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GREEN HYDROGEN FROM SUNSHINE

Hydrogen PROduction by MEans
of solar heat and power in high
TEmperature Solid Oxide Electrolysers

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Alberto Giaconia (ENEA)

Rome, 8 February 2024

The project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under Grant Agreement n° **101007194**. The JU receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe Research.

Clean Hydrogen Partnership

the origins of PROMETEO

PROMETEO "Hydrogen PROduction by MEans of solar heat and power in high TEmperature Solid Oxide Electrolysers" (2021-2024)

EU Grant Agreement n. 101007194

Research & Innovation Action (RIA)

co-funded by the European Clean Hydrogen Partnership

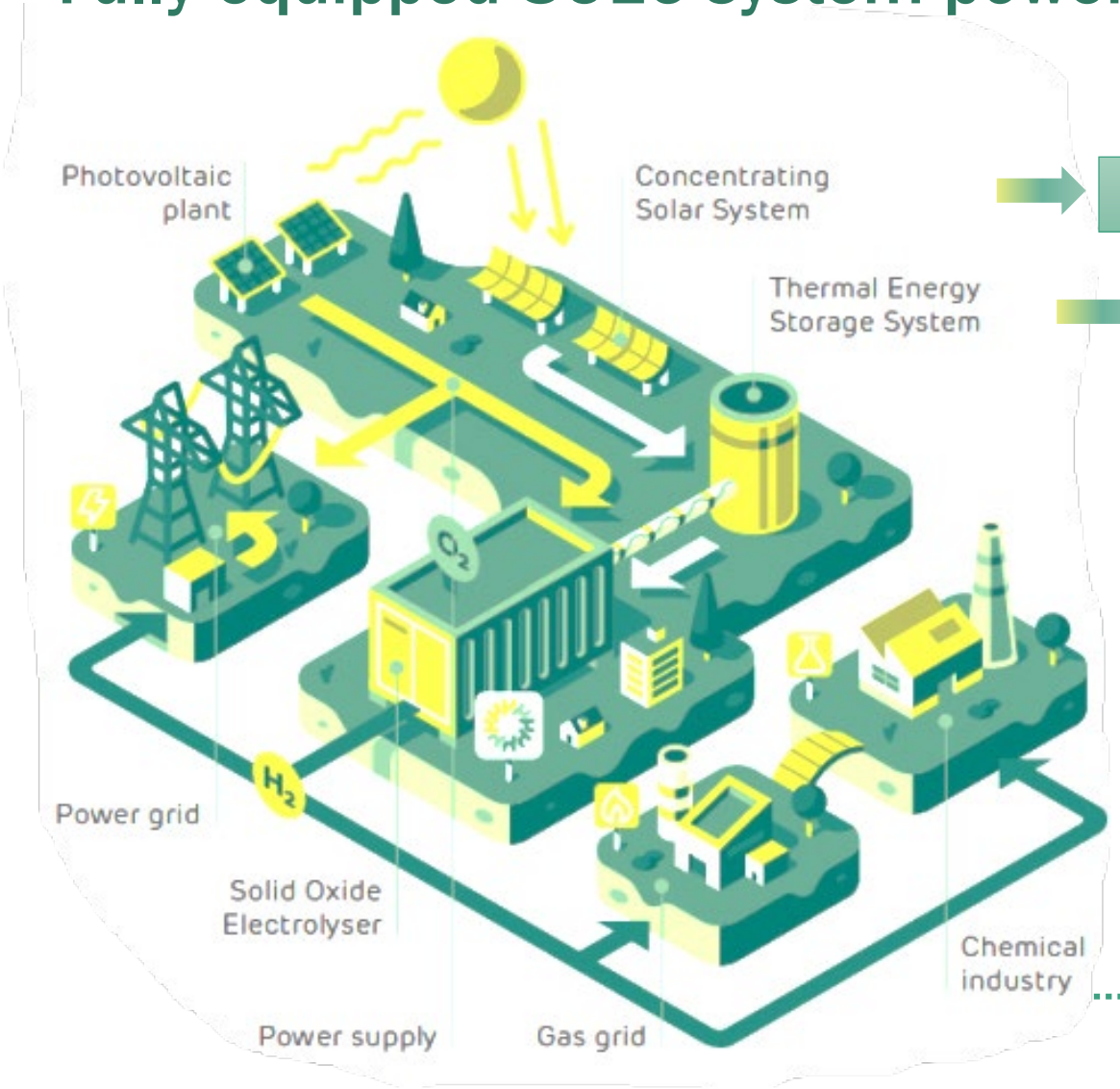
total budget 2,765,206 €

call reference: H2020-JTI-FCH-2020-1

topic: FCH-02-2-2020 – "Highly efficient hydrogen production using **solid oxide electrolysis integrated with renewable heat and power**"

Concepts & Objectives

Fully-equipped SOEC system powered with solar energy



- prototype's maximum rate ≥ 15 kg_{H2}/day = **7 Nm^3/h**
- **≥ 1,000 hours** operation of the prototype
- Power-to-H_2 efficiency (LHV): <39 kWhe/kg_{H2}, i.e. **≥ 85%**
- Solar-to-H_2 efficiency (LHV) **≥ 10%**
- LCOH **≤ 2 €/kg_{H2}** (after 2030)

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Introduction to the project PROMETEO

Prometeo project's timeline

1 Solid Oxide Electrolyser stack

Starting point: Solid Oxide Electrolyser (SOE), i.e. an advanced electrolysis system with high efficiency, fed with steam and operating at high temperatures (>750°C). The SOE was supplied by the partner SolydEra S.p.A. and is the basic component of the prototype.

2 Analysis of end-users' cases

The potential adopters of PROMETEO's prototype steer the R&D activities to find appropriate and effective solutions to end-users' applications:

- chemical storage of renewable electricity by Capital Energy
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- injection of green hydrogen into the gas grid, by Snam

3 Flow-sheeting & modelling

Prometeo analyses the most appropriate manner to integrate the SOE stack with the Balance of Plant (BoP) and Renewable Heat & Power Supply Systems to meet end-users' needs.

4 Lab validation of components

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8 Assessment

The final configuration of the system and test results are used to assess effective achievement of end-users' needs of modular scale-up systems for commercial exploitation.

Discover the prototype:
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Step 2: Analysis of end-users' cases

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Step 2: Analysis of end-users' cases

PROMETEO is a "product oriented" project...
→ so we started from end-users' requirements

Energy industry

- curtailment mgt
- grid services
- seasonal storage
- on-grid & off-grid

capital energy

SPAIN
Large renewable energy projects promotion platform focused on off/on shore wind energy, biodiesel, PV and

Chemical industry

- 24/7 operation
- +5/-10 % flow rate
- H_2 purity control

Stamicarbon

THE NETHERLANDS
Large company, leader in the development of fertilizer technology and in the supply of services related to urea

Gas industry

- power-to-gas appl.
- H_2/NG blends
- control H_2 properties

snam

ITALY
Large energy infrastructure company, operating the largest natural gas transmission network and

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Step 3: Flow-sheeting & system modelling

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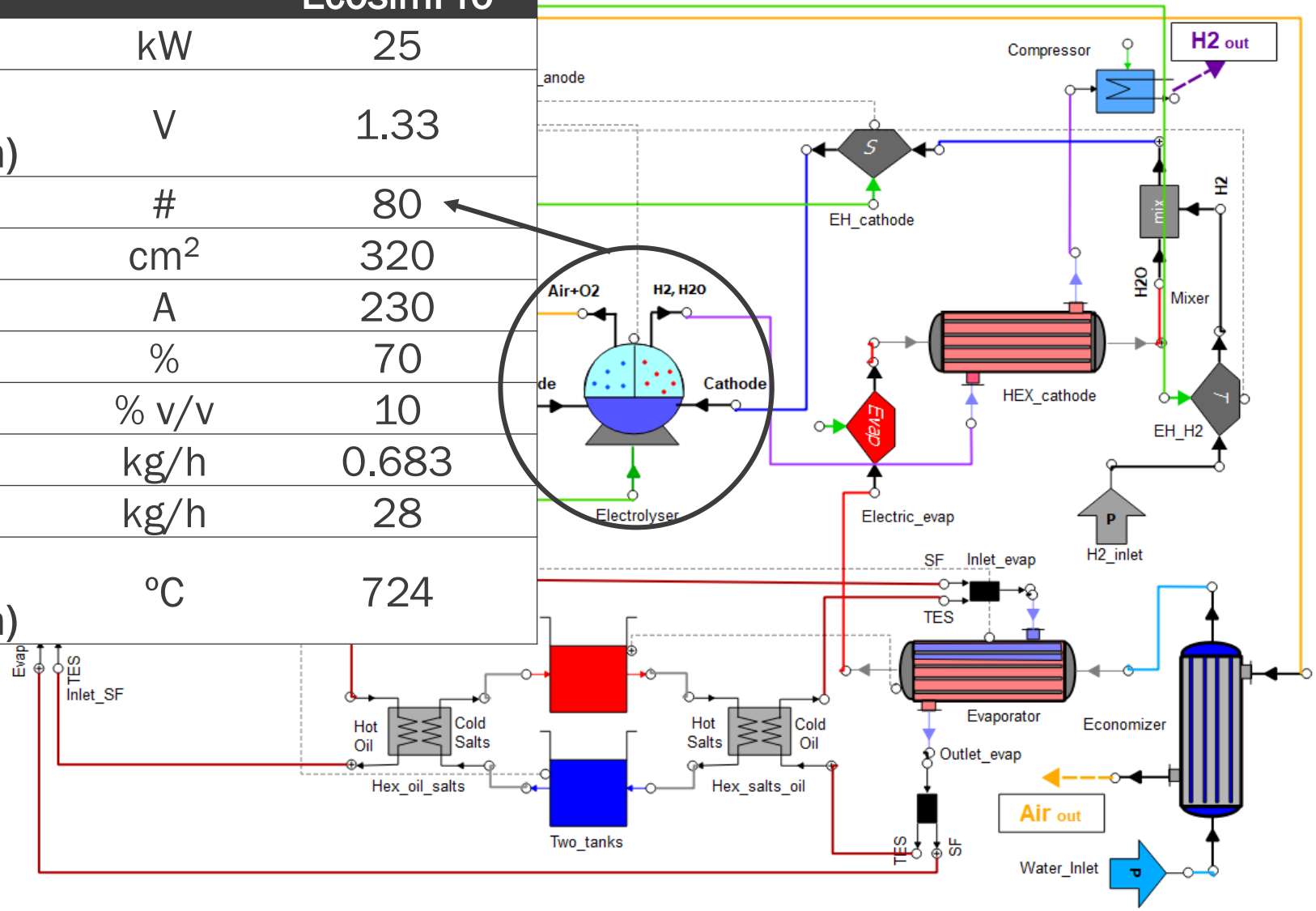
Step 3: Flow-sheeting & system modelling

Components of SOE	Unit	Value EcosimPro
SOE full power	kW	25
Voltage at full power (thermoneutral condition)	V	1.33
Number of cells	#	80
Surface area of the cell	cm^2	320
Current at full power	A	230
Steam utilization	%	70
Hydrogen inlet ratio	% v/v	10
Hydrogen production	kg/h	0.683
Airflow (dry air)	kg/h	28
Cell temperature (thermoneutral condition)	ºC	724

egrated system PFD



16.4 kg/day of H2

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Step 3: Flow-sheeting & system modelling

Design Point preliminary simulation results vs. KPIs

Key Performance Indicators (KPI)		Target	Definition	Calculated (EcosimPro)
ID	Definition			
R-max	Maximum measured instantaneous hydrogen production rate at full-capacity	≥ 15 kgH_2/day	$0.683\ kgH_2/hour\ \cdot\ 24\ hour$	16.4 kgH_2/day
Eff-w	Power-to-hydrogen conversion efficiency of the heat-integrated SOE system	< 39 kWh_e/kgH_2	$\frac{24kWh_e + 2.43kWh_e}{0.683kg_{H2}}$	38.7 kWh_e/kgH_2
Sol-%	Solar-to-Hydrogen energy conversion efficiency: from solar radiation to H_2 energy*	≥ 10%	$\frac{LHV_{H_2} \cdot 0.683kg_{H2}}{\frac{5.24kWh_{th}}{0.62} + \frac{26.43kWh_e}{0.17}} \cdot 100$	13.9 %

*Solar-to-Hydrogen efficiency

$$\eta_{Sun \to H2} = \frac{LHV_{H_2} \cdot kg_{H2}}{P_{thermal}/\eta_{CST} + P_{electric}/\eta_{PV}}$$

Symbol	Description	Value
LHV_{H_2}	Hydrogen Low Heating Value	33.3 kWh/kg
η_{SCA}	Concentrating solar field conv. efficiency vs. DNI	62%
η_{PV}	PV field conversion efficiency vs. GI	17%

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Step 4: Lab validation of components

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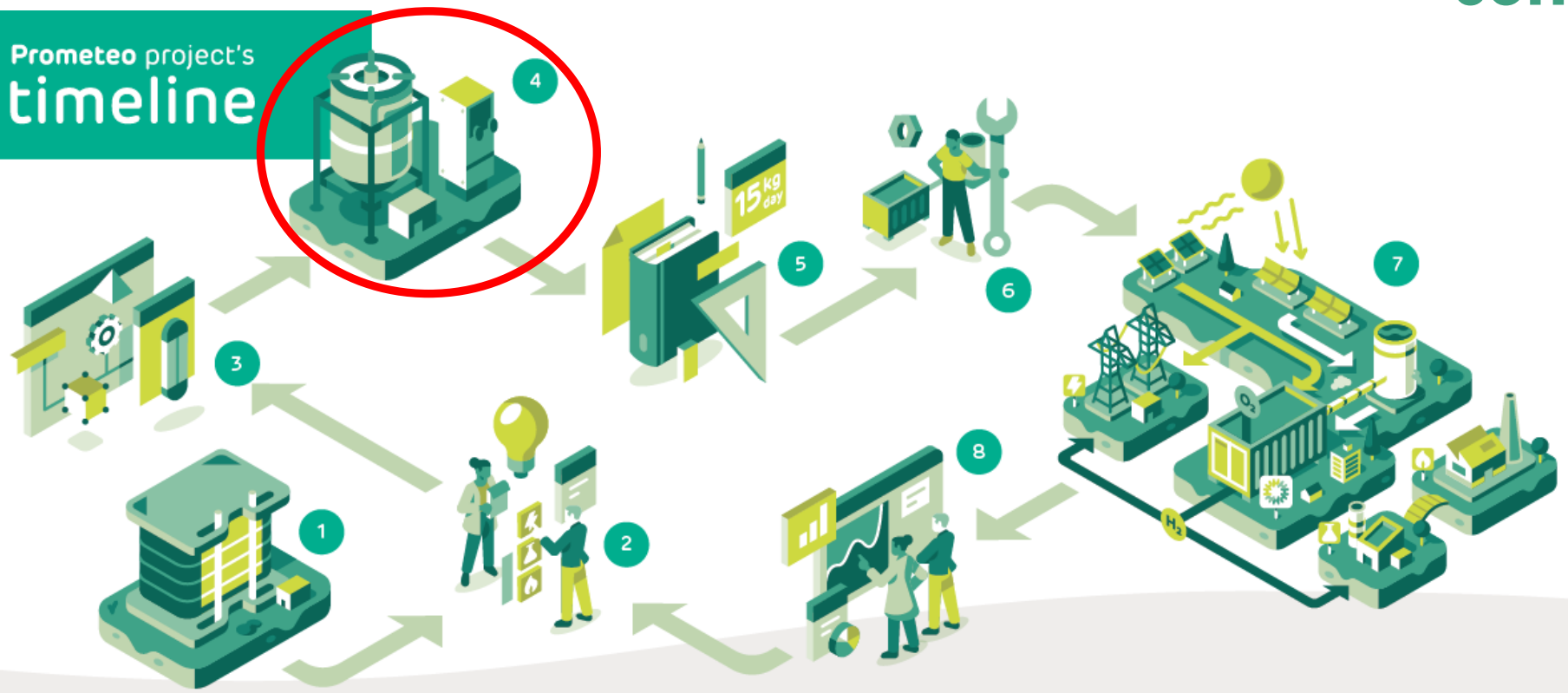

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Step 4: Lab validation of components

Developed TES-SG prototype

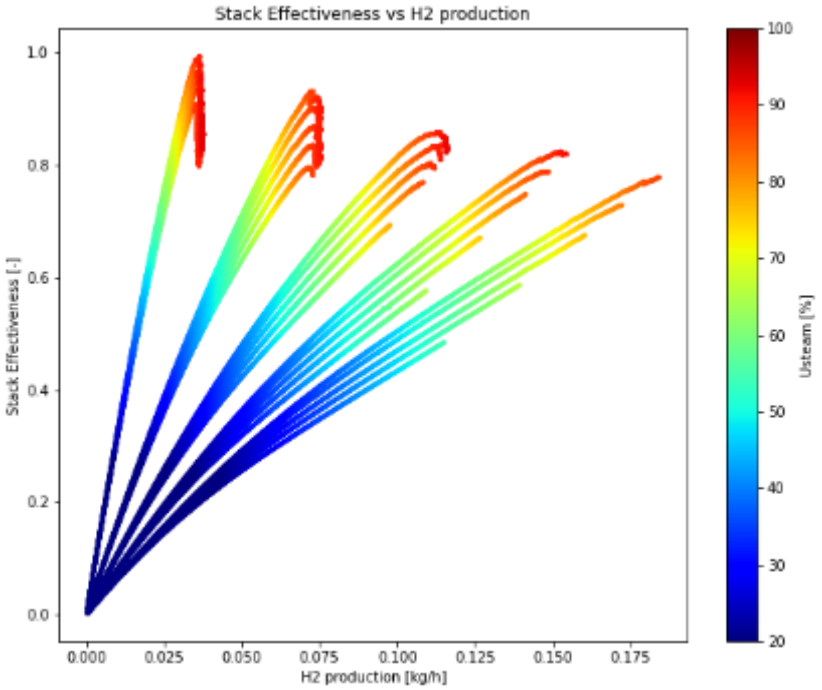
heat exchangers

TES-SG prototype with oil loops

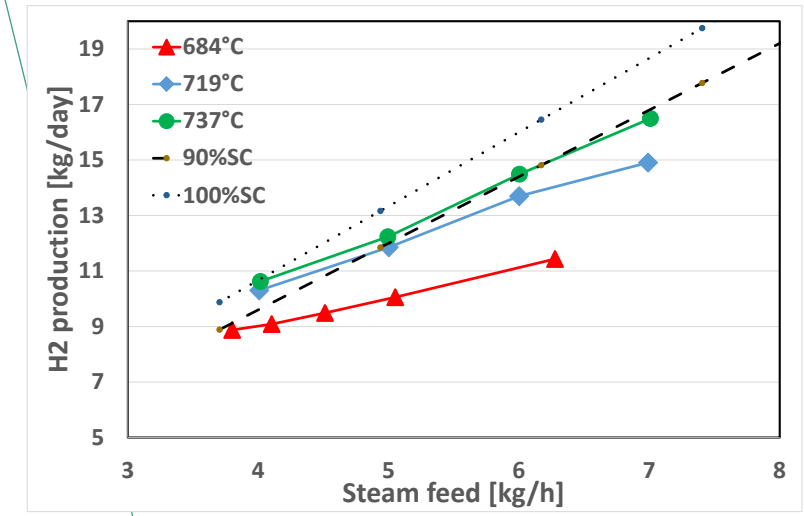
Step 4: Lab validation of components

Lab testing & mapping of SOE stacks prior system integration

5 kWe stack box
- 70 RU
- 80 cm^2/layer
- 1.8 kW SOFC / 5kW SOE



25 kWe stack box
- 80 RU
- 320 cm^2/layer
- 8 kW SOFC / 25kW SOE



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Steps 5 & 6: Design & construction of the prototype (25 kW)

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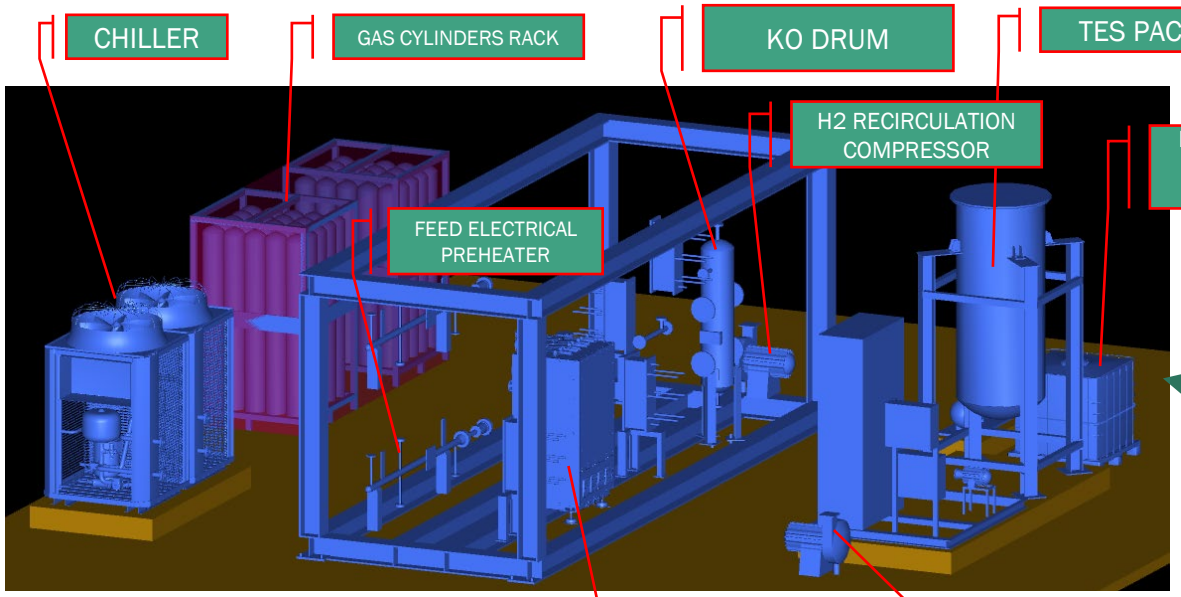
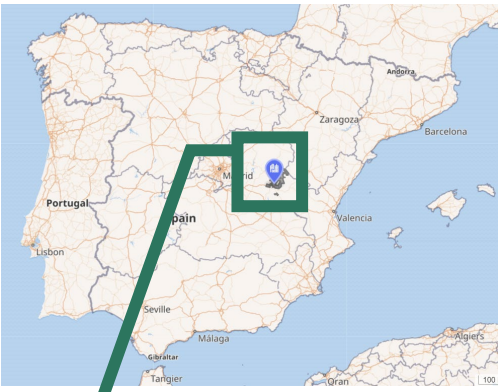
Steps 5 & 6: Design & construction of the prototype (25 kW)

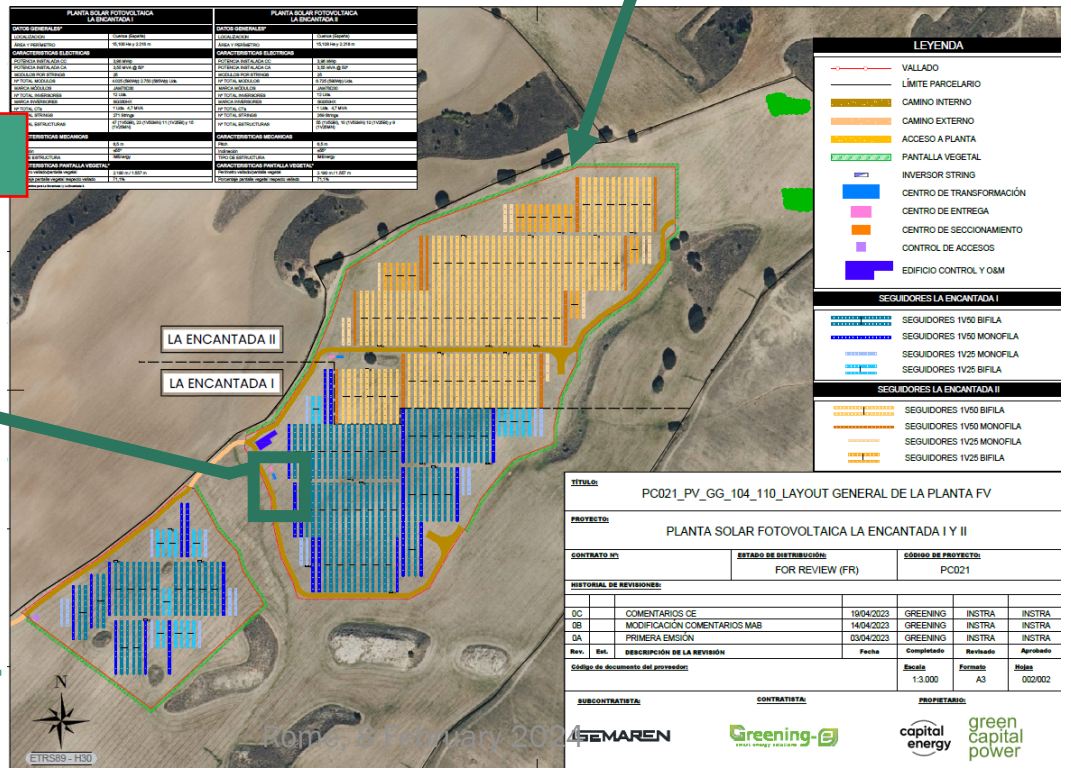
Current status of the project

- Final design and construction of the prototype
- Commissioning and testing in the project site in Cuenca, Spain, connected to a PV facility



3D rendering of PROMETEO prototype





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Step 7: Experimental validation of the prototype

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Step 8: Assessment: end-users' cases, LCA, roadmapping

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Thank you for your attention

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development
capital energy
FONDAZIONE BRUNO KESSLER
SolydEra
institute IMDEA energy
snam
EPFL
NEXTCHEM
Stamicarbon

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