transfer losses 3,6 times less** dependent on illumination deviation when using DC-DC converters + jet impingement compared to diodes with microchannels



Energy transfer losses as a function of irradiance non-uniformity.



Non-uniform irradiance profile with a deviation of 220 kW/m² from the average irradiance (800 kW/m²).

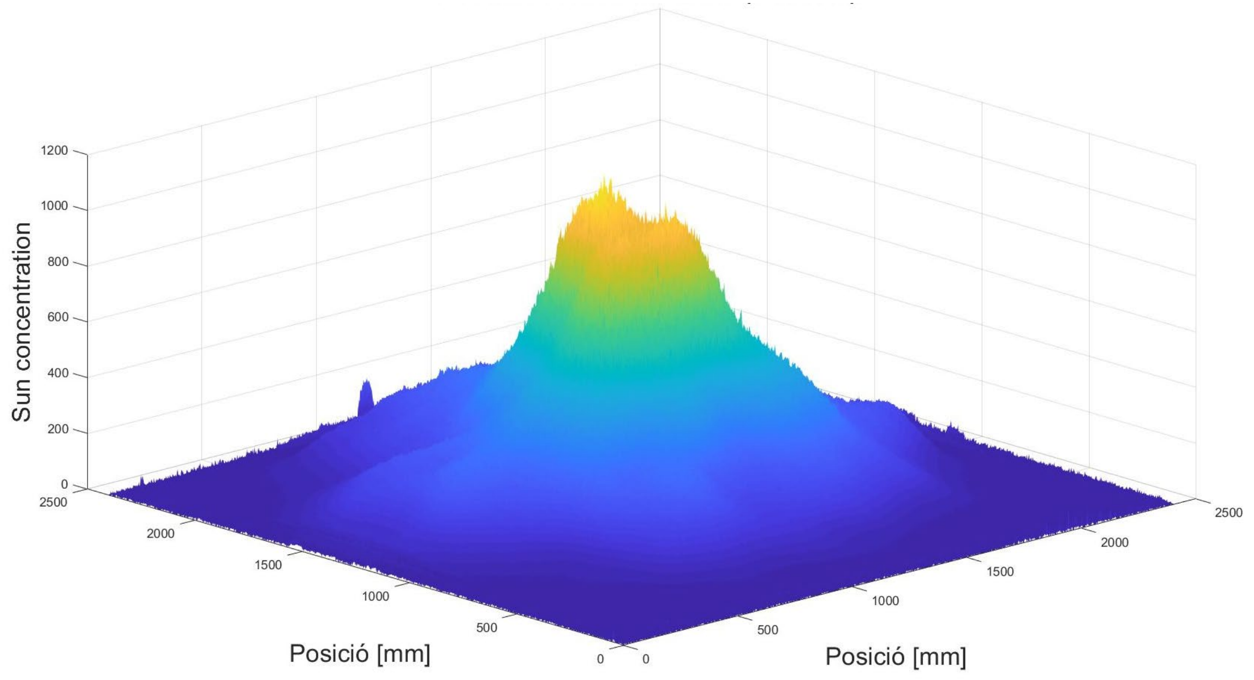
Title	Journal
Control of DC-DC converters polarizing a CPV receiver under non-uniform solar irradiance pattern	Solar Energy Materials and Solar Cells
Design methodology and performance analysis of a novel cooling system for concentrated photovoltaic receivers	Solar Energy journal

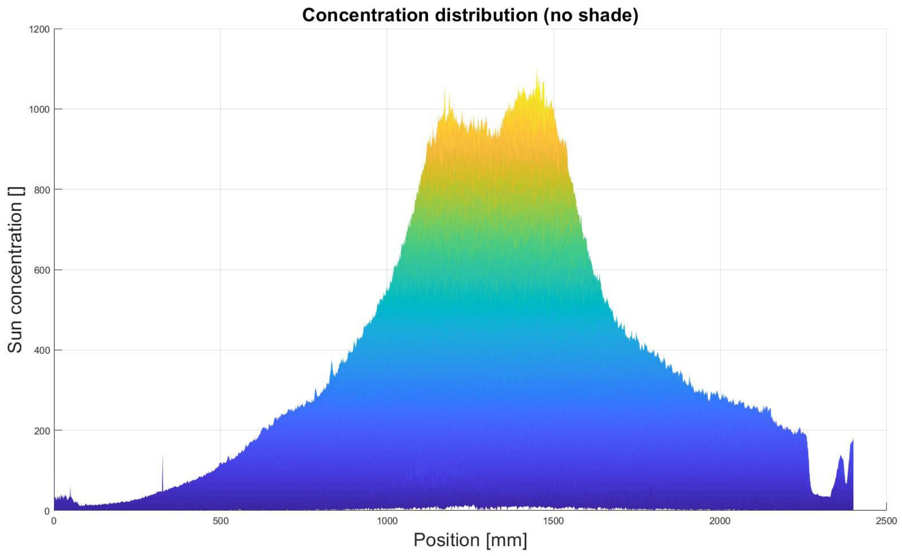
Outdoor characterisation

- **Method:** flux mapping with Photron FASTCAM Mini AX50 + alumina plate.
- **Calibration**: DNI measured with pyrheliometer.
- **Results:**
  - No shading mesh: peak 1121 suns (non-Gaussian profile).
  - 1 mesh: peak 421 suns, smoother distribution.
  - 2 meshes: peak 183 suns, flatter and homogeneous.

TEK3000 S10 automatic solar tracker pyrheliometer

Experimental setup for optical flux characterization





Manufacturing of advanced CPV receiver

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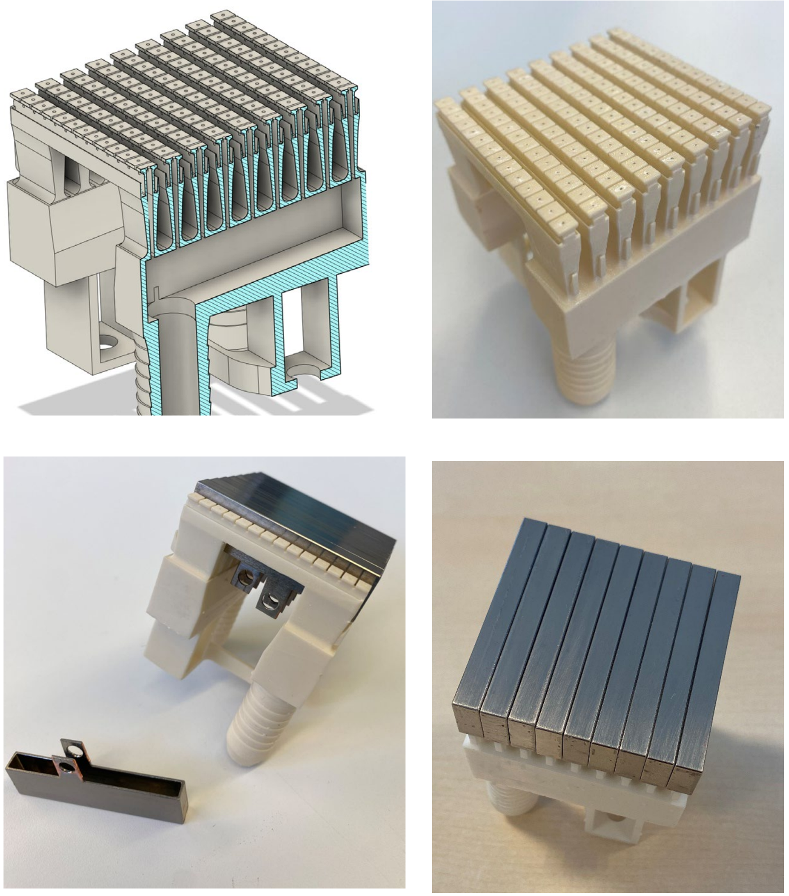
Fabrication workflow for manufacturing the dense array CPV receiver

- **Multi-step process:** machining, plating, 3D printing and assembly.
- **Objectives:** compact design, low ΔT, mechanical stability, electrical isolation.
- **Main stages:**

1. **Machining + nickel plating of copper cold plates:**
    - Prevents galvanic corrosion in contact with water.
    - **Uniform coating,** no delamination and improves solderability.
    - Ensures **long-term durability.**
2. **Fabrication of resin manifold (3D printing).**
    - SLA resin, high-T stability (>220 °C).
    - Integrated functions: **Jet impingement array + fluidic connectors + sawtooth profile** for CPV cells shingling.
    - Post-processing: curing and **thermal test up to 170 °C.**



Isometric views of the heat sink.

Manufacturing of advanced CPV receiver

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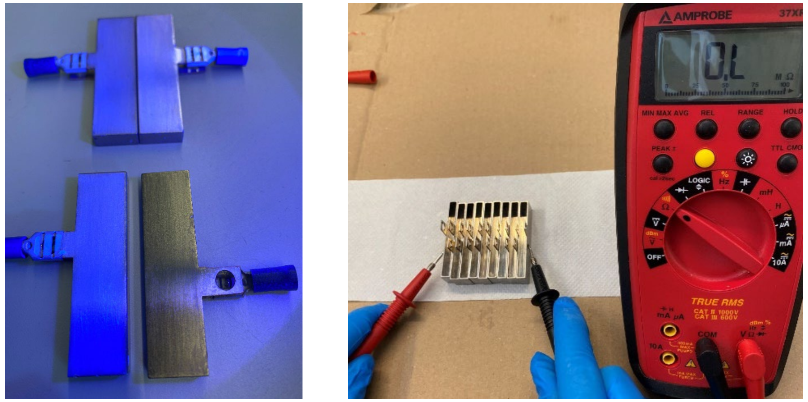
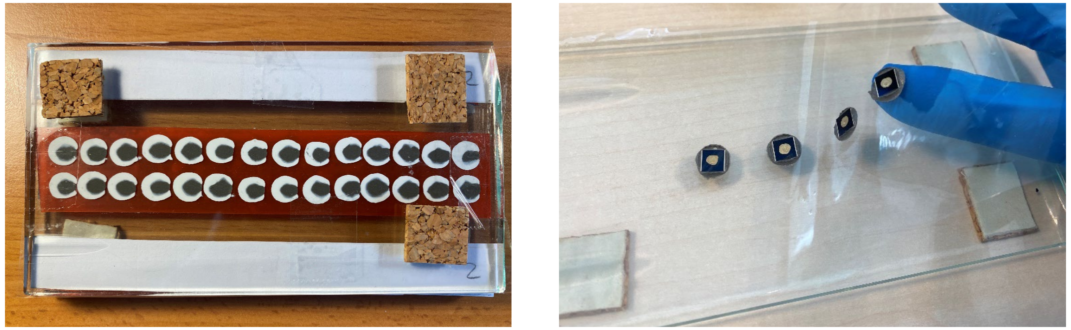
Electrical insulation & soldering preparation

3. **Application of dielectric varnish** (on copper plates):
    - **Prevent short-circuits.**
    - Easy inspection under UV.
    - Ensures insulation during reflow soldering.

4. **Solder paste deposition and alignment:**
    - **Low-T solder alloy** (Sn42/Bi57.6/Ag0.4, Tm = 140 °C).
    - **Precision jig (25 µm films)** for controlled deposition.
    - **Dielectric paste applied along 3 edges** → ensure insulation and prevent short-circuits at CPV cell edges.
    - **Teflon film handling** → avoids stress on cell front



Varnish inspection under UVA light and electrical test



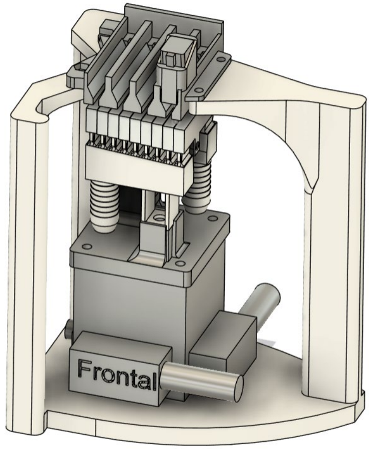
Solder paste deposition jig and Teflon film for safe cell handling

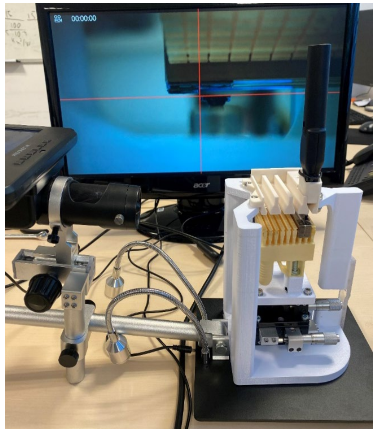
Manufacturing of advanced CPV receiver

CPV cell placement & final assembly

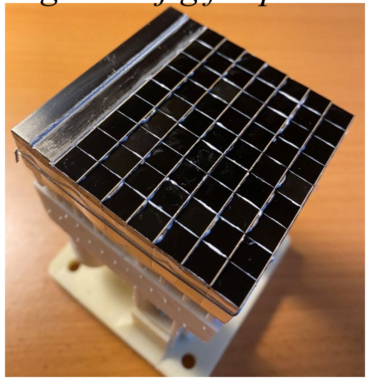
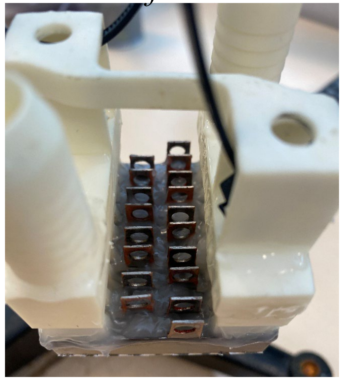
5. **Precision placement of CPV cells:**
   - Cells size: 5.5 × 5.5 mm².
   - Positioned with **micrometric base + precision vacuum pickup tool**.
   - The silicone suction cup compensates for local overloads.
   - Optical **microscopy validation.**

6. **Reflow soldering & final sealing:**
   - Controlled thermal profile up to 165 °C, slow cooling.
   - Prevents **microcracks and delamination.**
   - Final sealing with **epoxy manifold (Loctite HY4070).**
   - Assembly completed → **compact dense-array module.**





Alignment jig for precision placement of CPV cells

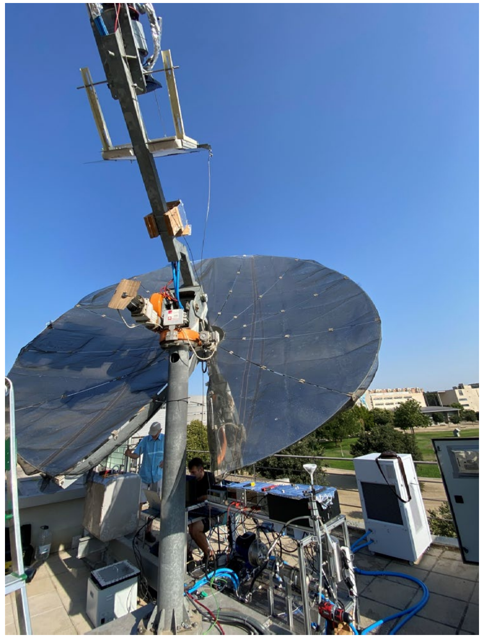



Progressive integration of cells and epoxy sealing views

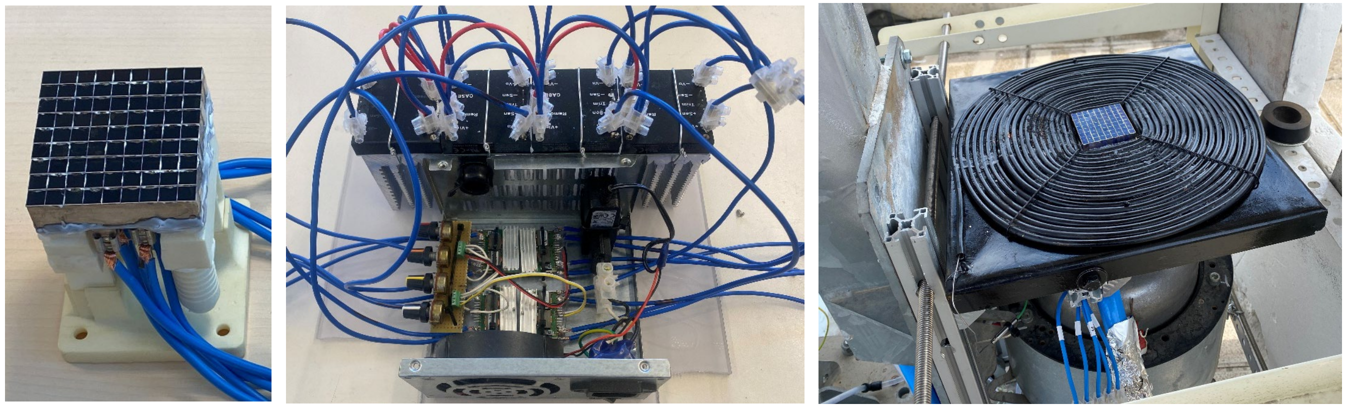
Task 2.6 – M30-M36: Testing including outdoor characterisation

Outdoor integration setup

- **Concentrator**: Innova TRINUM parabolic dish.
  - Diameter: 3.75 m, aperture: 11.23 m².
  - Peak optical flux: >1000 suns.
- **Location**: UdL CREA rooftop, with structural reinforcement.
- **Receivers integrated**:
  - CPV dense-array (9×9 cells, DC/DC converters).
  - Perimetral thermal absorber.
- **Cooling & monitoring system**: water–glycol loop, flow meters, thermocouples, LabVIEW DAQ.



Outdoor experimental setup with the TRINUM concentrator



CPV dense-array of 9×9 CPV cells, the DC/DC converters and the perimetral thermal absorber

CPV receiver

Key outcomes

- **Novel receiver fabricated and validated:** compact, modular, scalable.
- **Thermal performance:** $\Delta T < 5$ °C, HTC $>10^4$ $W/m^2 \cdot K$.
- **Outdoor setup ready** for extended testing.

CPV receiver in operation at dish focus

Next steps

- **Operational validation:** continuous electricity generation under real solar flux exposure.
- **Extended outdoor campaigns:** efficiency assessment of CPV receiver.
- **Comparison study:** validate mismatch reduction using DC/DC converters versus conventional bypass diodes.

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SOLAR X

Dispatchable concentrated Solar-to-X energy solution for high penetration of renewable energy

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