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FACING HIGH-TEMPERATURE CSP FOR ENERGY APPLICATIONS

Exploring Challenges and Innovative Solutions

30th January 2025

AGENDA

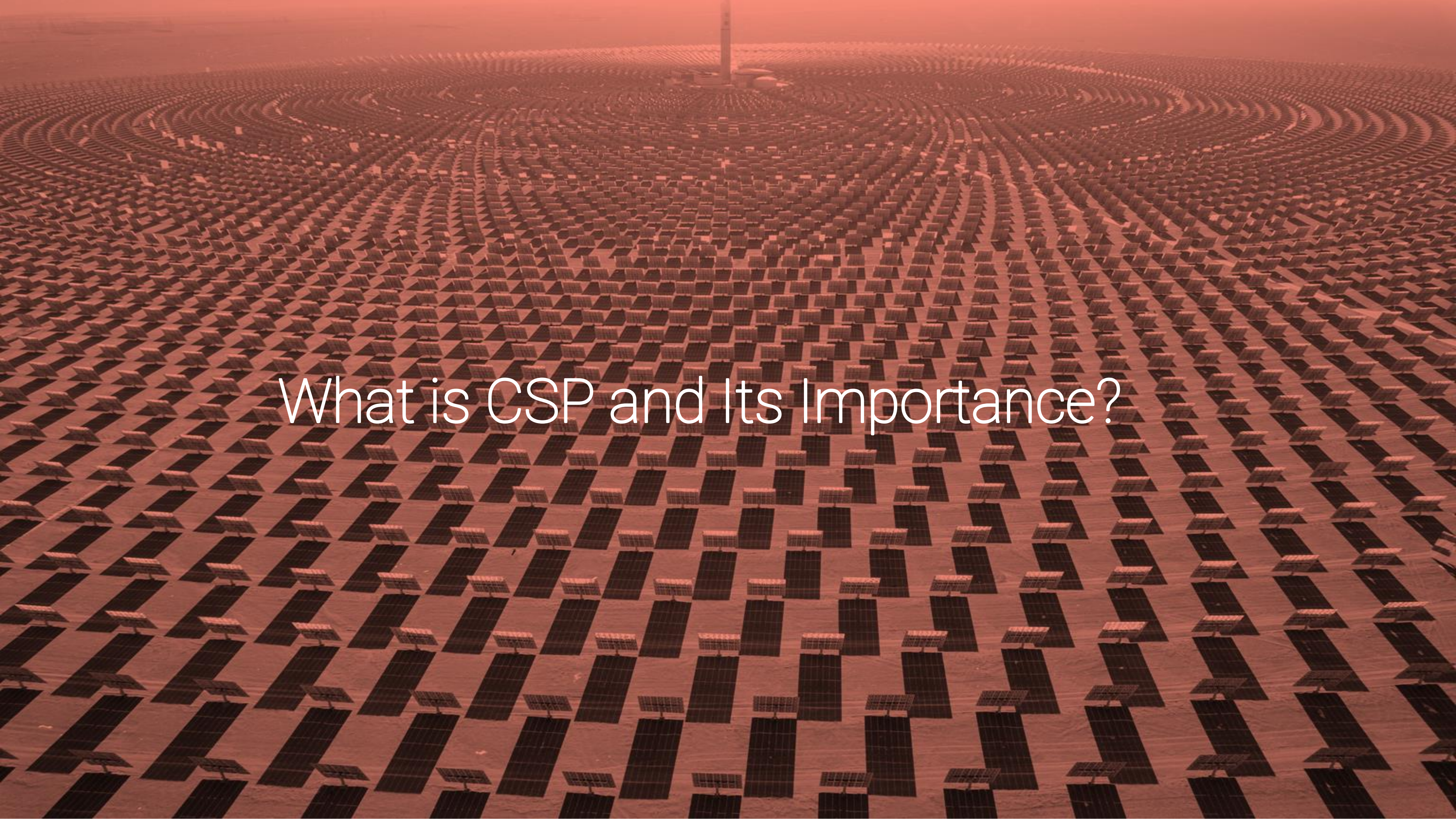
1) Introduction: What is CSP, and why does it matter?

2) Key Challenges in High-Temperature CSP Systems

3) Innovative Solutions and Current Developments

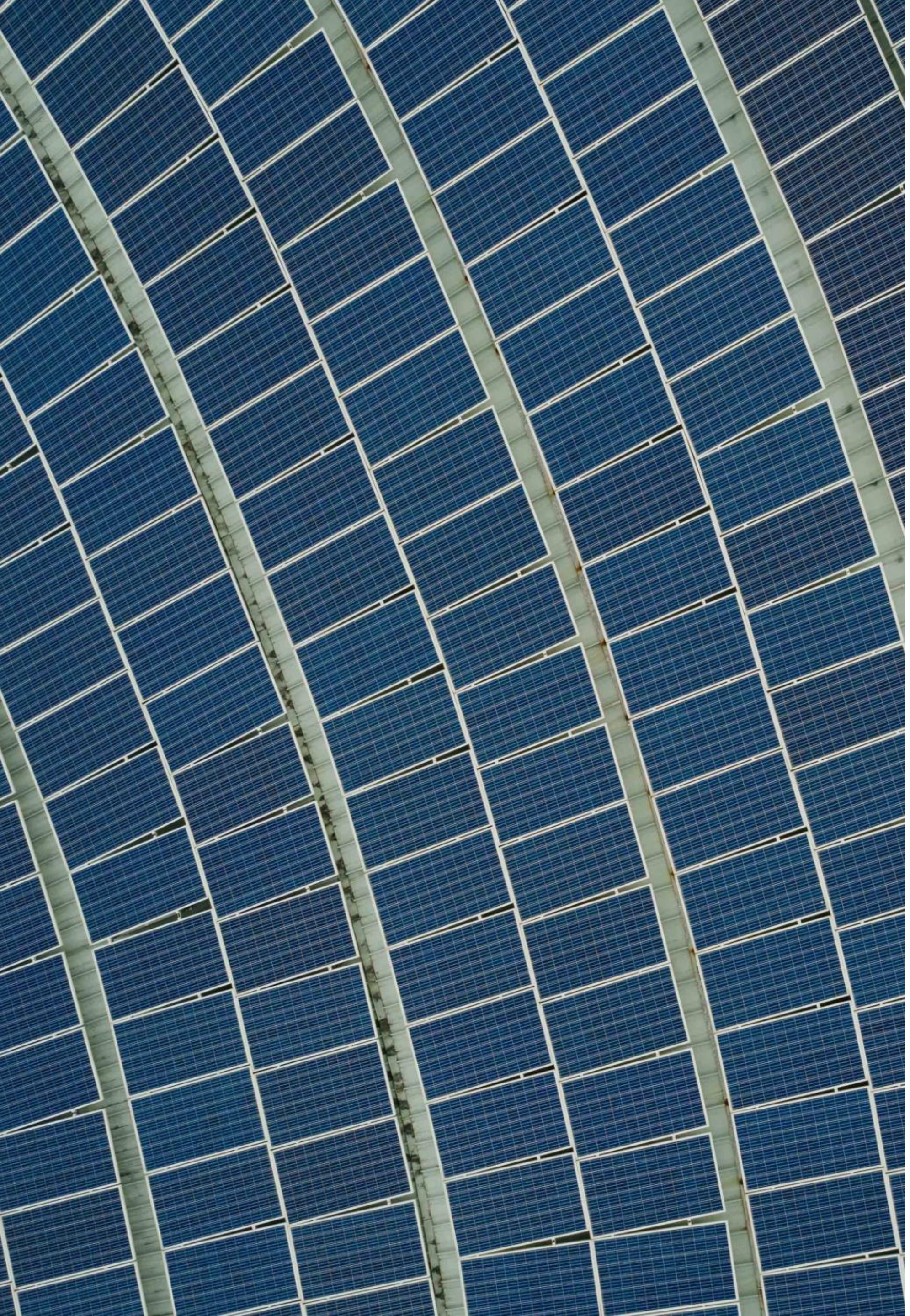
- ASTERIX-CAESAR
- ABRAYTCSPFUTURE
- SUNSON
- PYSOLO
- BLAZETEC
- COOPERANT

4) Q&A Session



What is CSP and Its Importance?

CSP is a renewable energy technology that uses mirrors or lenses to concentrate sunlight onto a small area. The concentrated sunlight generates heat, which is then converted into electricity through a heat engine or turbine.



Why High-temperature CSP is important?

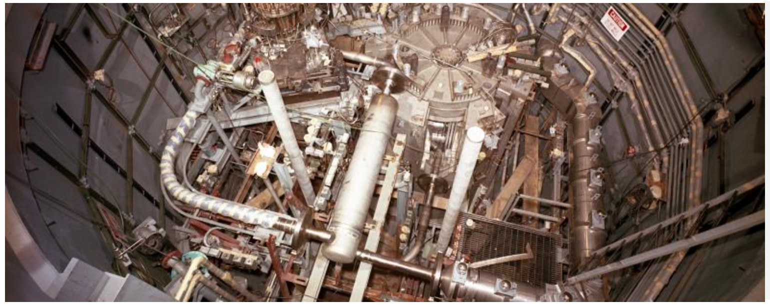
- **Efficiency boost:** Higher operating temperatures lead to more efficient power cycles (e.g., supercritical CO_2 cycles).

- **Industrial applications:** Enables use in sectors like process heating and hydrogen production, where high temperatures are essential.

- **Decarbonization potential:** CSP with thermal storage can replace fossil fuels for continuous, dispatchable energy generation

Challenges in High – Temperature CSP Systems

Heat storage and transfer systems under extreme conditions



Material limitations: thermal stability and durability

Efficiency trade-offs: balancing higher temperatures with system performance

Integration challenges with current energy grids.

Innovative solutions and current developments

ASTERIX CAESAR

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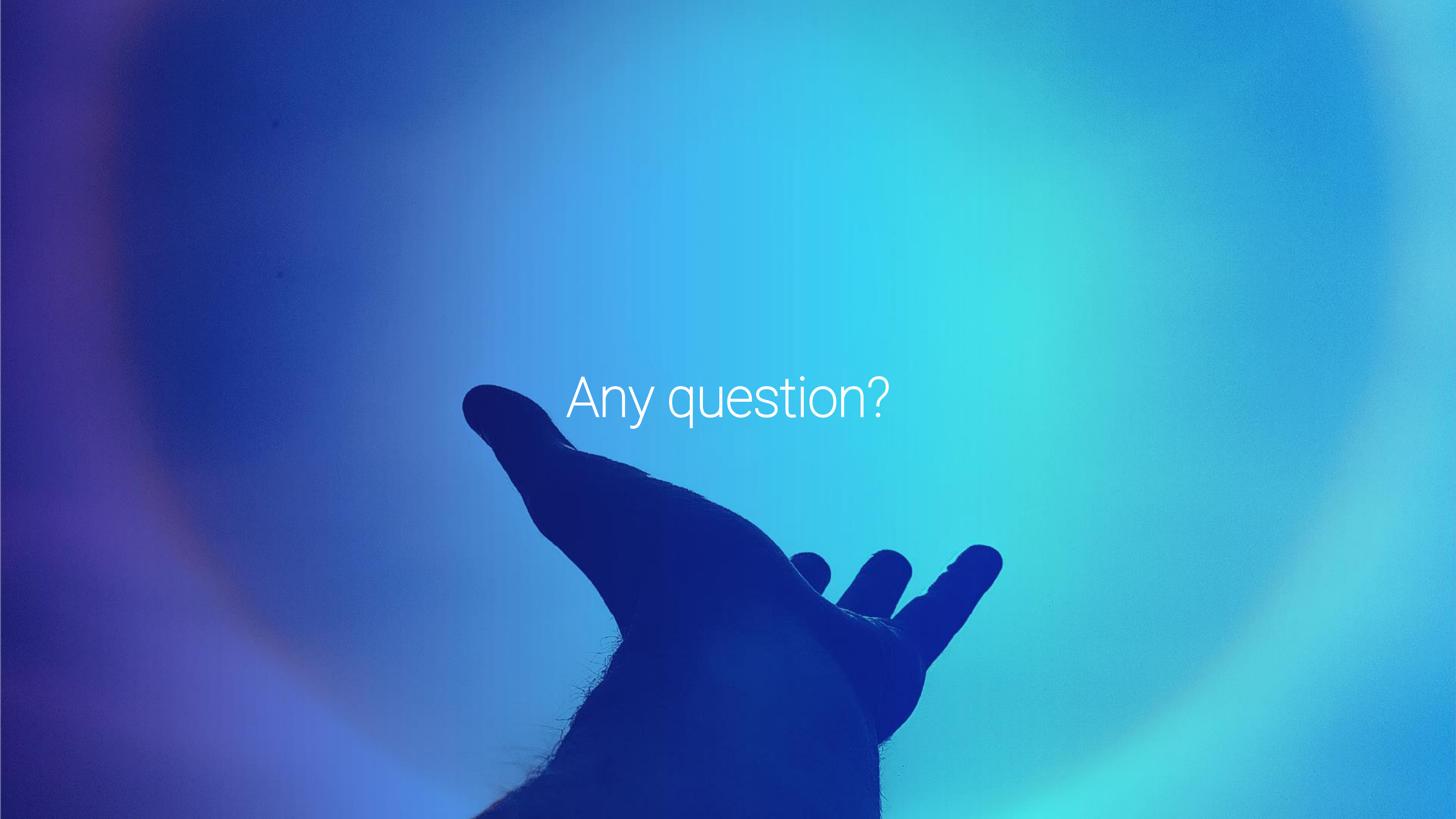
Any question?

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Thanks for your attention!

https://www.sunson.eu/

https://pysolo.eu/

https://blazetec.eu/

https://www.abraytcspfuture.eu/

https://asterix-caesar.eu/

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ASTERIX CAESAR

COOPERANT

Concentrated Solar Power

CAES

CSP

Compressed Air Energy Storage

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UK participant in Horizon Europe Project ASTERIx-CAESar is supported by UKRI grant number 10097908 (Bluebox Energy).

This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).

ASTERIx-CAESar project

17 Partners **10** Countries **4** Years(Oct 23-Sept 27) **7.2** M€ Budget **6-7** TRL

Concentrated Solar Power (CSP)

+

Compressed Air Energy Storage (CAES)

=

Higher share of variable output renewables and **new operation strategy** and business model for CSP

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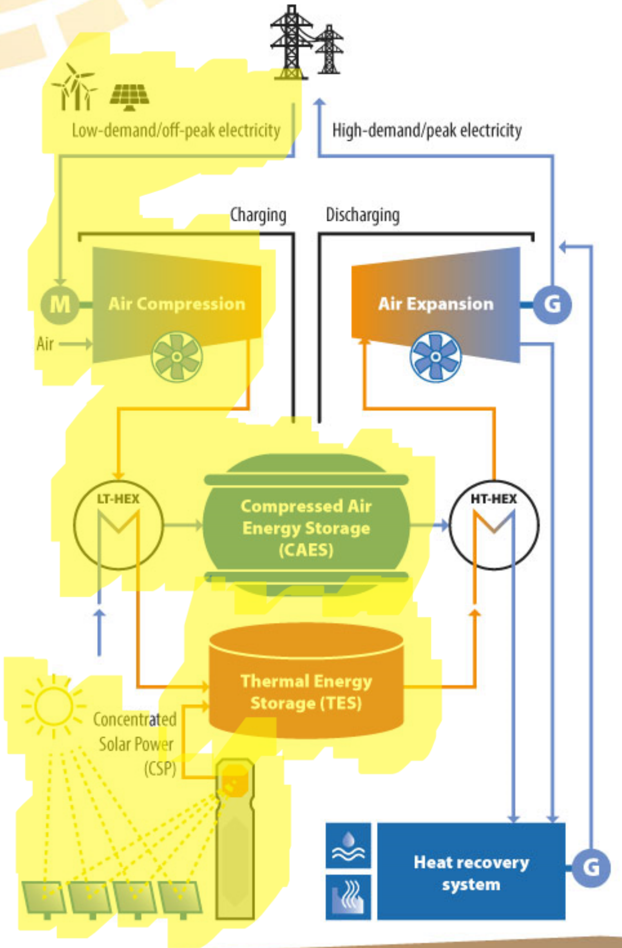
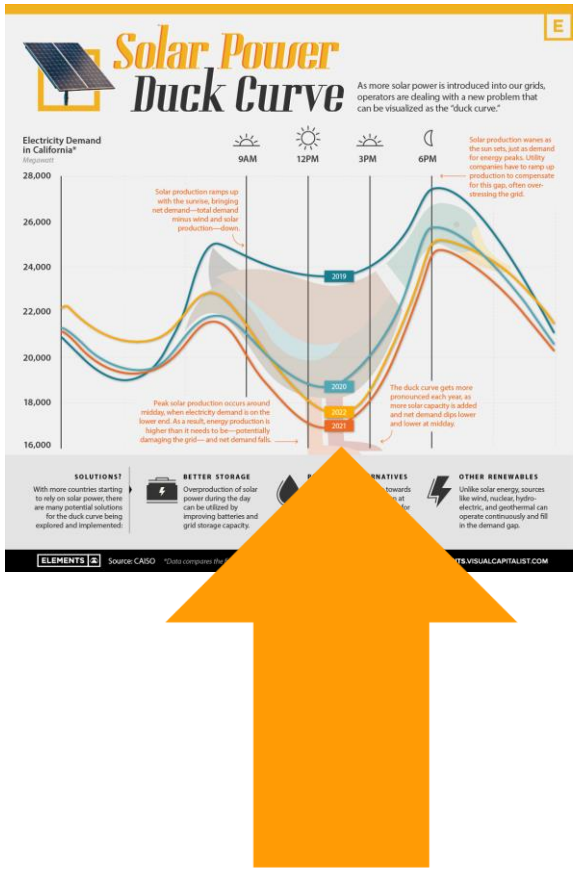
The project concept:
CSP-CAES innovative & adaptive power plant



Charging

- **Off-peak low-price electricity is used to drive a compression train** – compressed air is stored – heat of compression is also stored
- **Solar energy is captured through the air-based CSP** in the form of high-temperature heat (800°C)
- Thermal Energy Storage units consist of air-based **thermocline packed-bed** storage technology



ASTERIX CAESAR

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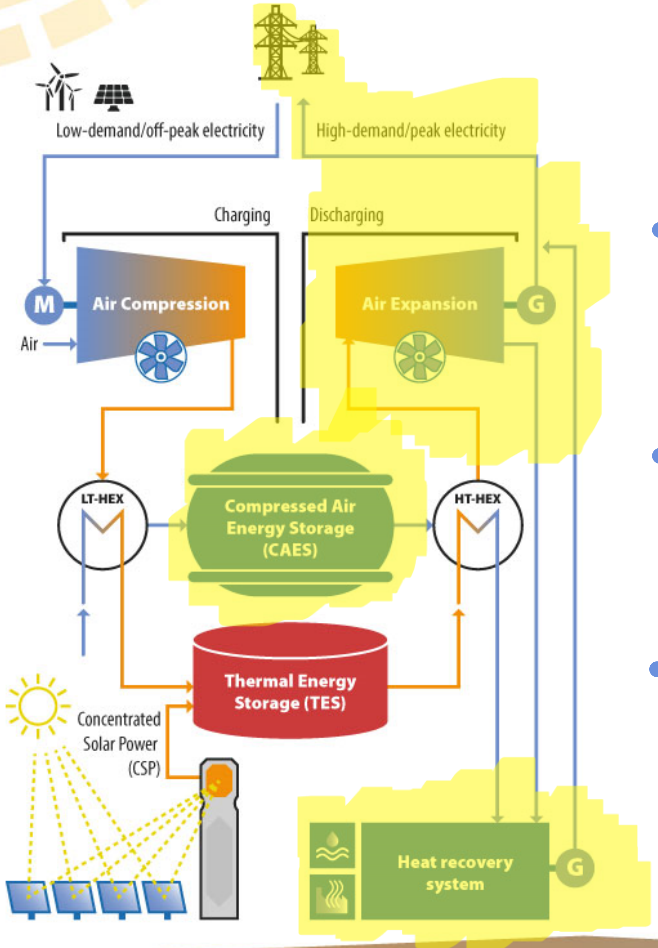
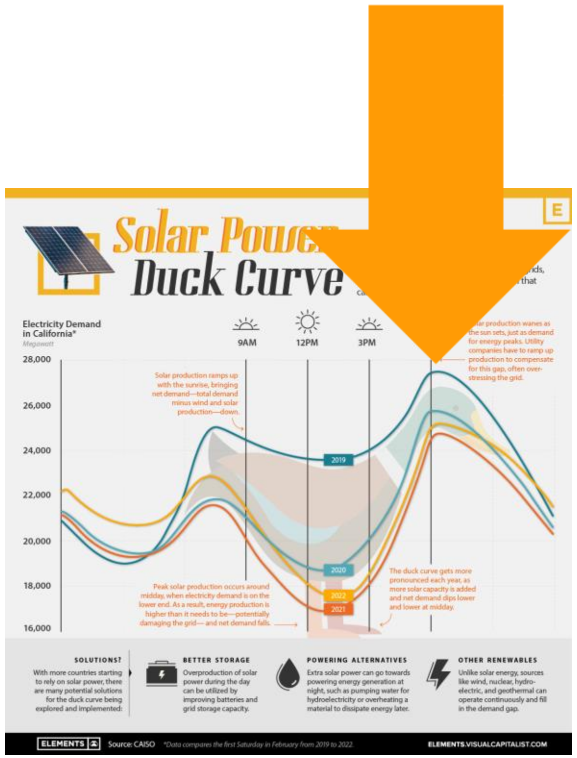


Discharging

- During **peak-hours**, the plant produces electricity via an **air expansion train**
- The **compressed air** is used to **substitute the compression work** of the topping gas turbine
- The project concept includes a **Heat Recovery system**: Rankine cycle, process heat for industry and/or desalination unit



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Key Innovation of the project - Charging

Advanced solar Receiver

A highly efficient **Open Volumetric Air Receiver** operating at high temperature (800 °C).

Advanced sensor technology and AI-based solar flux control

New **fiber-optic sensors** and advanced **AI-based** heliostat field/solar flux **control** and monitoring sys m to **re O&M eff**

Tailored air compressor Technology

Advanced compression train for small-scale and large-scale. Design and optimization of **cost-effective artificial ressu vess**

CHARGING

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Key Innovation of the project - Discharging

DISCHARGING

Advanced heat exchanger Technology

Advanced **air-to-air heat exchangers designs** that guarantee high conversion efficiency.

Tailored air expander Technology

Turbomachinery architecture is optimized for covering **a wide range of rated power outputs**, between 1 a d 150 V elec

Effective exhaust heat recuperation & integration with desalination

Advanced **gas/liquid pressure exchanger** uses the energy stored in the compressed air vessel to power the se mo desa nati

ASTERIX CAESAR

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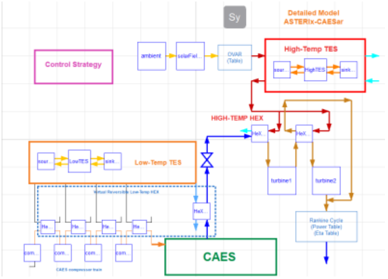
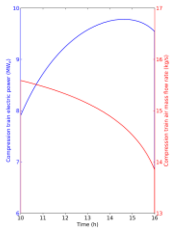
Path of the project

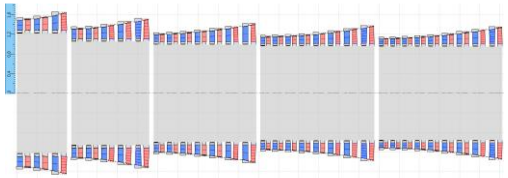
Oct 2023 — Jan 2025

Start — Today

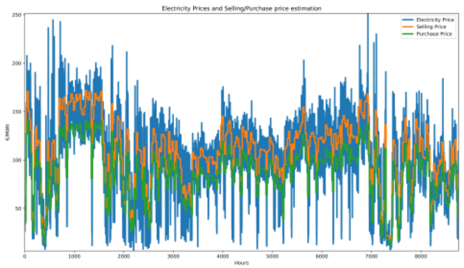
Thermodynamic Analysis: Evaluation of ASTERIx concept

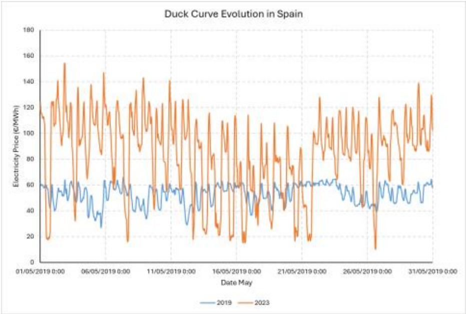




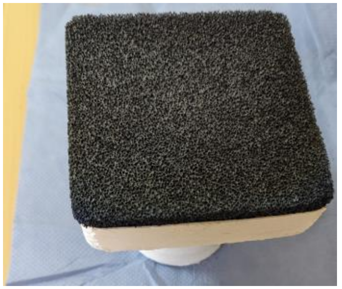


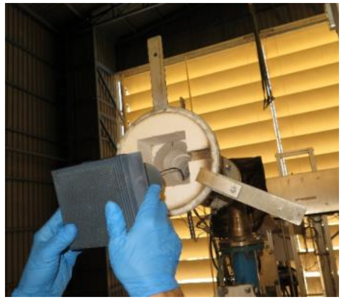
Grid Analysis: Electricity prices





Testing of Advanced Open Volumetric Air Receiver





Developing of Optical Sensors and AI-based tracking control

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www.asterix-caesar.eu

info@asterix-caesar.eu

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Air-Brayton cycle Concentrated Solar Power future plants via redox oxides based structured thermochemical heat exchangers/thermal boosters

ABraytCSPfuture

CSP Sisterhood Community,

Webinar: “Facing High-Temperature CSP for Energy Applications”, January 30th, 2025

DLR

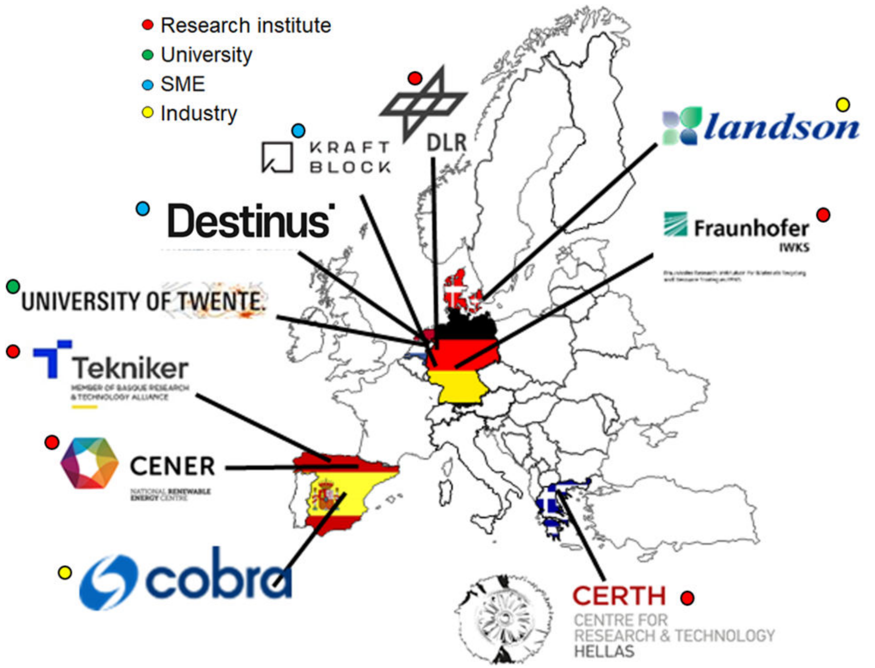
ABraytCSPfuture partnership

- Horizon Europe Call HORIZON-CL5-2021-D3-03: “Novel approaches to concentrated solar power (CSP)”
- Funded by European Commission
- Requested contribution: 2,995,457.50 Mio. €

- Coordinated by DLR
- Duration: 48 months (1/11/2022–30/10/2026)
- 10 partners from
  - Germany (3)
  - Spain (3)
  - Netherlands (2)
  - Greece (1)
  - Denmark (1)

- Requested contribution ~ 3 M€

DLR (coordinator) (DE)	593k€ (20%)
CERTH (EL)	400k€ (13%)
UT (Un. of Twente) (NL)	240k€ (08%)
CENER (ES)	305k€ (10%)
TEKNIKER (ES)	340k€ (11%)
FRAUNHOFER (DE)	205k€ (07%)
DESTINUS (NL)	60k€ (02%)
KRAFTBLOCK (DE)	225k€ (08%)
LANDSON (DK)	487k€ (16%)
COBRA (ES)	142k€ (05%)



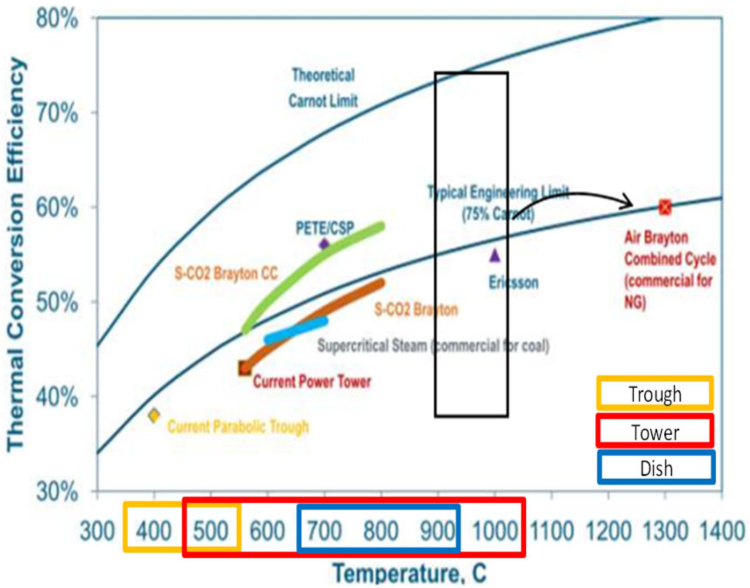
ABraytCSPfuture: Why ? Problem addressed

Current, state-of-the-art CSP plants apply Rankine steam cycles, hence **their thermal-to-electric conversion efficiencies range between 30 - 40%, an order unlikely to be sufficient to allow CSP to be competitive in the future given the cost decrease pace of PVs.**

By increasing the maximum cycle temperature to 850–1000°C efficiencies of ≈ 53% would be achievable in an air Brayton/Rankine Combined Cycle giving CSP a unique competitive edge.

Such efficiencies are non-reachable by either PV systems or by CSP plants operating with molten salts or thermal oils employed as Heat Transfer Fluids (HTFs) and storage media.

Even for the lower-temperature sCO_2 Brayton cycle, the outlet temperature of the receiver needs to be > 700°C. Not possible with oils or molten salts; hence the issues of **higher-efficiency gas turbine cycles and storage media/HTFs are closely coupled and should be tackled in conjunction.**



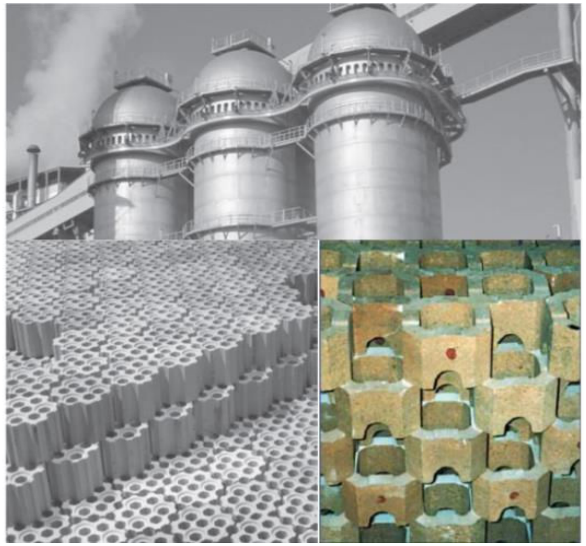
N. Siegel et al., Energy Procedia 49, 1015–1023, (2014)

Among the currently technologically mature CSP plants operation concepts, properly customized **air solar tower receivers, that can provide temperatures of 700–950 °C, represent a feasible solution** for pushing solar systems to enable integration with combined cycles.

INDUSTRIAL and SOLAR sensible heat storage and waste heat recovery systems

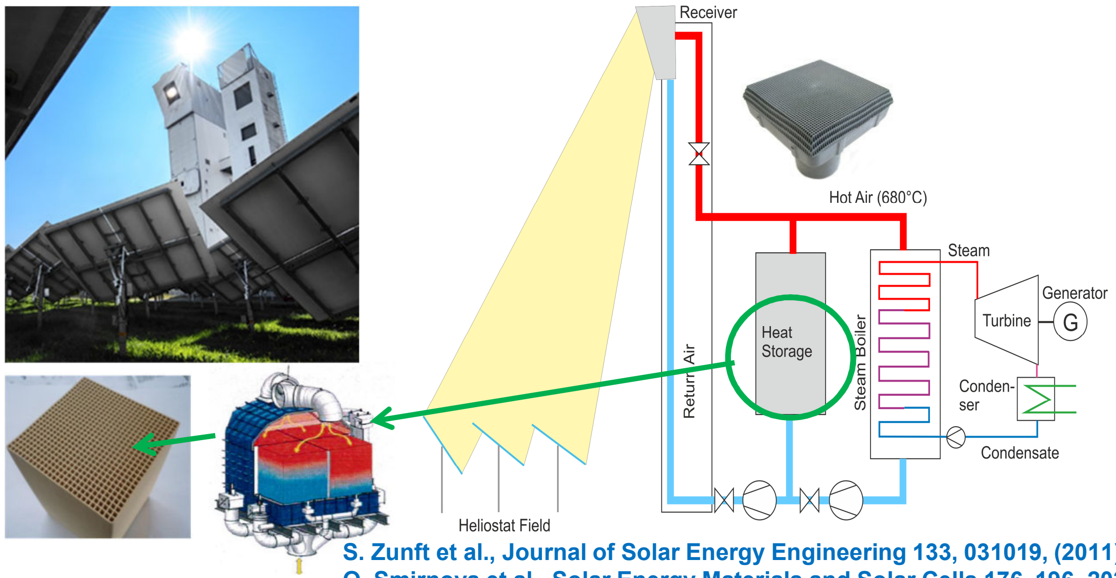
Industrial sensible heat recovery from combustion flue gases:

- high temperature regenerative storage systems (Cowper) used with blast furnaces: a **firebrick-pattern** storage medium with air channels,
- “charged” with hot combustion gases flowing through it
- “discharged” by blowing cold air through the charged (hot) brickwork; heated air is coupled back to the combustion-driven industrial process



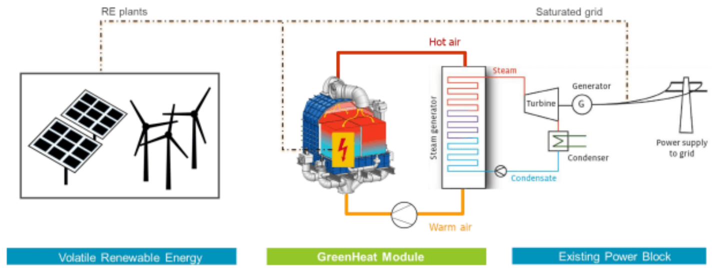
D.C. Stack et al., Applied Energy 242, 782–796, (2019)

Same concept implemented in CSP air-operated plants: STJ.



S. Zunft et al., Journal of Solar Energy Engineering 133, 031019, (2011)
O. Smirnova et al., Solar Energy Materials and Solar Cells 176, 196–203, (2018)

RE-electricity to-heat-to-power



https://www.kraftanlagen.com/en/solutions/energy/green-heat-module/

What are the limitations?

Solar receivers and sensible-only storage systems cannot produce heat transfer fluid (HTF) streams of temperatures higher than those of the streams coming into them (e.g. acquired in the solar receiver).

➯To render such HTFs "working fluids" in a Brayton gas turbine cycle, their temperature has to be raised somehow.

➯This is possible only **if the enthalpy of an exothermic chemical reaction is added to that of the HT/working fluid stream ("thermal boosting")** (exactly the role of "traditional" fossil fuels burners).

➯The concept proposed is to substitute this fossil fuels combustion with the **"clean combustion" of redox oxides, performing it as a "milder oxidation": the reduced oxides are our "clean" fuels.**

How ? Exploiting the thermal effects of **reversible redox oxides reactions in direct contact with air:**

$$MeO_{oxidized} + (Q_1) \xrightarrow{P = 1\ atm} MeO_{reduced} + \tfrac{1}{2} O_2\ (g) \quad (1)$$

$$MeO_{reduced} + \tfrac{1}{2} O_2\ (g) + (N_2\ (g)) \xrightarrow{P > 1\ atm} MeO_{oxidised} + (N_2\ (g)) + (Q_2) \quad (2)$$

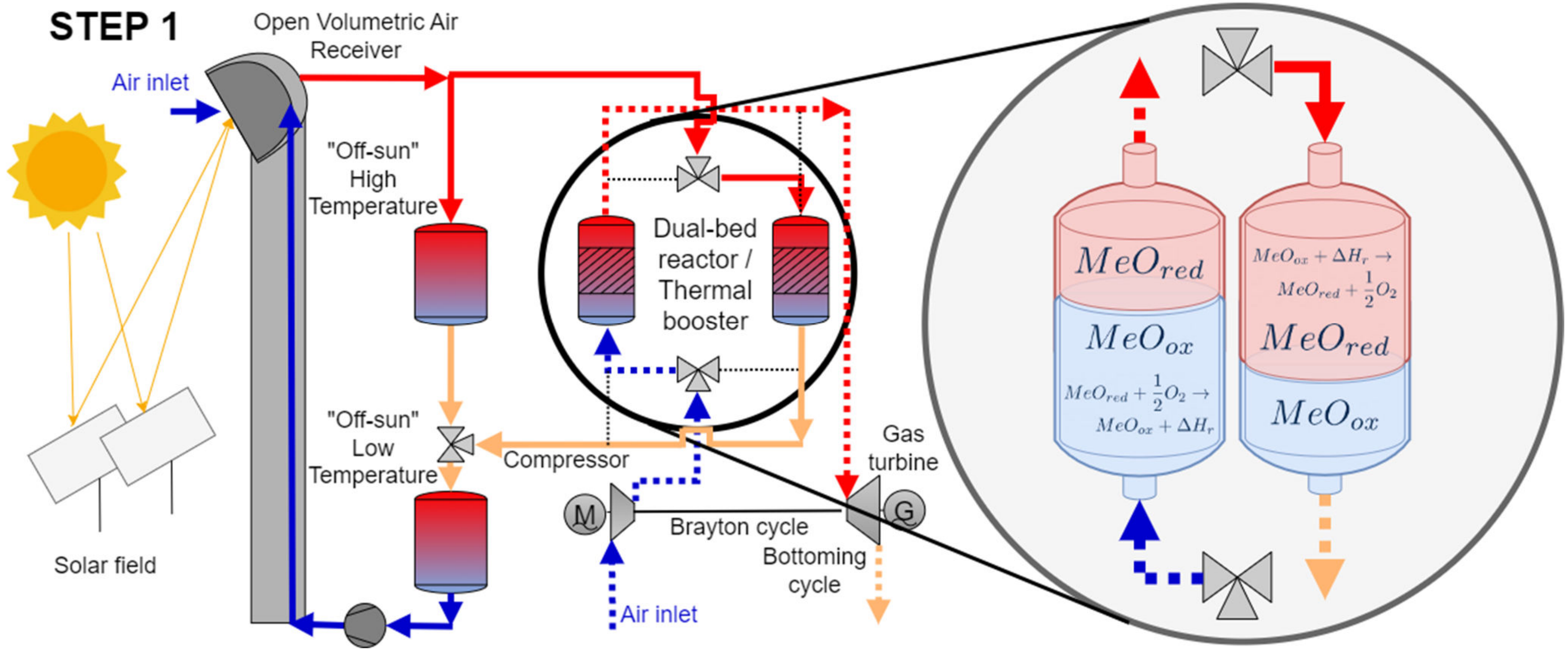
Q2 > Q1

➯ **If we make our "bricks" out of redox oxides** capable of cyclic, reversible reduction/oxidation upon heating/cooling under air, we can **generate "extra" heat in the same volume and exploit it together with sensible one, i.e. hybridize sensible with thermochemical heat storage (TCS).**

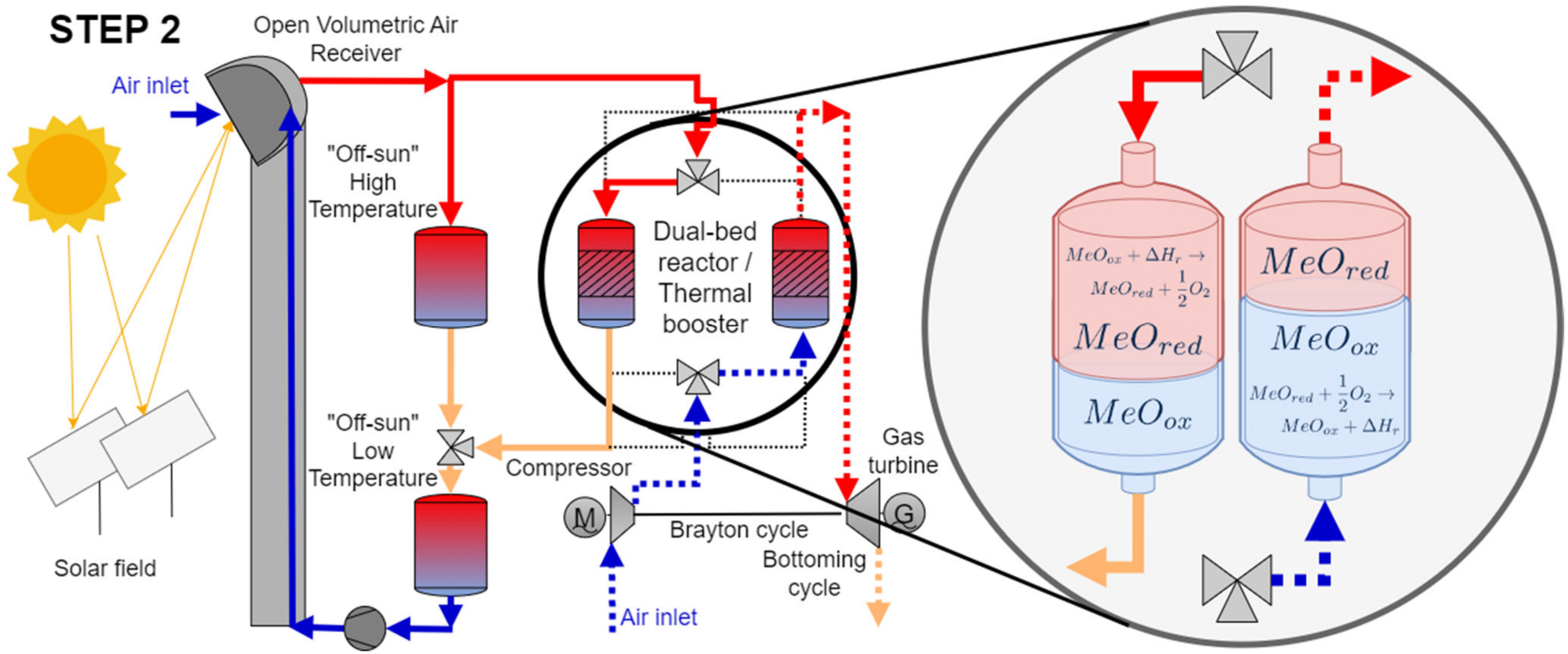
➯ **Furthermore:** If we perform the **oxidation with pressurized air we can shift the oxidation reaction equilibrium to even higher temperatures: thermal "boosting".**

ABraytCSPfuture plant operation principle (1)

Dual-bed heat exchanger/regenerator/ "thermal booster" made of redox oxide structured porous ceramics, designed to transfer heat from a non-pressurized air stream to a pressurized one, increasing in parallel the temperature of the pressurized stream to levels required for gas turbine air-Brayton cycles.



ABraytCSPfuture plant operation principle (2)



Materials aspects

- **Important**: low cost, non-toxic redox materials + high reaction enthalpy
- Examples of redox TCS materials so far:
  - ***Cobalt oxide***: *cyclability, reaction enthalpy, cost, potentially toxic*
  - ***$(Mn,Fe)_2O_3$***: *cyclability, cost, non-toxic, reaction enthalpy*
  - ***$MgMn_2O_4$***: *cyclability, reaction enthalpy, high T_{redox}, structural stability*
  - ***Perovskites***: *cyclability, low cost, non-toxic, broad temperature range → quasi-continuous redox operation, reaction enthalpy ?*

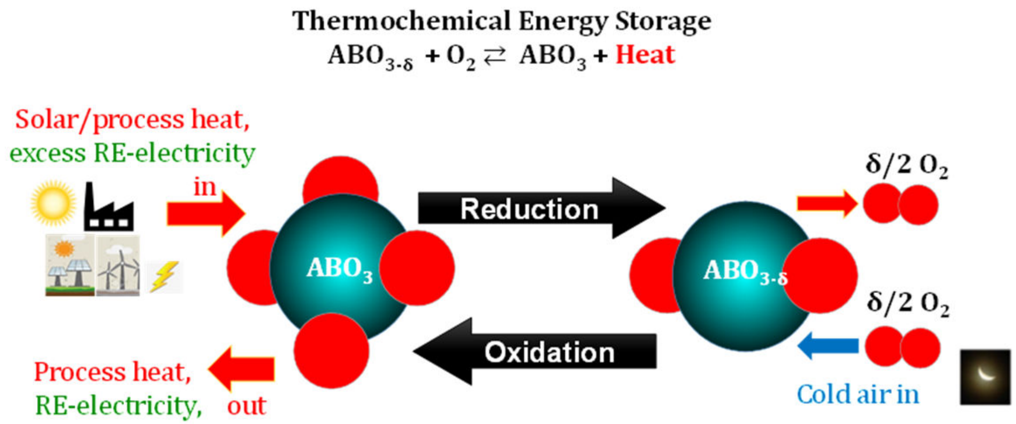
Heat storage →

$$CaMnO_3 \leftrightarrow CaMnO_{3-\delta} + \delta/2\ O_2$$

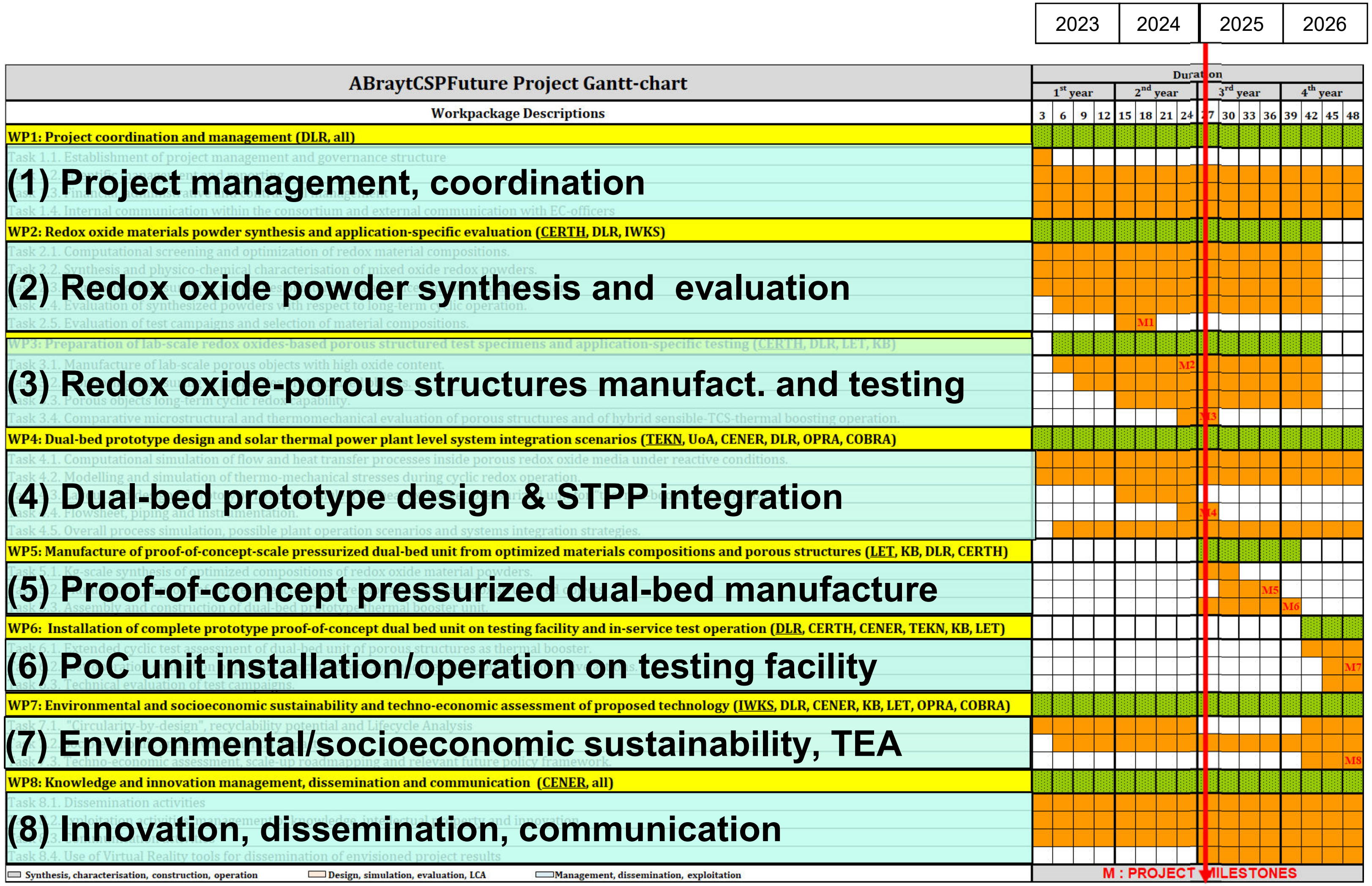
Heat release/thermal boosting ←

$$\Delta H_{rxn} = f(\delta);\ \uparrow \delta \rightarrow \uparrow \Delta H_{rxn}$$

$$T = 750 - 1100^{o}C$$



ABraytCSPfuture Gantt chart



Perovskite porous structures already manufactured, under ongoing testing

Results so far:

- Porous structured ceramics, namely honeycombs and reticulated porous ceramics (RPCs-“ceramic” foams), **made entirely out of $CaMnO_3$–based perovskite redox compositions were successfully prepared and tested.**
- Several of these structures are sturdy and rigid enough to be subjected to a plethora of post-shaping tests relevant to the targeted applications: hybrid sensible-TCS + thermal boosting (ongoing). In fact, **honeycombs** of specific compositions and porous microstructure have **extremely high mechanical strength.**
- **To the best of the partners’ knowledge this is the first time that a systematic production of such a variety of structured redox perovskite ceramics of such dimensions has been accomplished.**
- TCS-targeted experiments **with $CaMnO_3$–based honeycombs and foams** in in-house built test rigs demonstrated **the ability of such structures to store and release heat defined by the enthalpy of a reversible redox reaction.** Not only the heat stored during endothermic reduction was reversibly released during exothermic oxidation, **but such heat effects during exothermic oxidation could be clearly manifested as a measurable temperature rise of both the specimen tested as well as of the air stream flowing through it. Temperature increase of the porous solid from 140-200 ^oC and of the air stream of 75-140^oC were recorded.**
- **To the best of the partners’ knowledge, this is the first time that the ability of a perovskite – or in general of a redox oxide operating via partial reduction (oxygen vacancies) mechanism - to generate repeatable heat effects manifested as sensible temperature rise of a working/heat transfer fluid upon cyclic redox operation is demonstrated.**
- The respective **combined sensible/TCS storage density values range so far between 372 – 840 kWh/m^3**, exceeding significantly that of state-of-the-art molten salts.

Work ongoing !!

Website: https://www.abraytcspfuture.eu/

Twitter/X: https://twitter.com/ABraytCSPfuture

LinkedIn : https://www.linkedin.com/company/abraytcspfuture-project/

Thank you for your attention !!!

Questions ?

Facing high-temperature CSP for energy applications

SUNSON project

Esther López and Alejandro Datas

SUNSON

30th January 2025, Online

Funded by the European Union

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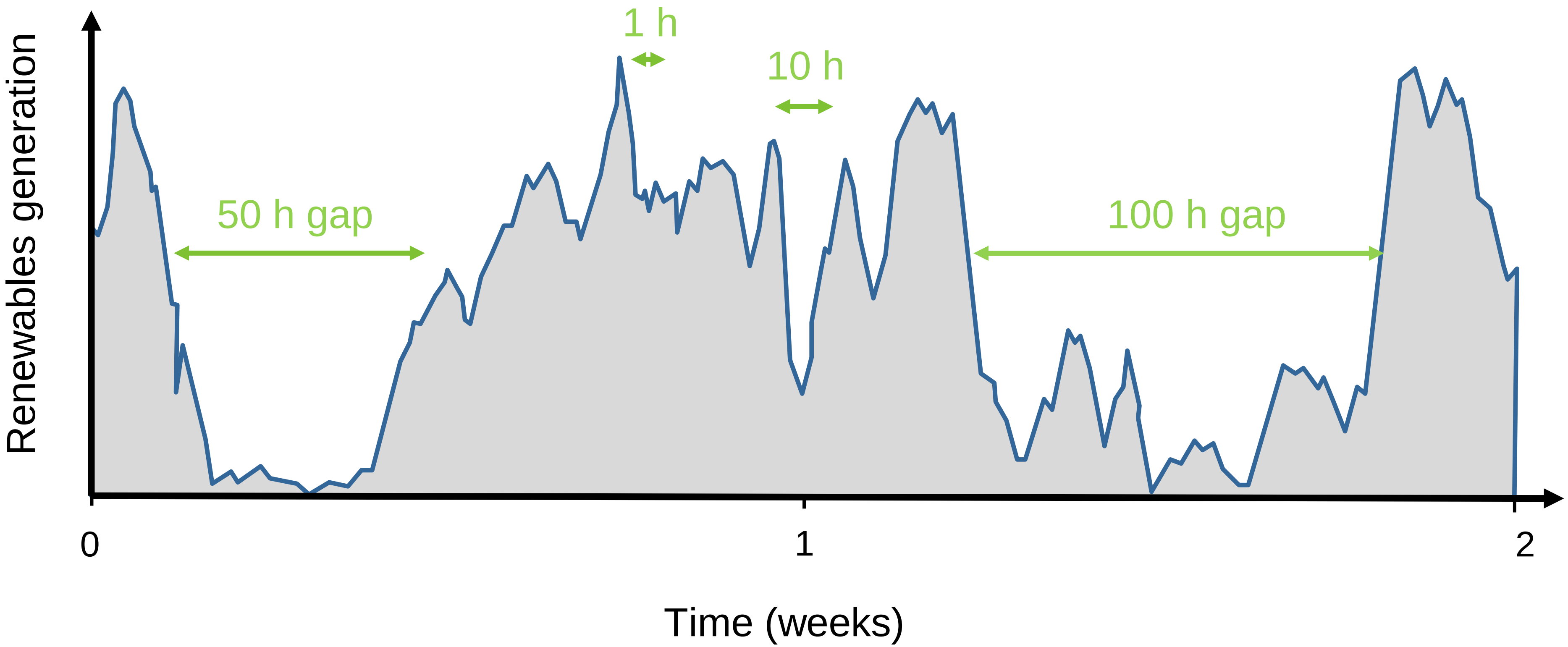
Global Perspective

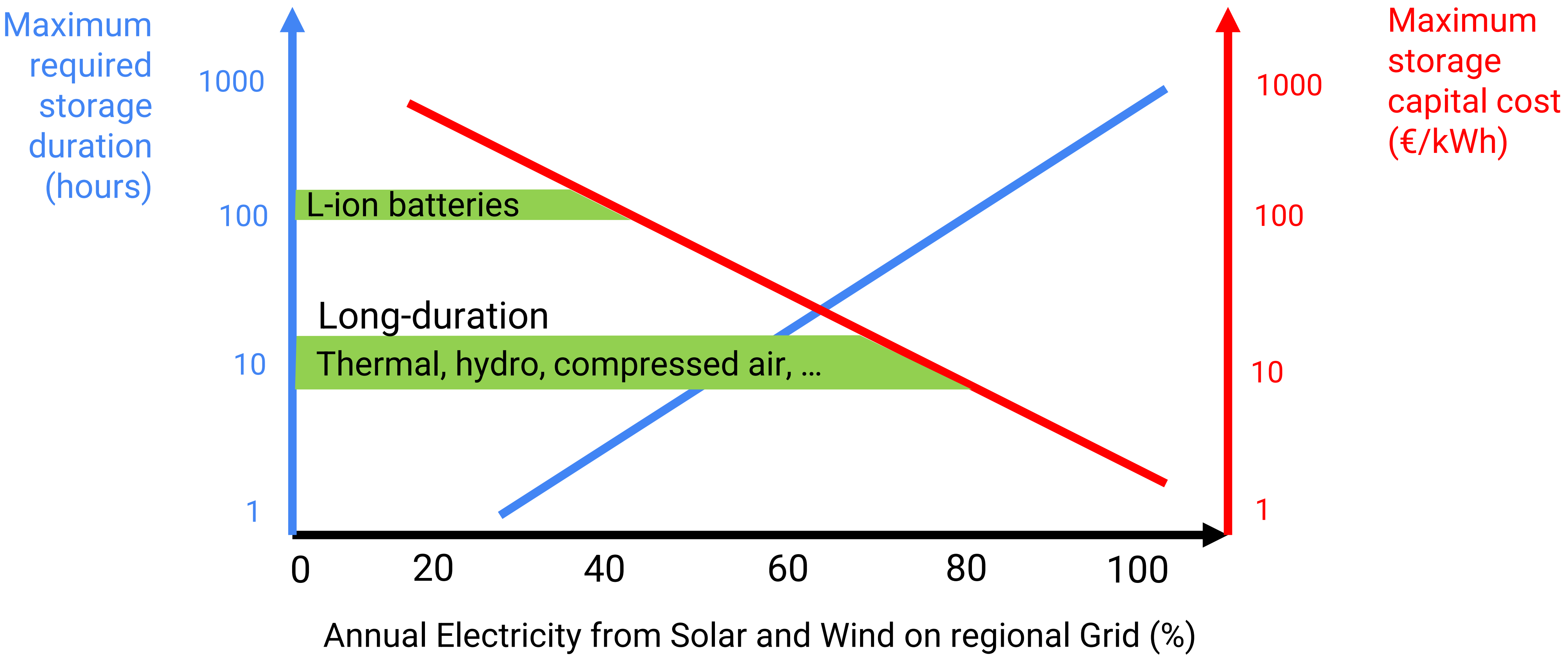
Rise of solar and wind electricity



Global Perspective

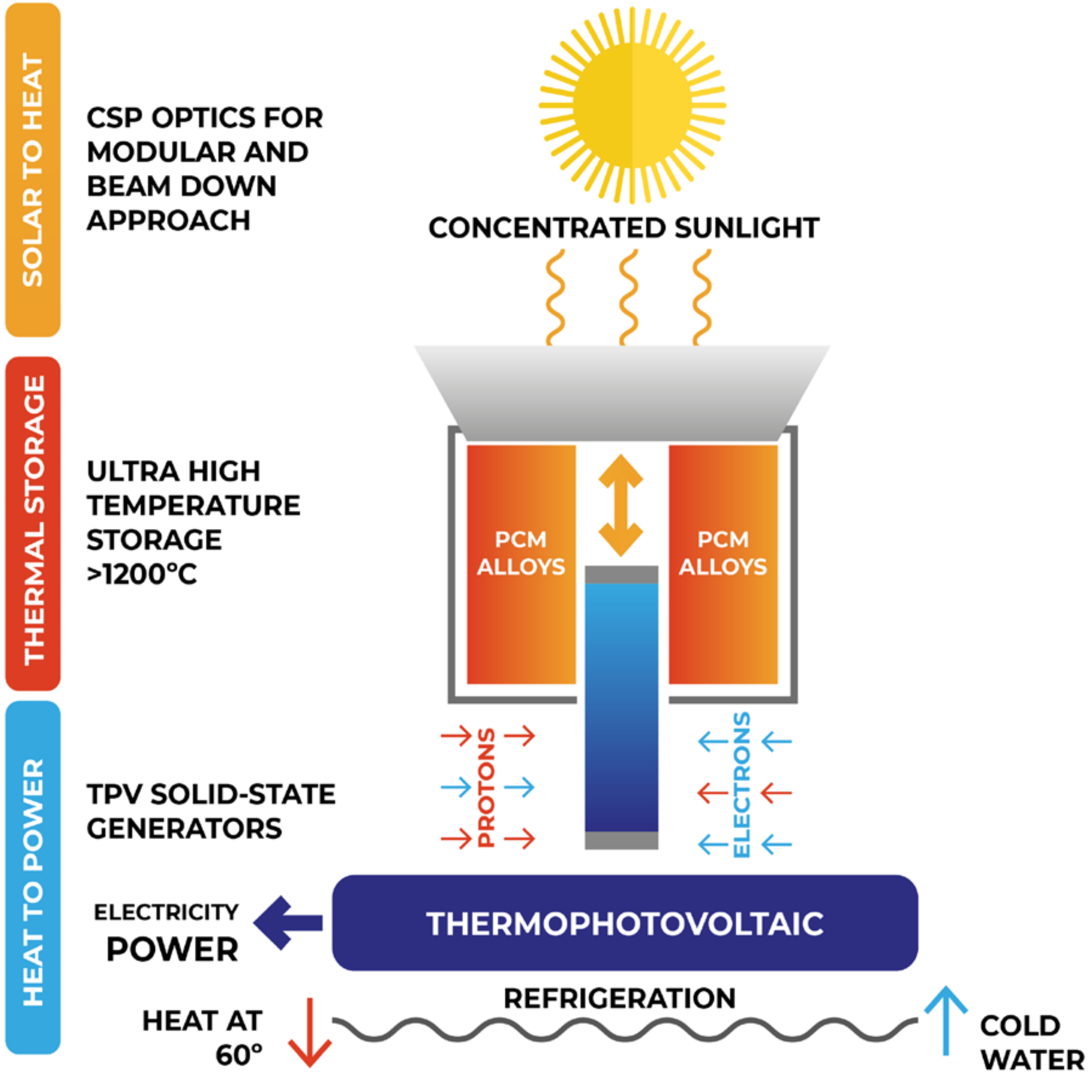
SUN SON

Storage duration / cost requirements



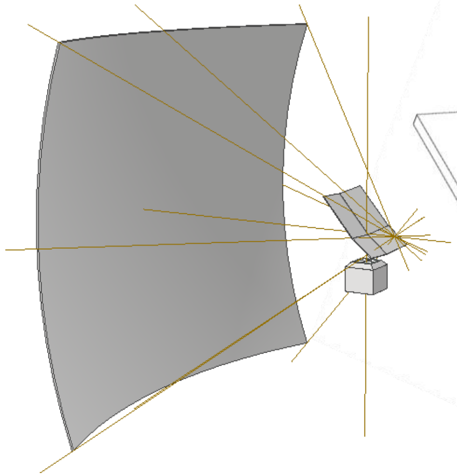
Overview of the SUNSON project

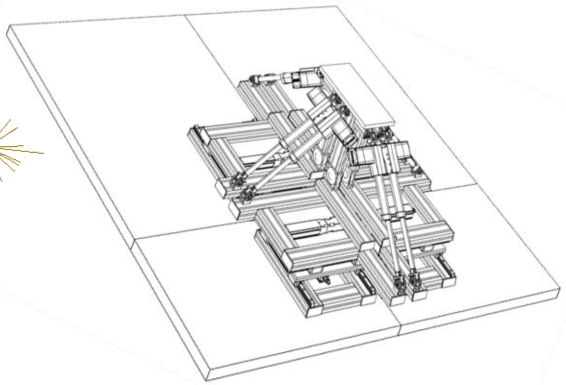
Solar-to-Heat-to-Power Storage:

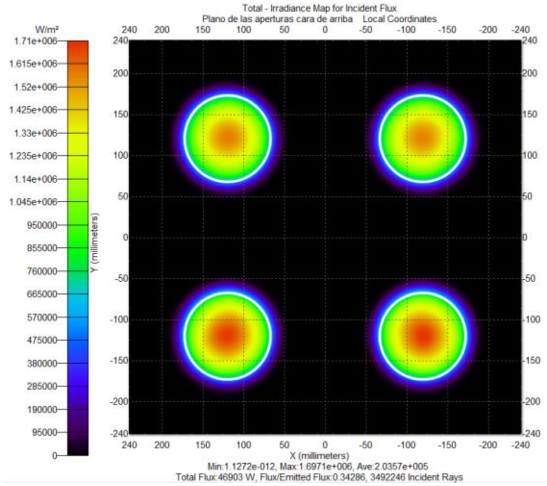


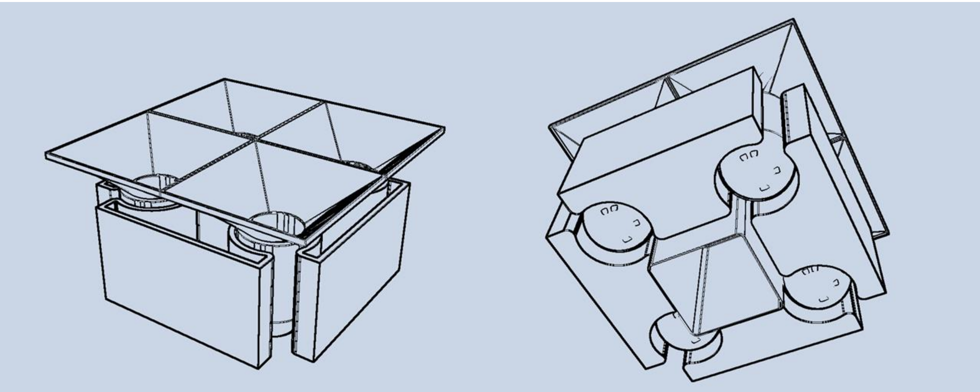
Solar to Heat conversion

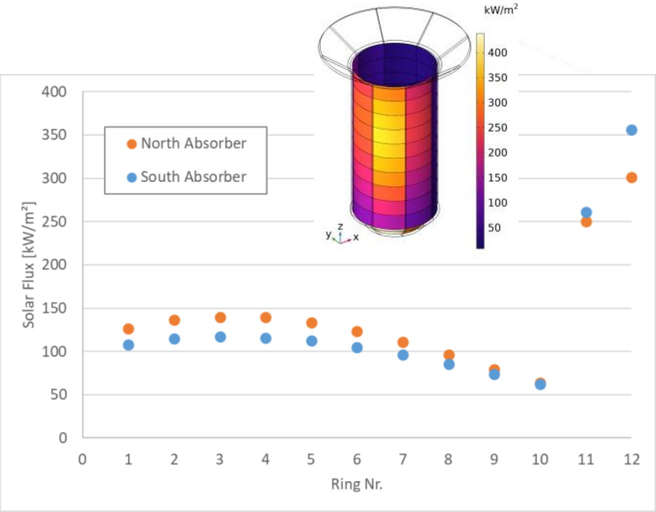
Modelling, design and fabrication of CSP optics

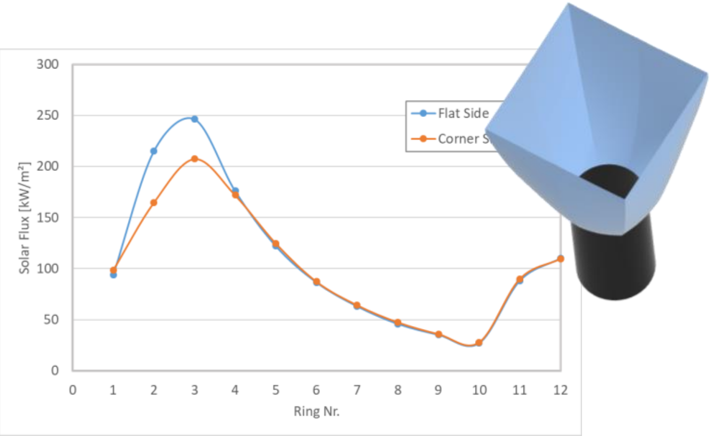










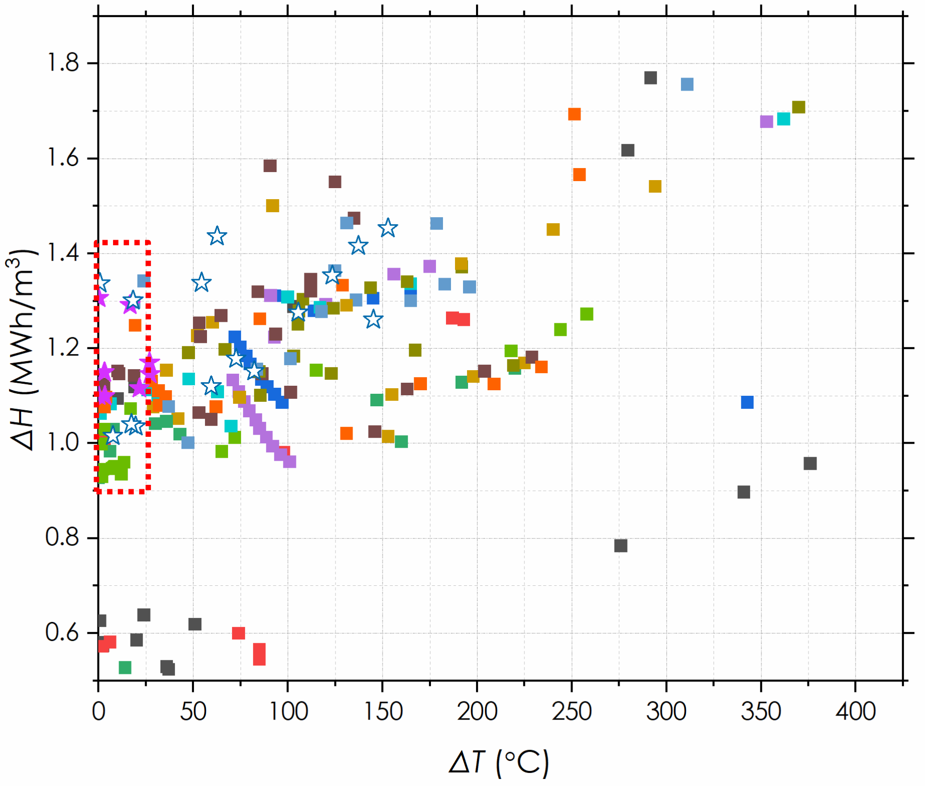


Thermal storage

SUNSON

Development and characterization of PCMs

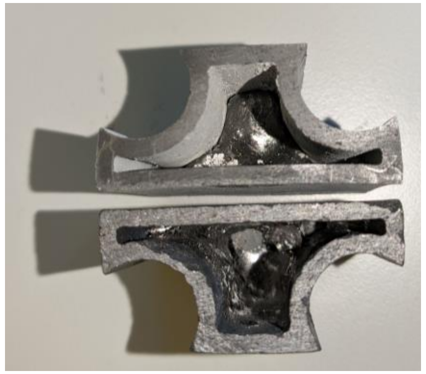
137 chemical compositions



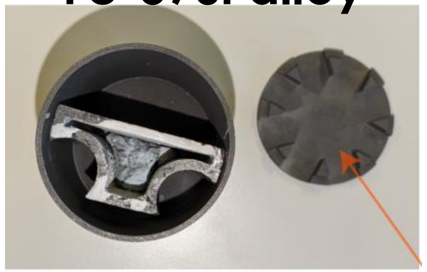
7 semi-finalists => 2-3 finalists

Alloy composition (wt %)	ΔH (MWh/m³)	T Liquidus (°C)	ΔT (°C)	**λ (W/mK)**
40Mn-46.5Si-11B-2.5Cr	1.33	1340	1	81.35
24Mn-64Si-10B-2Cr	**1.34**	1362	24	**100.67**
46Mn-40Si-14B	1.30	1335	0	86.27
49Fe-46Si-5B	**1.09**	**1159**	**10**	**109.11**
43Fe-57Si	**1.01**	**1217**	**3**	**128.99**
50Mn-50Si	1.08	1153	3	74.21
12Fe-34Mn-54Si	1.03	1181	23	113.02

Fe-46Si-5B alloy



Fe-57Si alloy

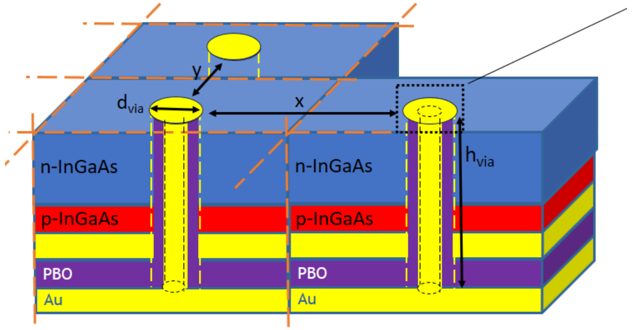


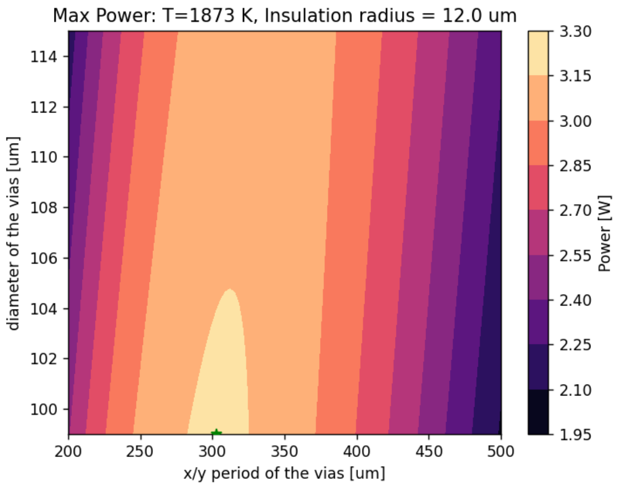
BN-coated graphite containers

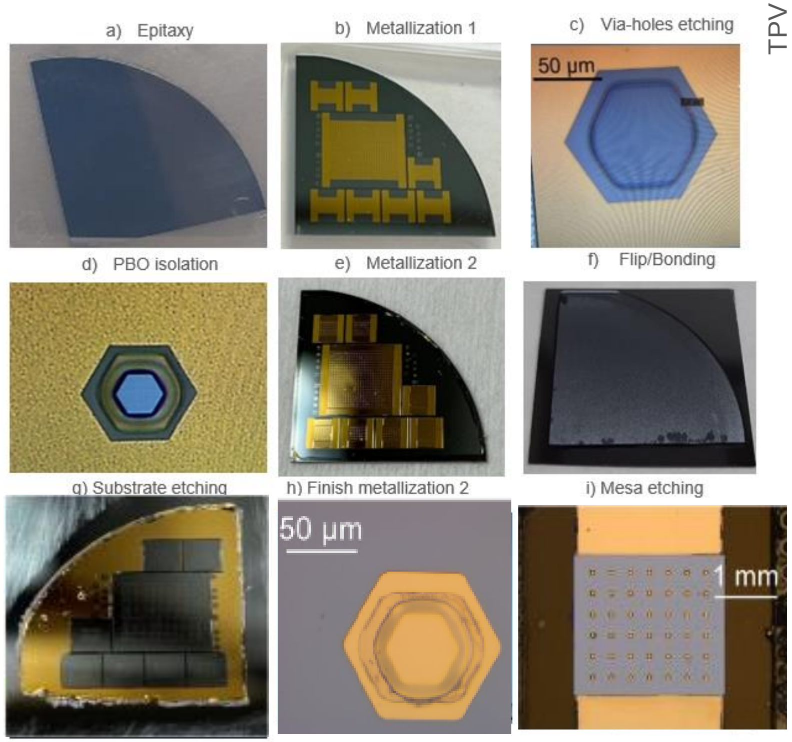
Heat to Power Conversion

Design and fabrication of MWT-TPV cells and modules

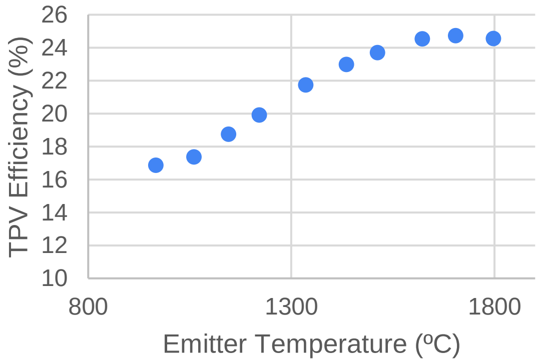
MWT-TPV cells

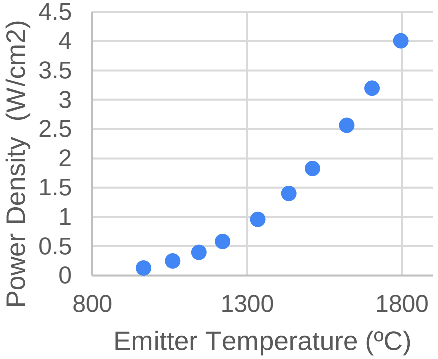


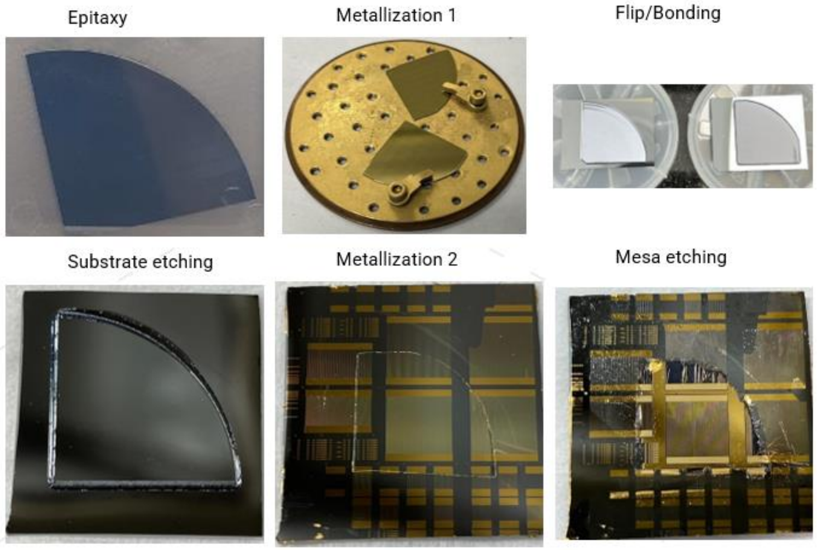




Thin film TPV cells

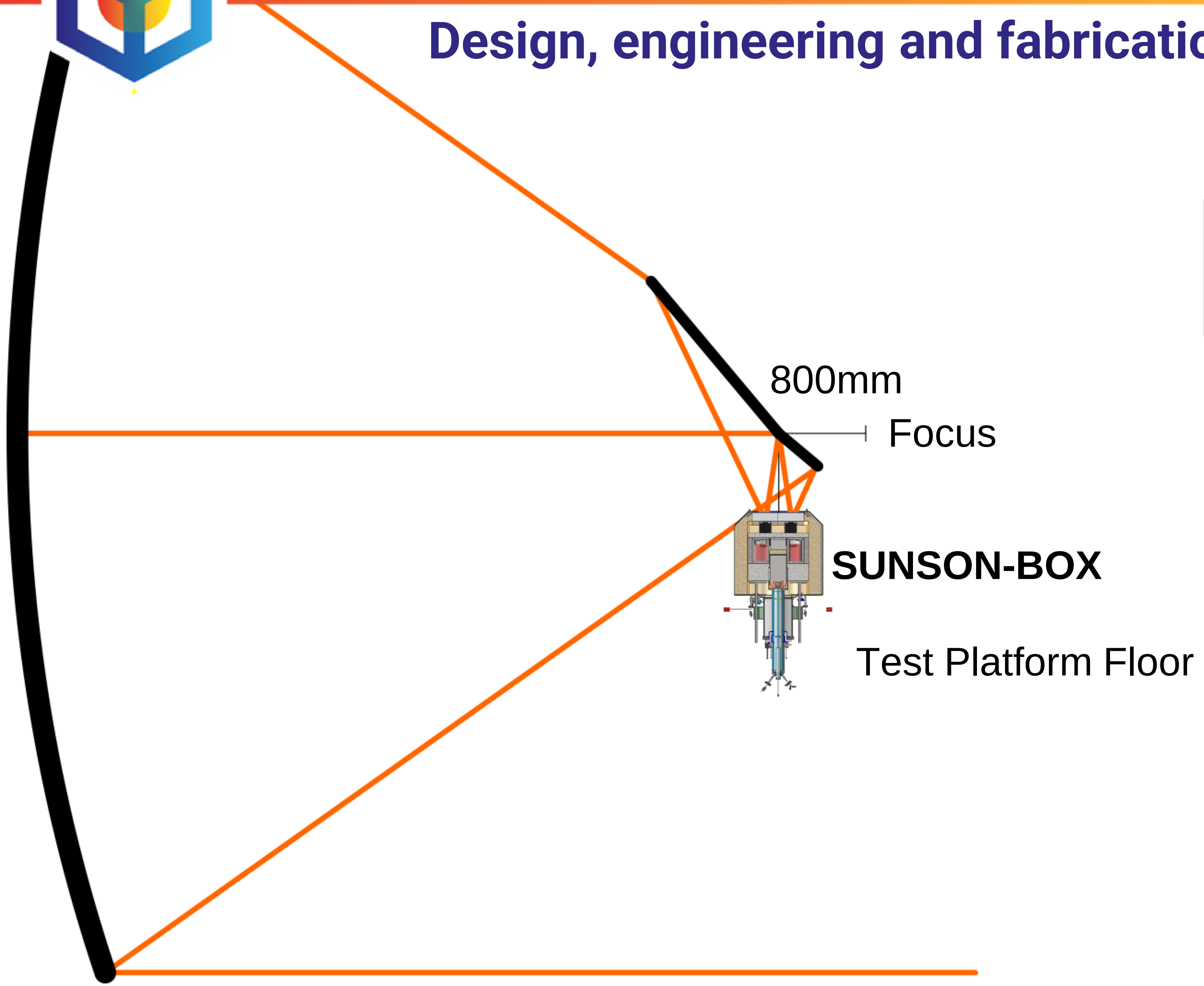


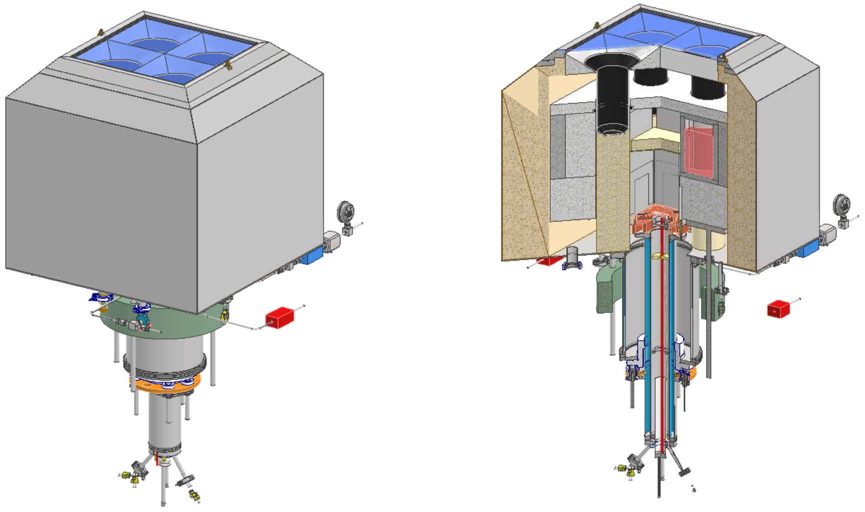




Flagship demonstration

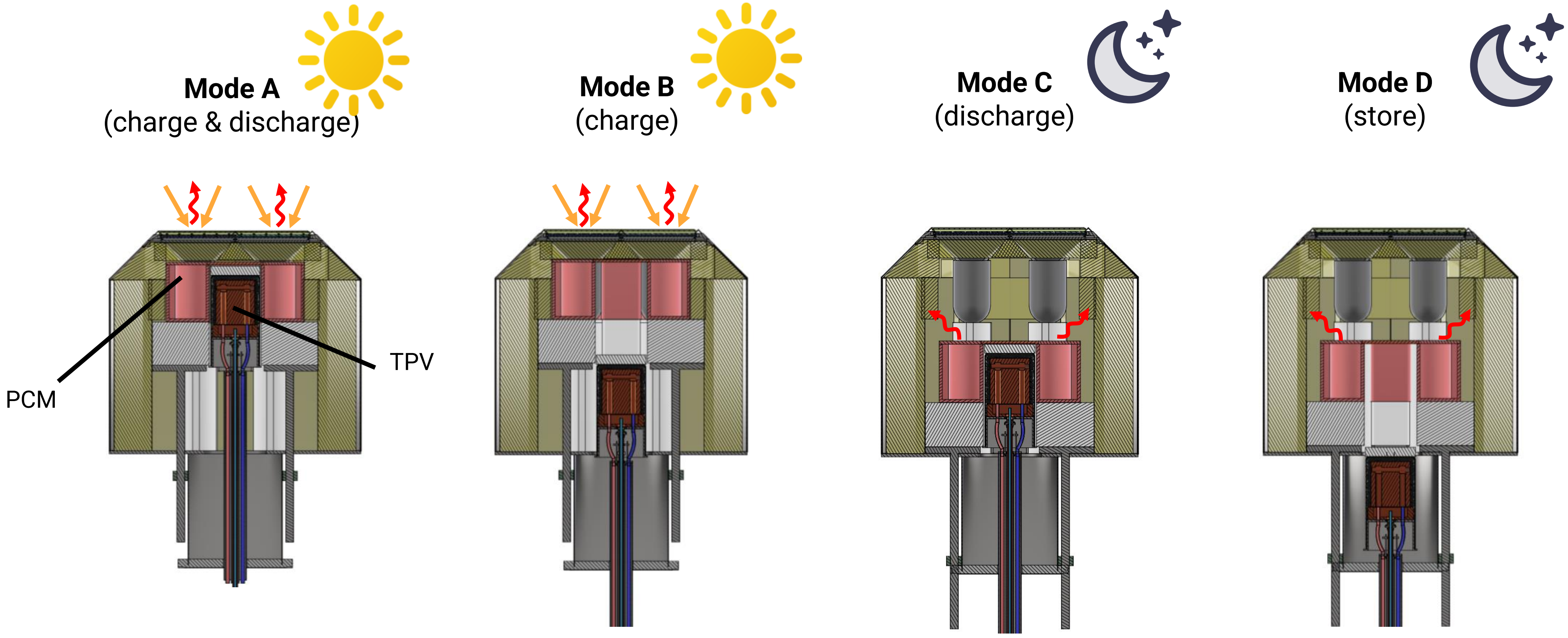
Design, engineering and fabrication of the demonstrator





Flagship demonstration

Operational modes



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Thank you for your time and attention!

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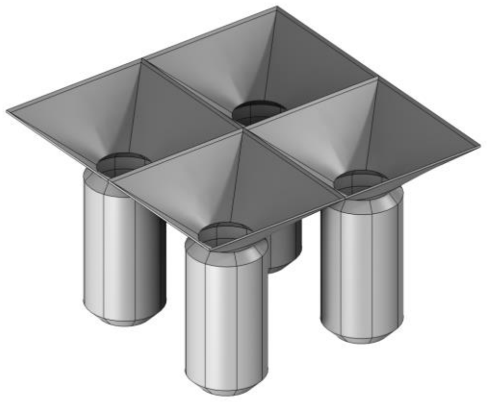
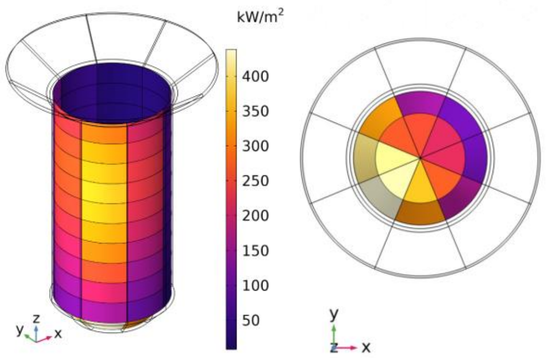
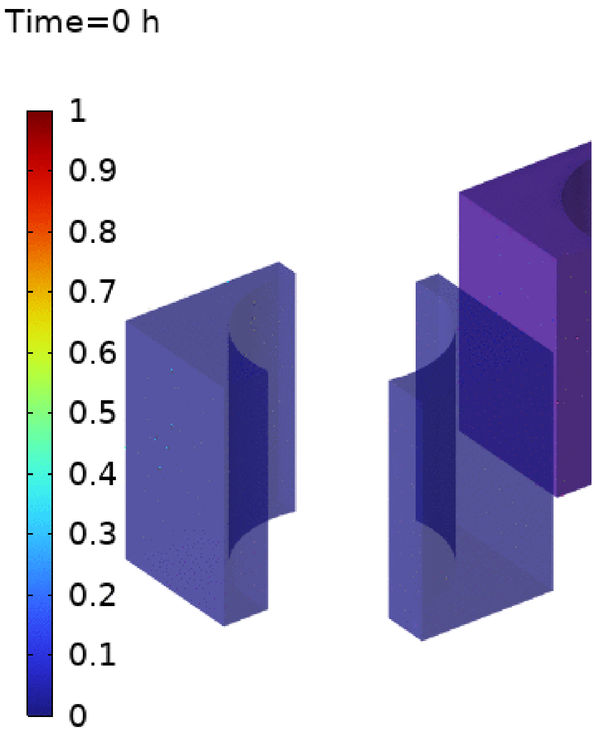
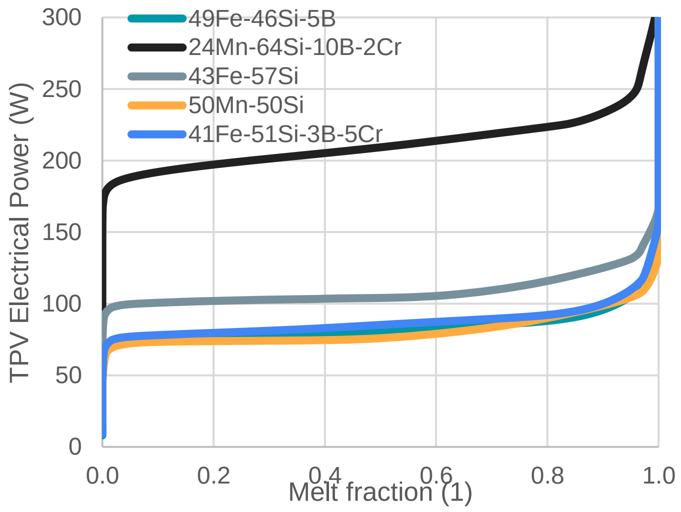
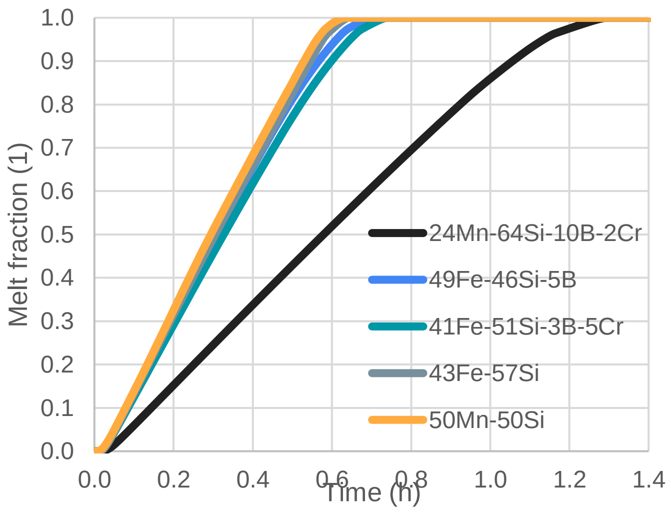
Modelling and design of the PCM-TES system











PYSOLO:
Pyrolysis of biomass by concetrated Solar Power

Facing High-Temperature CSP for energy applications

Marco Binotti, Politecnico di Milano, 30-01-25

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Funded by the European Union

Outline

- The PYSOLO project
- Conventional pyrolysis
- The pysolo concept
- Pysolo concept and experimental activity
- Status at M18: experimental activity
- Status at M18: simulation activity

The PYSOLO Project

Title: **PY**rolysis of biomass by concentrated **SOL**ar p**O**wer

Scope: PYSOLO will **integrate CSP** technology and **biomass pyrolysis** in an innovative and very flexible concept at TRL4 able to produce increased amount of high value bio-products (bio-oil and bio-char) compared to existing technologies and able to efficiently use renewable heat and electricity from variable renewable energies

Funding mechanism: HORIZON Research and Innovation Actions

Budget: 4.9 M€

Starting date: July 2023

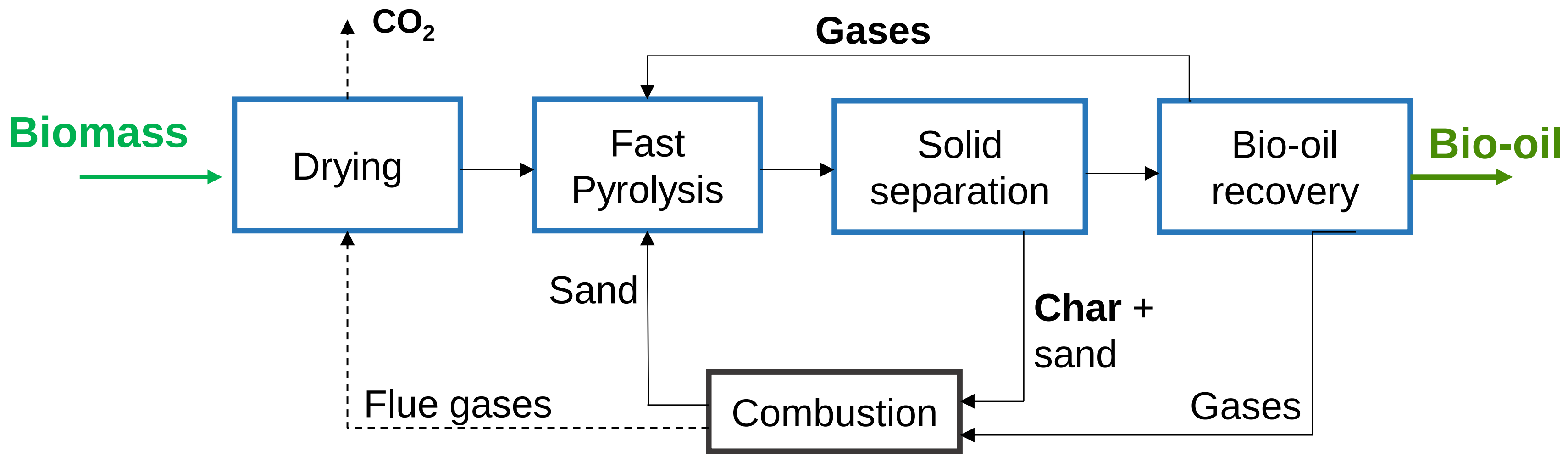
Duration: 4 years

Coordinator: Politecnico di Milano

Consortium: 9 partners, 4 countries

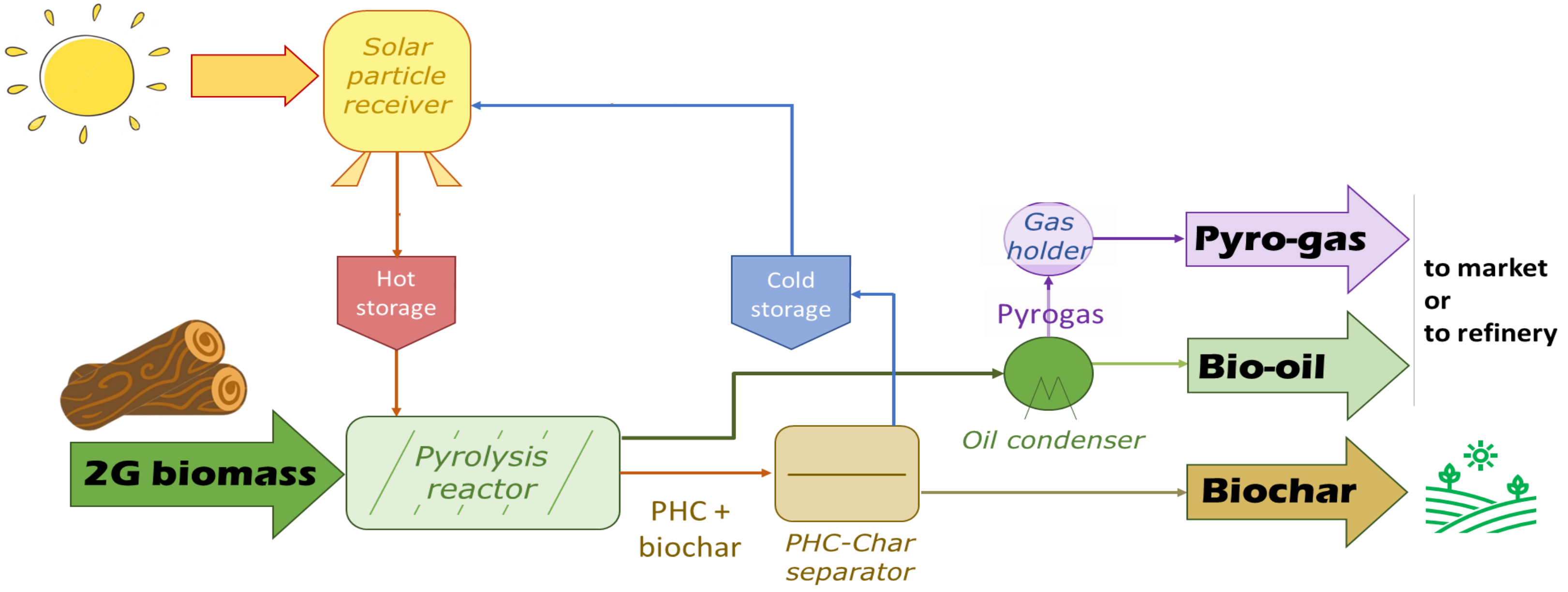
Conventional Pyrolysis

- **Biomass Pyrolysis** is a thermal degradation induced by supplying **heat (250-700°C)** in inert environment
- The pyrolysis **products** are: **bio-oil**, **pyro-gas** and **char**
- The **heat** required **for the reaction** is usually provided by **burning a fraction of the pyrolysis products** (pyro-gas/char): this represents an economic and environmentally inefficient step as it involves the loss of high value biogenic carbon emitted as CO_2, causing the reduction of the carbon efficiency and of the overall yield of bio-products



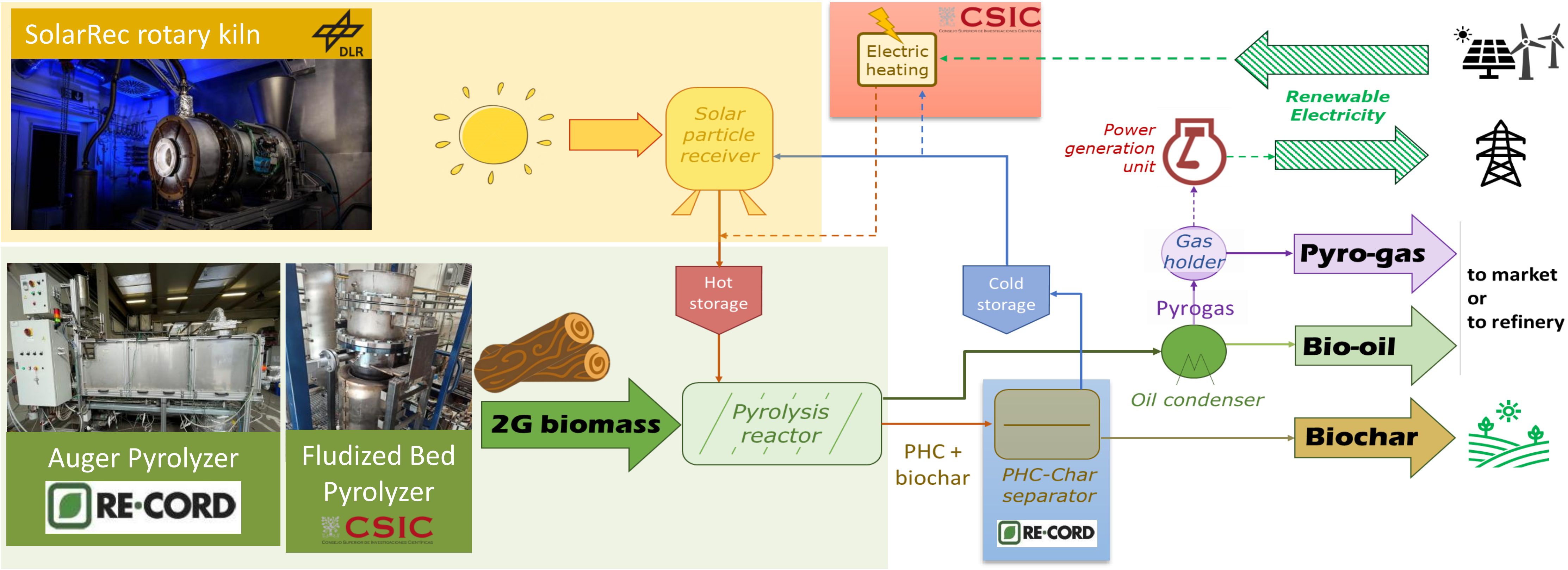
The PYSOLO Concept

- **Heat for pyrolysis** is provided by **solid particles** (e.g. sand, bauxite) heated in a rotary kiln solar receiver
- Excess thermal power can be stored in a **hot particle storage** to run the pyrolyzer for more hours
- Low cost **excess renewable EE** could be used to **heat** up the **particles** with extra advantages
- If **high EE costs** are expected gas and bio-oil might be burnt in an **Internal Combustion Engine** to produce EE



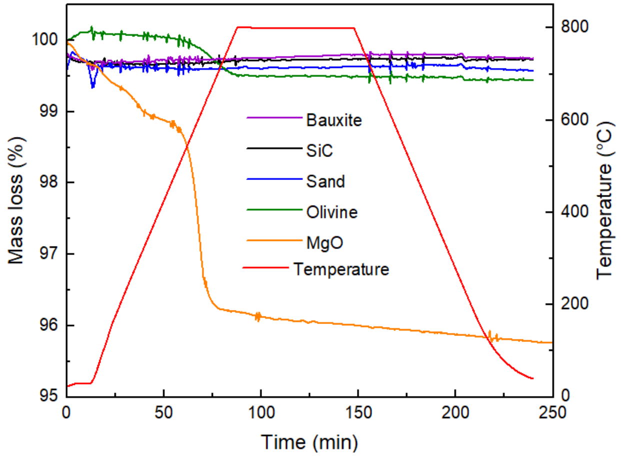
PYSOLO concept and experimental activity

- **4 different PHC** will be selected for the experimental activity in the pyrolyzers
- Both **stand-alone plants** and plants **integrated** with a **bio-refinery** will be investigated
- Key components will be **tested** at **TRL4:** 2 pyrolyzers, the rotary kiln receiver, the PHC/char separator and the electric heating



Status at M18: Experimental Activity

- Experimental characterization of the optical, mechanical, thermal and chemical properties of **biochar** and of **5 particle heat carriers** (bauxite, sand, MgO, SiC, Olivine) assessed at DLR [1]



- Adaption and commissioning of the **2 Pyrolysis units** and of the **induction heating system** concluded

CSIC FB reactor

Biomass flowrate: 3 kg/h

Operating T: up to 500-700ºC

REC AUGER reactor

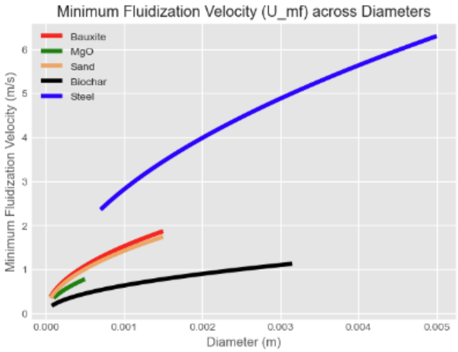
Biomass flowrate: 3 kg/h

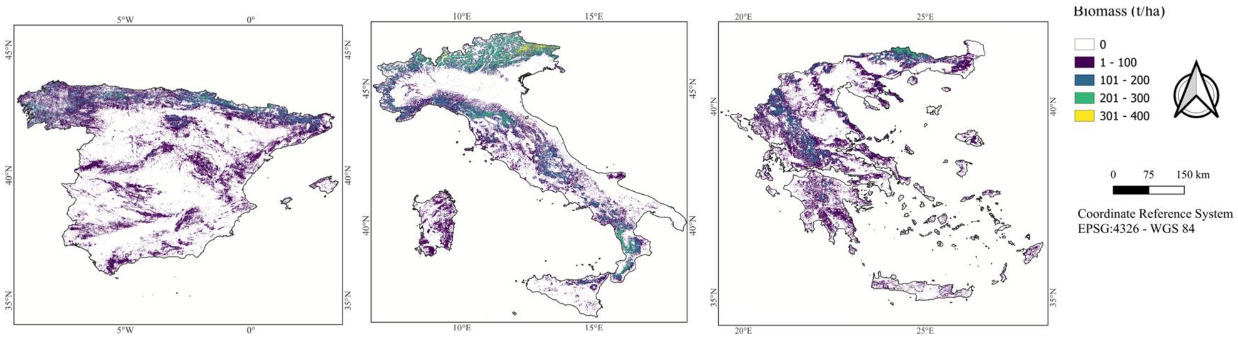
Operating T: up to 600ºC

[1] J. P. Rincon Duarte et al., *Solar absorptance measurements of particle heat carriers in a solar driven biomass process*, to be presented at ASME ES2025

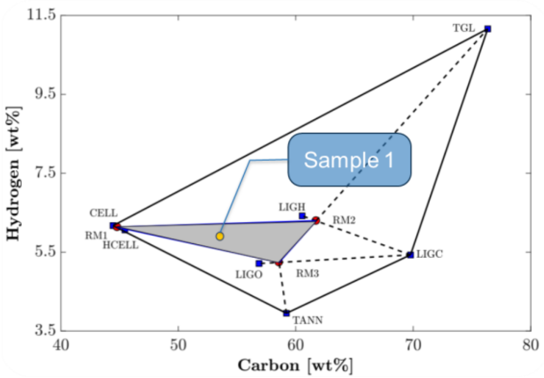
Status at M18: Simulation Activity

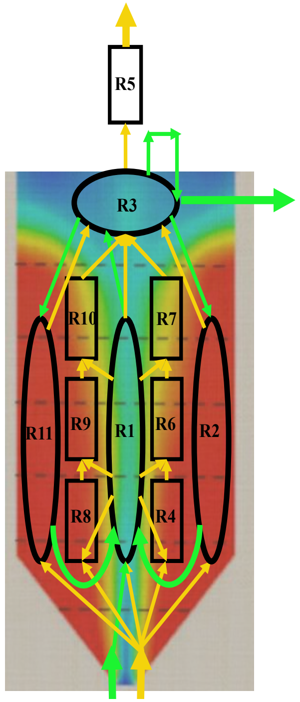
- Fluidized Bed PHC/Char separator designed, theoretical separation efficiency assessed [2]
- Selection of **pine wood** as biomass for testing activity and theoretical assessment of the biomass potential in Italy, Greece and Spain





- Developed improved pyrolysis models at molecular and reactor scales that consider fluid dynamics and varying product compositions. The model can be integrated in Aspen Plus [3]

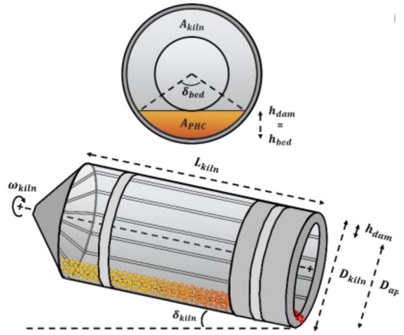


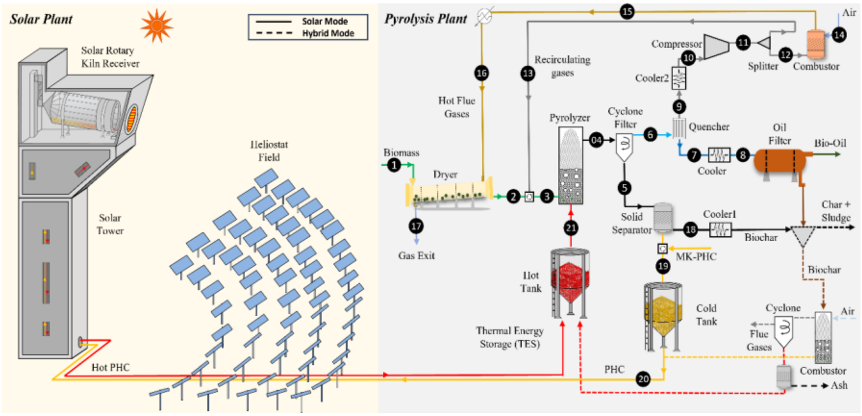


[2] Prussi, M., Danesh, P., Laveneziana, L., & Chiaramonti, D., *A fluidized bed separator for biochar – PYSOLO project*. EUBCE 2024, Marseille, France. https://doi.org/10.5281/zenodo.14264857
[3] Muhammad Ahsan Amjed, *Solar Driven Biomass Pyrolysis for High Efficiency Biofuel Production*, PhD thesis, Politecnico di Milano

Status at M18: Simulation Activity

- Preliminary evaluation of the solar field and rotary kiln receiver design and optical-thermal performance assessment [4]
- Definition of plant KPI's, overall system analysis and comparison of conventional, solar only and hybrid modes operation considering falling particle receiver [3, 5] and rotary kiln receiver [4]





Annual Performance	Conventional	Solar	Hybrid
Annual Solar-Thermal Efficiency [-]	-	0.551	0.549
Carbon Efficiency [-]	0.743	0.903	0.844
ETO net	0	-24.64	-18.89
MFSP [€/GJ_{OIL}]	**28.85**	**25.71**	**21.36**

$$\boldsymbol{ETO_{net}} = -\frac{\dot{m}_{char,i} \cdot y_{C,char} \cdot {}^{44}/_{12}}{Oil_t}$$

$$\boldsymbol{\varepsilon_C} = \frac{\sum_i \dot{m}_{prod,i} \cdot y_{C,prod,i}}{\dot{m}_{biom} \cdot y_{C,biom}}$$

$$NPV = -TCI + \sum_{j=-2}^{30} \frac{P_{by-prod} \times M_{y-prod,y_j} + \boldsymbol{MFSP} \times M_{oil,y_j} - T_j - C_{OP,VAR,j} - C_{OP,FIX,j} - L_j}{(1+i)^j} = 0$$

[3] Muhammad Ahsan Amjed, *Solar Driven Biomass Pyrolysis for High Efficiency Biofuel Production*, PhD thesis, Politecnico di Milano
[4] M.A.Amjed, M.Colombi, et al. *Solar-driven Biomass Pyrolysis Plant for Negative-Emission Biofuels Production*, Proceedings of SolarPACES 2024, Rome, Italy
[5] M.A.Amjed, F.Sobic, M.Romano, T.Faravelli and M.Binotti, *Techno-economic analysis of a solar-driven biomass pyrolysis plant for bio-oil and biochar production,* Sustainable Energy & Fuels 2024

Marco Binotti

Project Coordinator
marco.binotti@polimi.it

Associate Professor
Politecnico di Milano

Thank you!

BLAZETEC

Daniele M. Trucchi[1] and the BLAZETEC consortium[1-7]

[1]Consiglio Nazionale delle Ricerche – Istituto di Struttura della Materia, Italy;
[2]Universidad Politecnica de Madrid – Instituto de Energia Solar, Spain;
[3]RGS Development, The Netherlands;
[4]Ionvac Process, Italy;
[5]The Cyprus Institute, Cyprus;
[6]Centre Suisse d'Electronique et de Microtechnique, Switzerland;
[7]Thermophoton, Spain

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BREAKTHROUGHS IN THERMAL BATTERIES THROUGH ZERO-EMISSION HIGH-TEMPERATURE STATIC THERMAL-TO-ELECTRIC CONVERTERS

Call: HORIZON-CL5-2023-D3-03-01
Increasing the efficiency of innovative static energy conversion devices for electricity and heat/cold generation
Project budget: 3 M€
Project type: RIA
Project duration: 42 months
https://cordis.europa.eu/project/id/101160724
https://www.blazetec.eu

Increased potential for wider application of electricity and heat/cold static generators due to increased efficiency of energy conversion devices using physical effects such as:

- Thermoelectric -> Thermoelectric Generators (TEG)
- Thermovoltaic -> Thermophotovoltaic Generators (TPV)
- Thermionic -> Thermionic Generators (TIG)

Specific Topic Conditions: Activities are expected to achieve TRL 5

BLAZETEC: Ultra-high Temperature Applications (1200 – 1600 °C)

Daniele M. Trucchi – danielemaria.trucchi@cnr.it

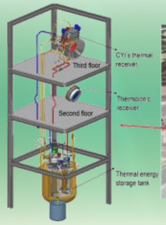
European Climate, Infrastructure and Environment Executive Agency

Solar-to-heat-to-electricity

Electricity-to-heat-to-electricity

Technology Demonstration
TRL 4 → TRL 5

Sensible heat thermal battery



Latent heat thermal battery

Technology Innovation on hybrid devices
TRL 3 → TRL 4

TITEG
1200 – 1600 °C
>30 %
> 5 W/cm²

TIPV
1200 – 1600 °C
> 30 %
> 8 W/cm²

Technology Innovation on independent devices
TRL 3 → TRL 4

Multi-module TEG
800 – 1000 °C
≥ 15 %
> 1 W/cm²

Vacuum TIG
1200 – 1600 °C
> 20 %
> 4 W/cm²

Multi-junction TPV
1200 – 1600 °C
> 40 %
> 4 W/cm²

Thermoelectrics (TEG)

Thermionics (TIG)

Thermophotovoltaics (TPV)

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Thermophoton POWERING ENERGY STORAGE

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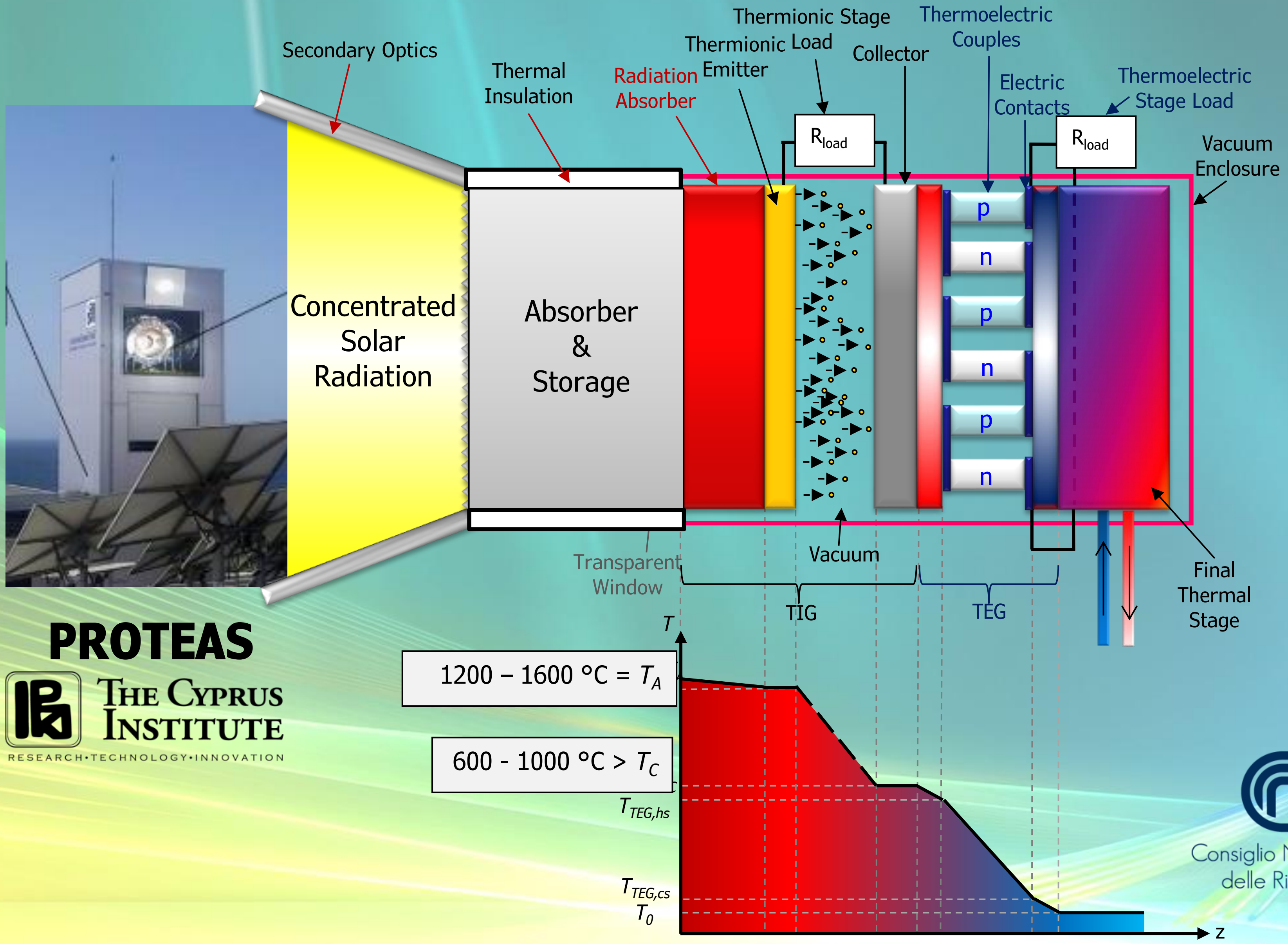
Sensible Heat Thermal Battery



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The Cyprus Institute
RESEARCH·TECHNOLOGY·INNOVATION

- PROTEAS is located in Pentakomo, near Governor's Beach
- Area : 20,000 m^2
- Inaugurated in 2015

70 tilt-roll rectangular heliostats of 5 m^2 each (2.25×2.25 m^2), yielding thus a combined mirror surface of 350 m^2.

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THERMOPHOTON
POWERING ENERGY STORAGE

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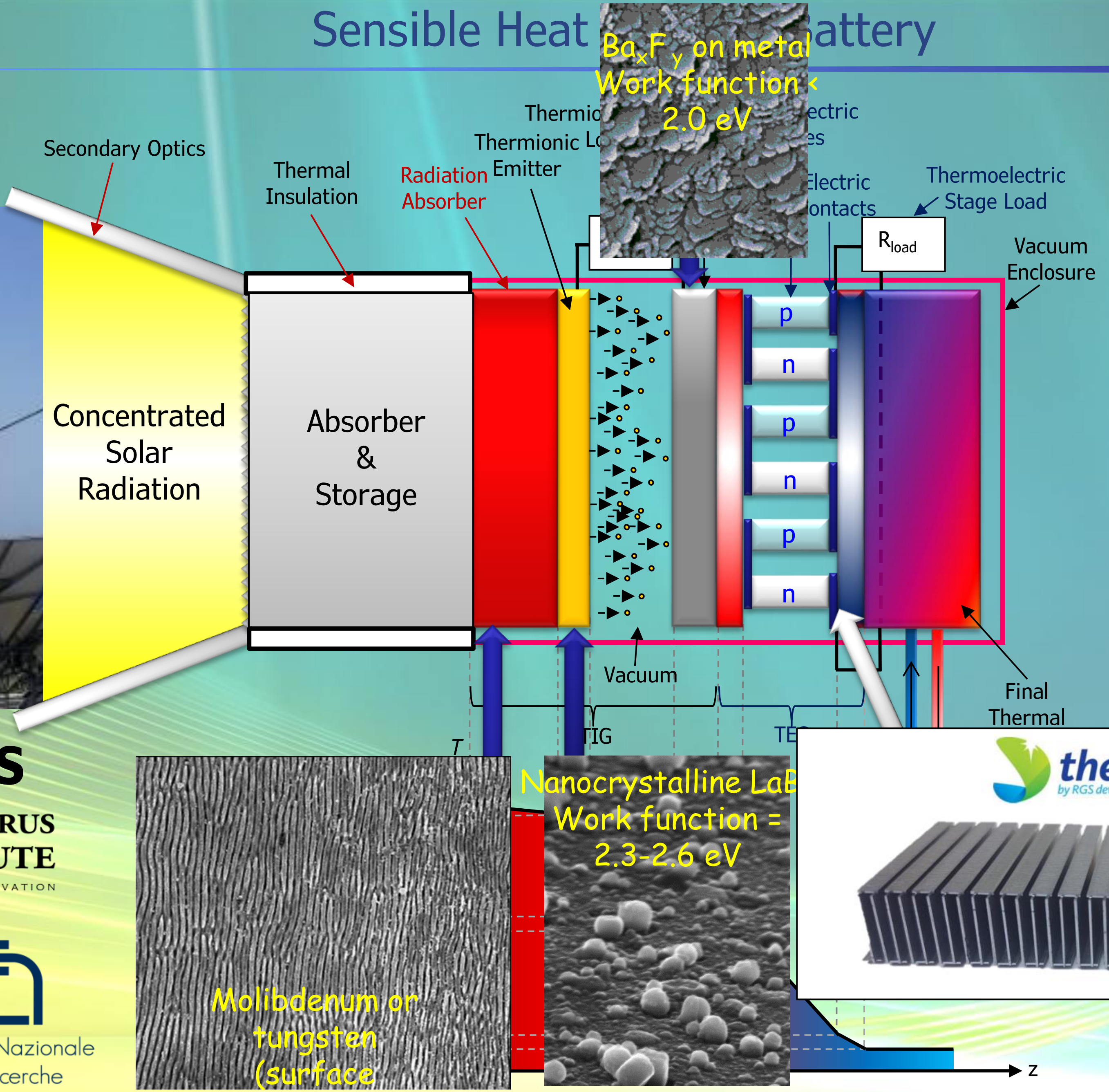

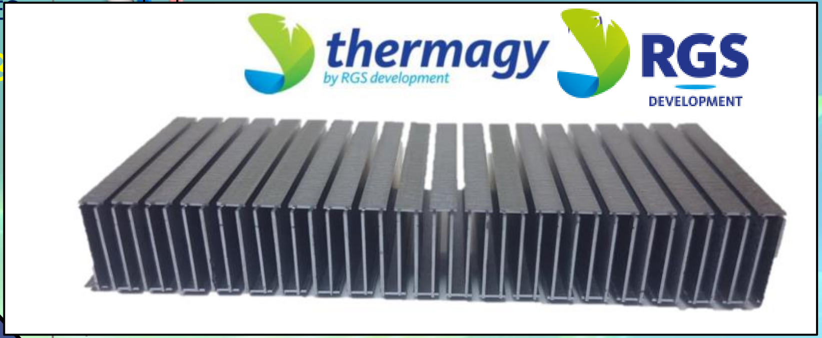

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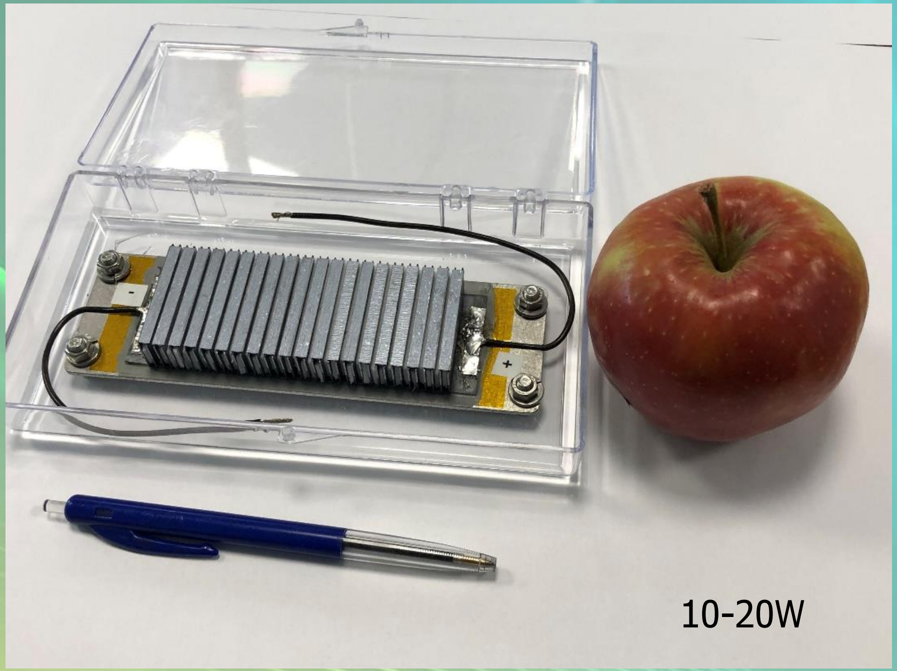
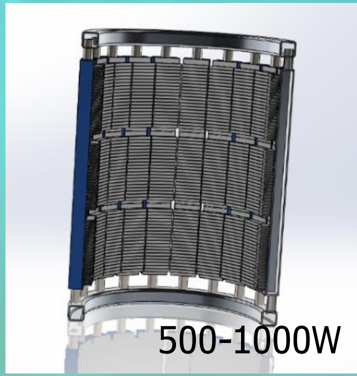
THERMOPHOTON POWERING ENERGY STORAGE

TEG: RGS ThermagyTM - Silicon Germanium TEG devices





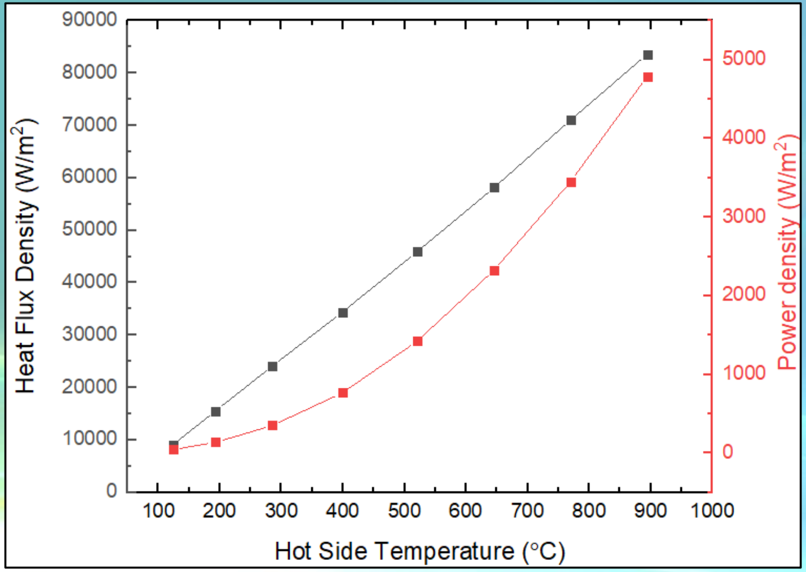
A TEG concept for various configurations (device shape, surface and architecture) capable of high temperature operations (up to 900 °C)

A unique Thermoelectric Generator (TEG) module design for high temperature radiative heat sources

Robust – Stable and proven materials

Silent - No moving parts

Mono block design



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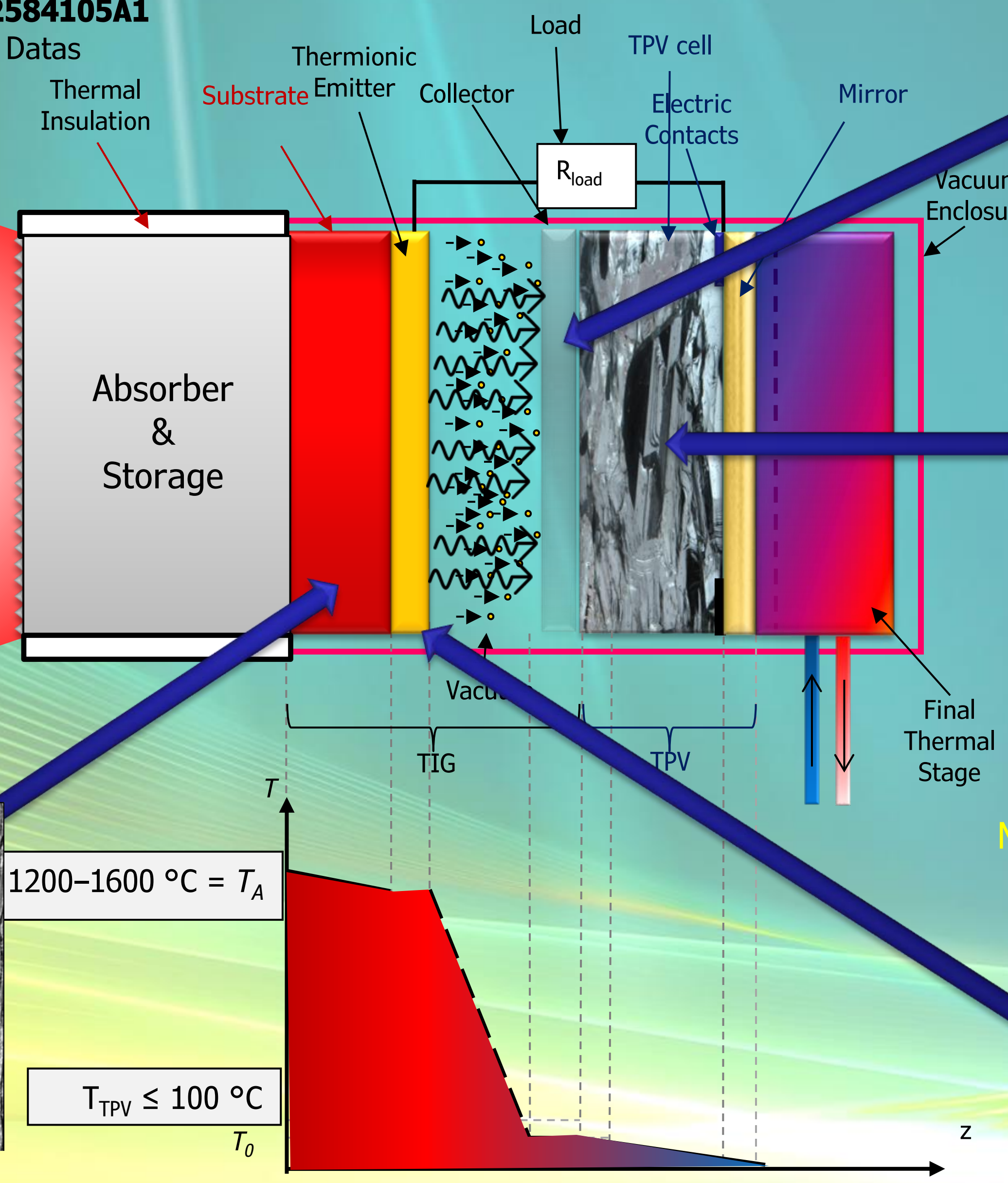
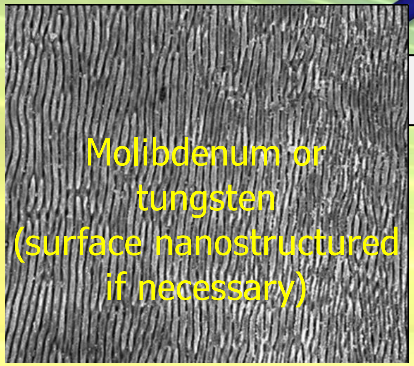
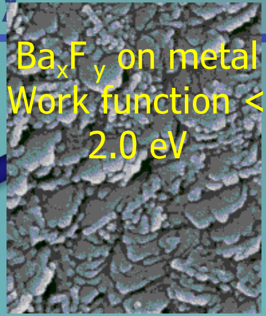
TIPV - Latent Heat Thermal Battery

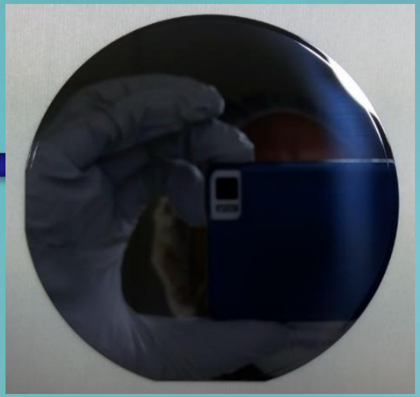
Patent n. **ES2584105A1**
Inventors: A. Datas



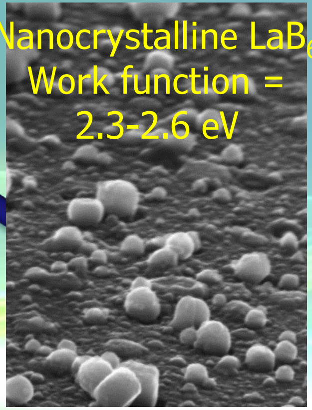




Collector coating has:
-more relaxed conditions for temperature stability than TITEG
-stricter conditions for optical transparency



Multijunction TPV based on InGaAs



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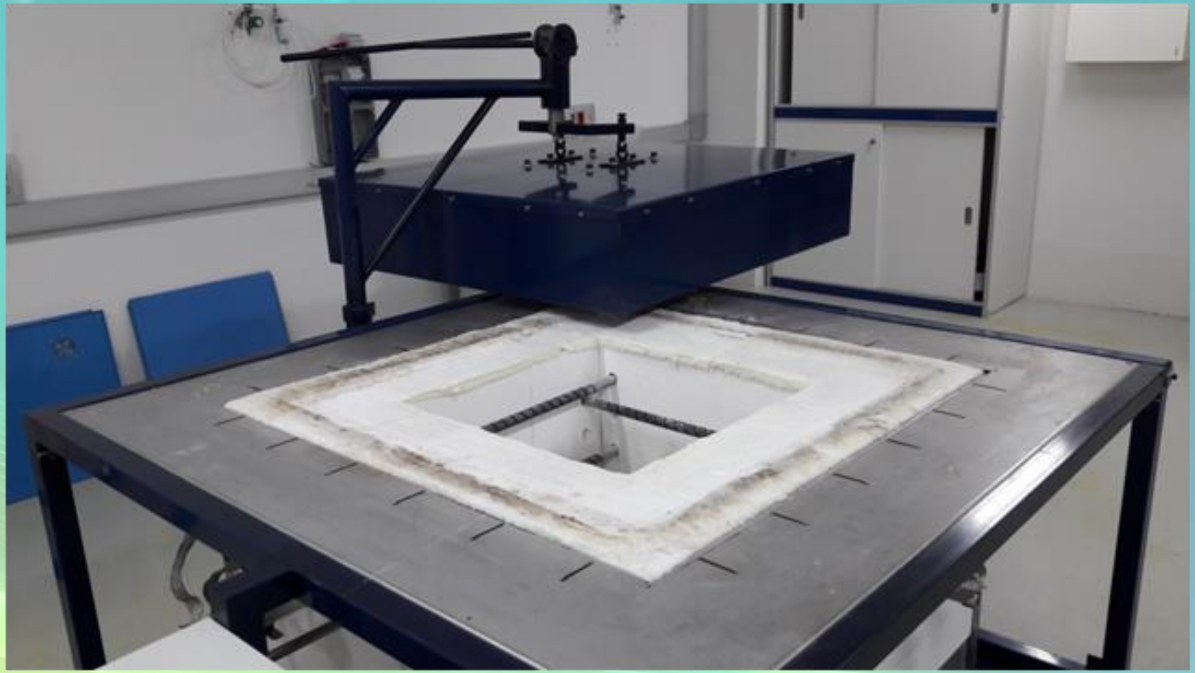
THERMOPHOTON POWERING ENERGY STORAGE

High Temperature Electric furnace

POLITÉCNICA Instituto de Energía Solar



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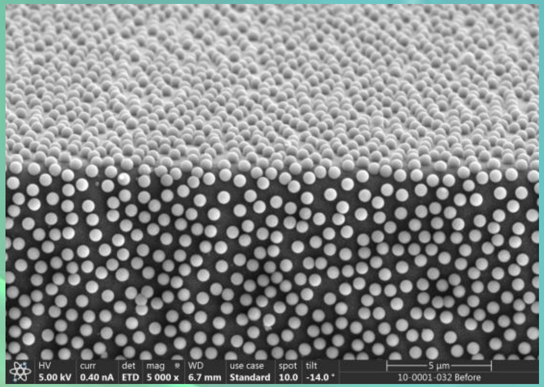
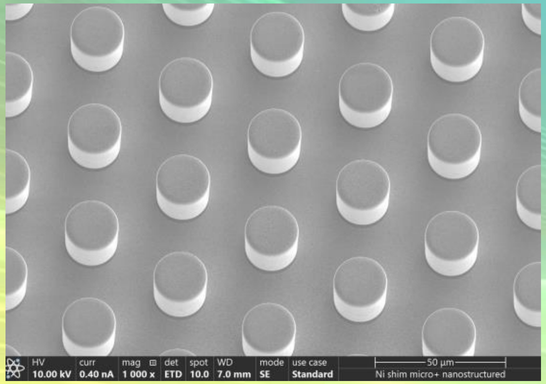
Open Challenges

Dielectric MicroSpacers





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Encapsulation Technology

- *Vacuum sealing in UHV conditions*, to guarantee the lowest possible leak from the ambience
- *Vacuum compensation* from components' degassing with getter strips activated by high-temperature

IONVAC Process

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- Single TIG, TEG, TPV stages are under efficiency improvement
- Hybrid TITEG and TIPV stages will be developed and optimized to maximize the converters' performance
- Two thermal battery demonstrators will be fabricated:
  - Sensible heat battery based on TITEG and fed by concentrated sunlight;
  - Latent heat battery based on TIPV and fed by an electric furnace.

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Thank you for the attention!

... and thanks to the funding Institutions

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COOPERANT

Leading-edge cooperative advances towards the next generation of concentrated solar power (CSP) technology

Patricia ROYO (IDENER R&D, www.idener.ai)
30th January 2025

Funded by the European Union

COOPERANT project is funded by the European Union under the Grant Agreement N° 101172882. This work was supported by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract N° 2400402. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Background and Motivation

Concentrated Solar Power (CSP) technologies progress

EU solar generation reached a new all-time high of 246 TWh in 2023,

but still, CSP represents less than 1% of the electricity production share.

954 GW of installed CSP capacity by 2050
would mean 6.7 GW of added capacity per year in EU,
while at present only ~2.3 GW.

Current status not on track with climate and energy agendas

EU Net Zero scenario emissions target by 2050

COOPERANT introduces disruptive innovations in CSP to reach global climate goals

https://ember-energy.org/latest-insights/european-electricity-review-2024/data-tool-eu-electricity-source-trends/

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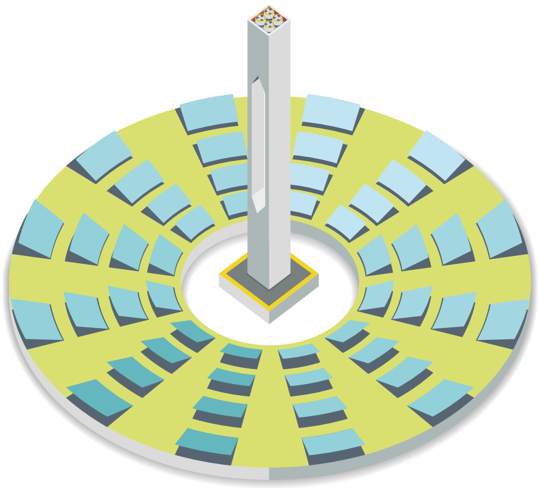
Limitations in CSP & Thermal storage

The next generation of CSP devices must overcome the current limitations

- Operation at T >600°C for supercritical steam Rankine cycles and T >750°C for supercritical CO_2 or Brayton cycles to reach higher cycle efficiencies (>42%).
- Current commercial "two tank molten salt" storage is limited to 565°C.
- Reduction of costs for advanced materials and critical components in cycle power blocks to withstand harsh conditions.
- Need for better system integration capabilities through digital tools deployment.
- Scarce demonstration of novel CSP approaches and testing proficiency in prototypes.
- Lack of consideration of human health and sustainability impacts.



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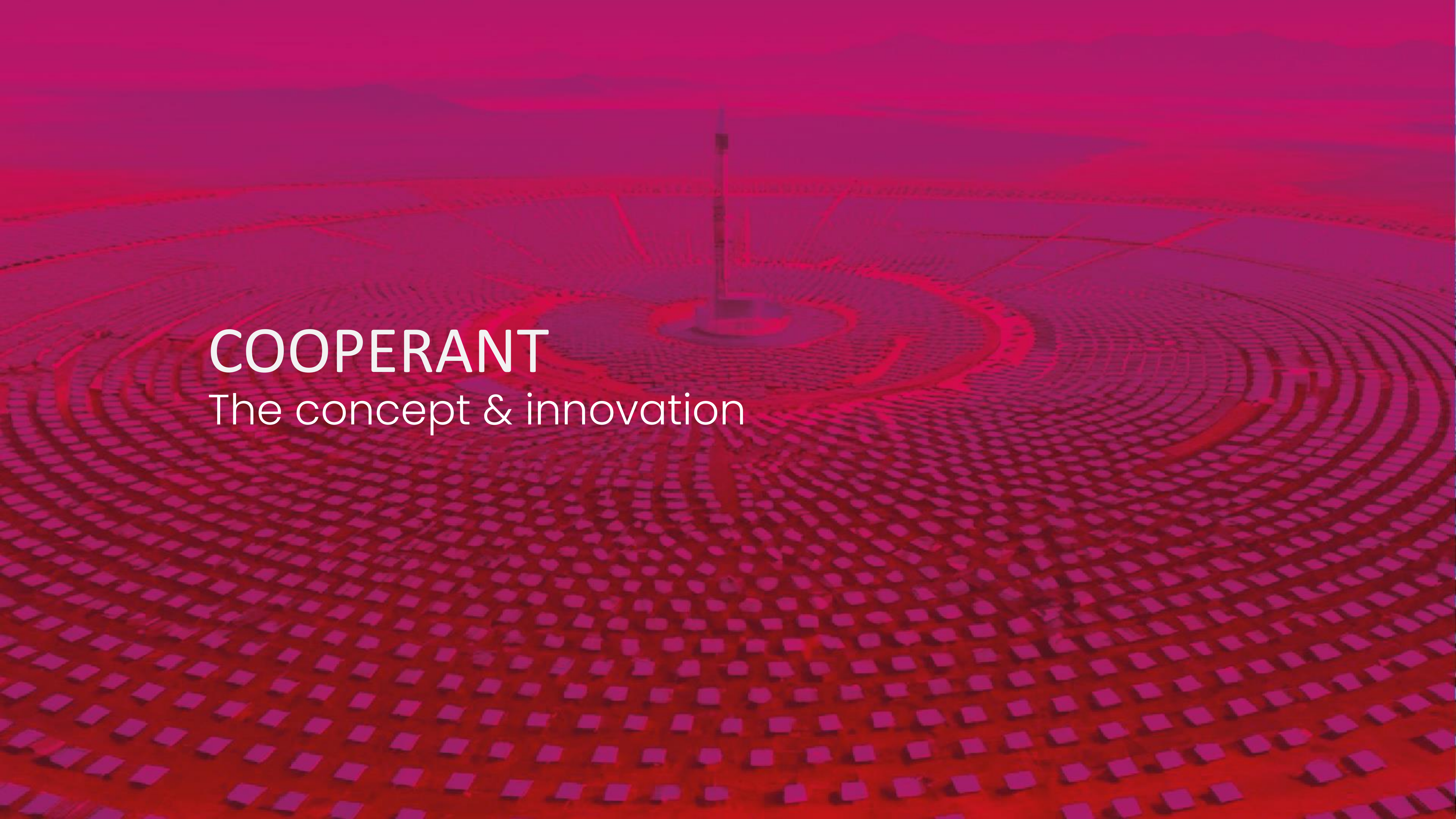

COOPERANT

The concept & innovation

COOPERANT

COOPERANT concept

Contribution and Benefits

R&D project
From TRL2-3 to TRL4-5

COOPERANT proposes a revolutionary technological integration to unlock the potential of the 3rd **CSP generation** to favour **dispatchable RES generation**.

1. Reaching high-temperature operation at approximately 1000ºC by coupling more efficient power cycles
2. Overcoming variability with a novel TES system to improve dispatchability of solar energy.
3. Upscaling feasibility in line with CSP roadmap supported by digitalisation to ensure broader adoption.

Round-trip efficiency
Higher than 90% to be competitive with available SoA

High-temperature operation
Up to 1000ºC

Cost-effectiveness
Savings of TES construction materials (-25-30%)

Modularity and scalability
To adapt to any system power capacity

Customisation
Cascade approach and materials chosen fitting to requirements

Air as a sustainable HFT
To achieve high temperatures, has great availability

High energy density
>600 kWh/m3 combining sensible and latent storage

Flexibility
Hourly, daily, weekly storage cycling

Compactness
4-10 times more compact than sensible storage

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COOPERANT Innovations

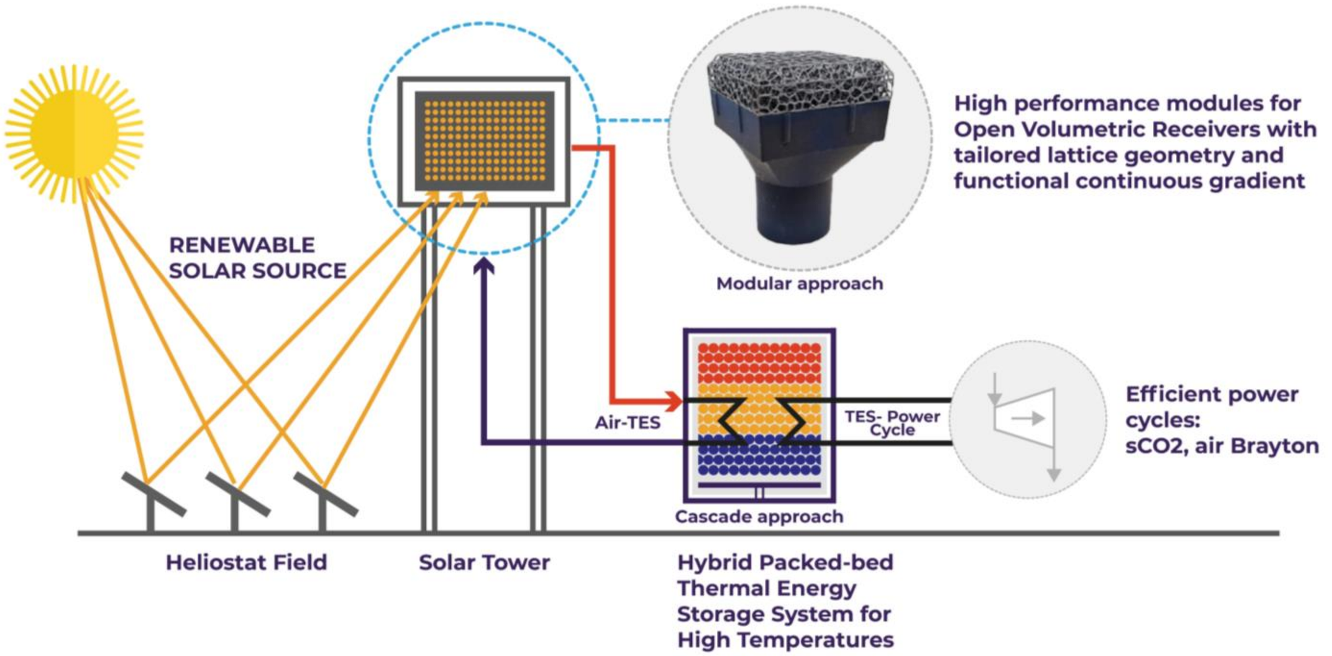
COOPERANT CSP-TES

COOPERANT is at the forefront of advancing the **next generation** of concentrated solar power technologies by **tackling typical limitations** of conventional CSP facilities, such as **dispatchability**, **cost-effectiveness**, and **sustainability**.

To achieve so, three differentiated initiatives will work synergistically:

1. COOPERANT CSP-TES: Development of a novel prototype with three main features:

1) High-performance Open Volumetric Receivers (OVR) for solar absorption and use of air as HTF.
2) Thermal Energy Storage (TES): a hybrid packed bed system combining sensible and latent heat storage.
3) Development of high-temperature ceramic solid-state mixtures and phase change materials (molten salts and new metallic PCMs) that can work at high temperatures (800-1300°C).



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COOPERANT Innovations

COOPERANT AI-Tool

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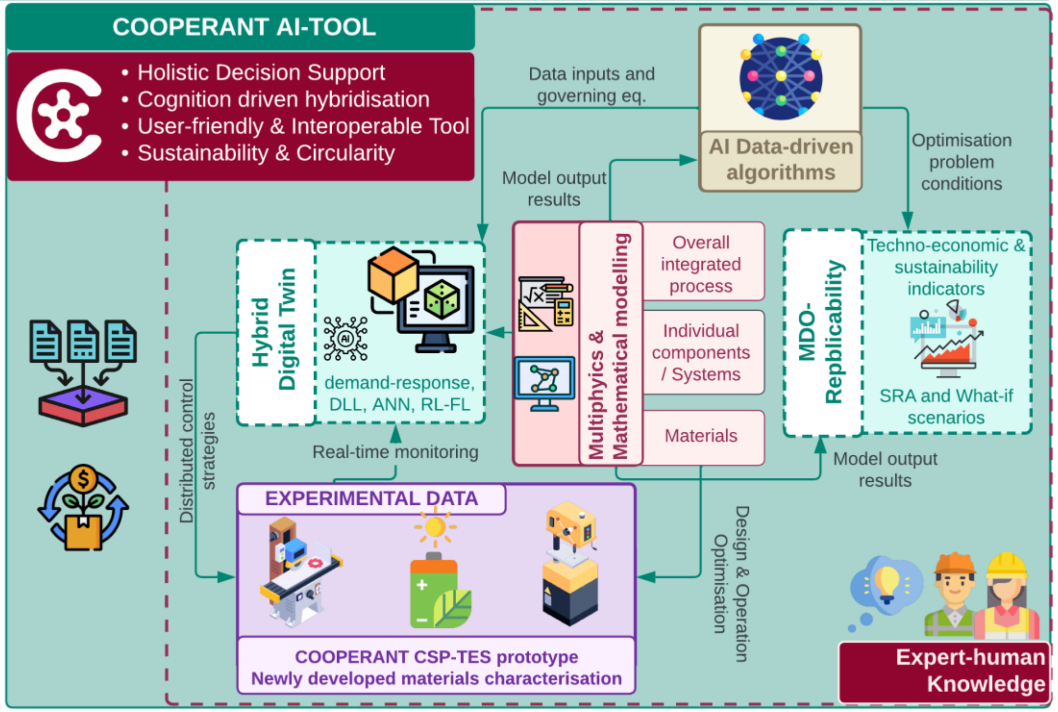
To achieve so, three differentiated initiatives will work synergistically:

2. COOPERANT-AI TOOL: monitor and control the management of the TES coupled with the CSP generation.

It proposes advanced control based on:

a) Reinforced Deep Learning (rDL) technique to develop a Digital Twin (DT).

b) Multicriteria Design Optimization (MDO) to make informed decisions towards feasibility and replicability.



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COOPERANT Innovations

COOPERANT-Transfer

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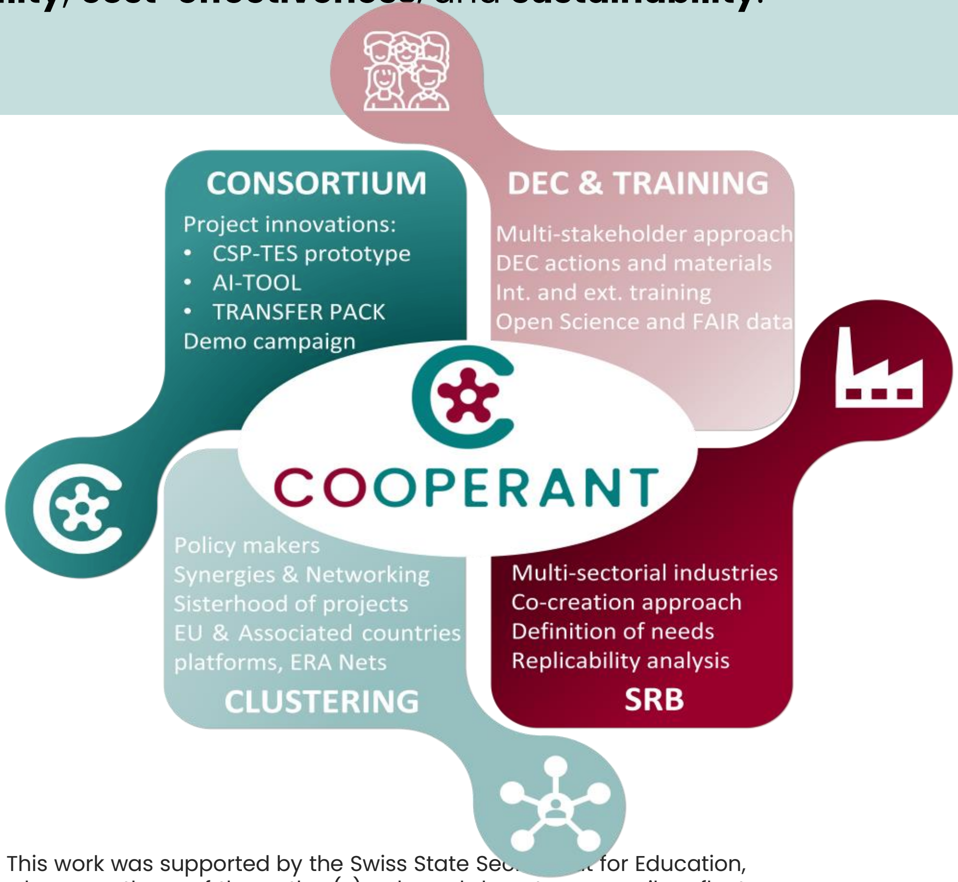
To achieve so, three differentiated initiatives will work synergistically:

3. COOPERANT-TRANSFER PACKAGE:

A transference program involving a multi-sector industrial board for clustering, networking and synergetic actions.

It includes the Dissemination, Exploitation, Communication (DEC) and training material, Open Access publications, best practices, factsheets, and a live lab demo

Increasing scientific, industry, policy and social acceptance.



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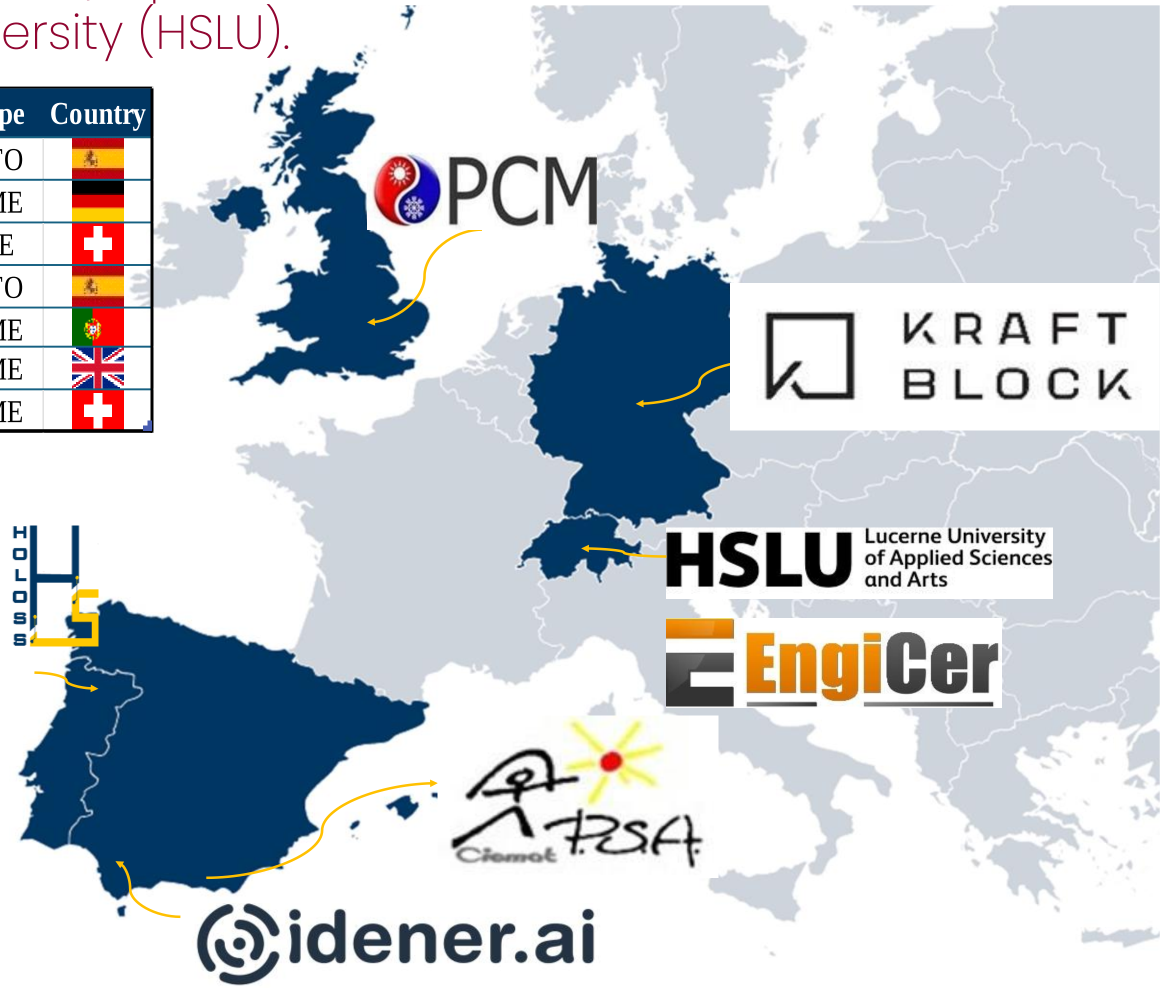
Consortium Interdisciplinary

Type of organisations: 4 SMEs (KB; HOLOSS; PCMP; ENGI), 1 private RTO (IDE), 1 public organisation (CIEMAT) and 1 university (HSLU).

Nº	Acronym	Participant Organisation Name	Type	Country
1	IDE	IDENER Research & Development Agrupación De Interés Económico **(Coord)**	RTO	
2	KB	KRAFTBLOCK GMBH	SME	
3	HSLU	Fachhochschule Zentralschweiz - Hochschule Luzern	HE	
4	CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas	RTO	
5	HOLOSS	Holistic And Ontological Solutions For Sustainability, LDA.	SME	
6	PCMP	Phase Change Material Products LTD	SME	
7	ENGI	ENGICER SA	SME	

COOPERANT team

The consortium of 7 partners from 5 different countries



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Stakeholder Replicability Board (SRB)

Industrial involvement

- Identification of potential applications of COOPERANT CSP-TES in the energy and industrial sectors.
- Provide specifications and requirements of the most relevant identified processes.
- Best practices and recommendations for further implementation to achieve the technology scale-up.
- Increase the impact with international companies to validate COOPERANT CSP-TES and AI-TOOL solutions.
- Review and feedback on COOPERANT open reports especially interesting for industrial partnerships and policymakers.
- Engagement through DEC and training actions, as key target audience by COOPERANT-TRANSFER.
- Participate in the Stakeholder events.

COOPERANT offers a unique opportunity to overcome the current CSP-TES obstacles by **acquiring knowledge and evidence** in close cooperation between the **consortium and industrial partners**.

Pharmaceutical industry

EII Industrial partnership

Municipal district heating network with RES integration

CSP key stakeholders' network

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COOPERANT

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