



Power to Hydrogen:

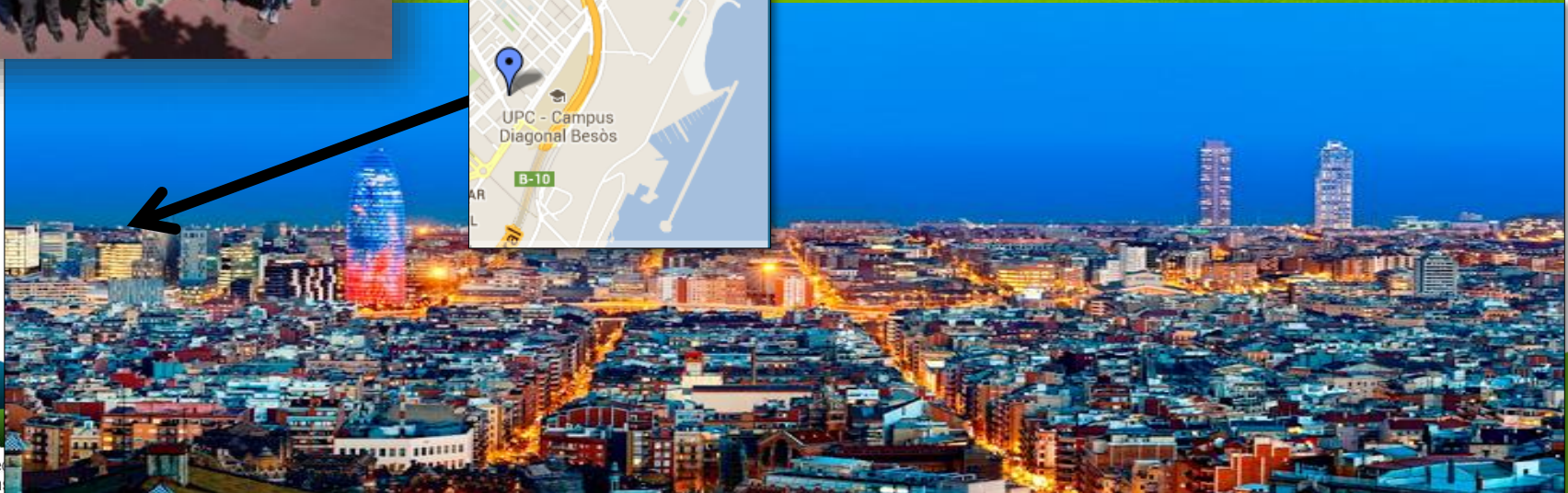
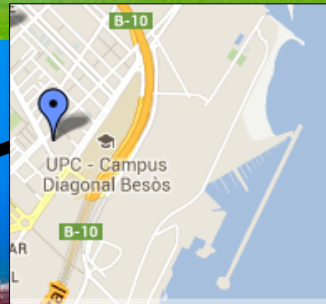
High temperature electrolysis activities in the frame of the
CoSin and **Eco** projects

- Marc Torrell Faro
Nanoionics and Fuel Cells Group

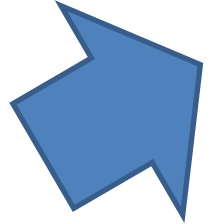
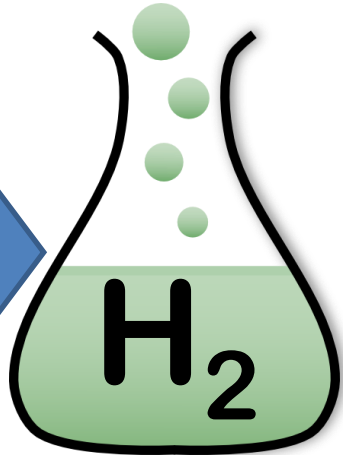
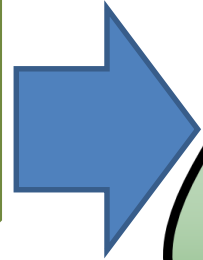
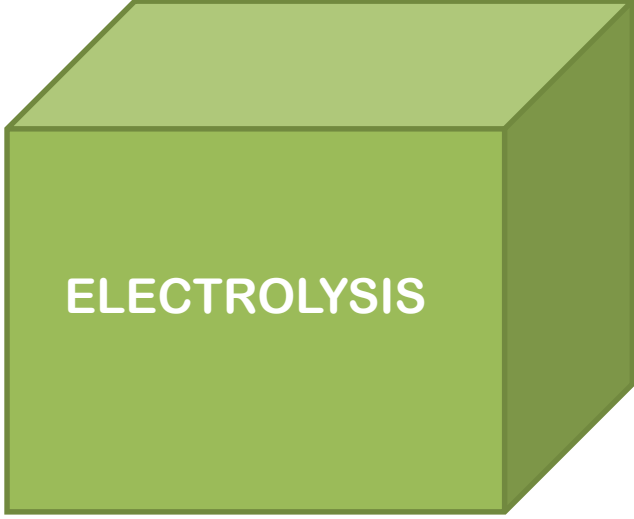
IREC MISSION

The Institute's orientation takes a dual approach:

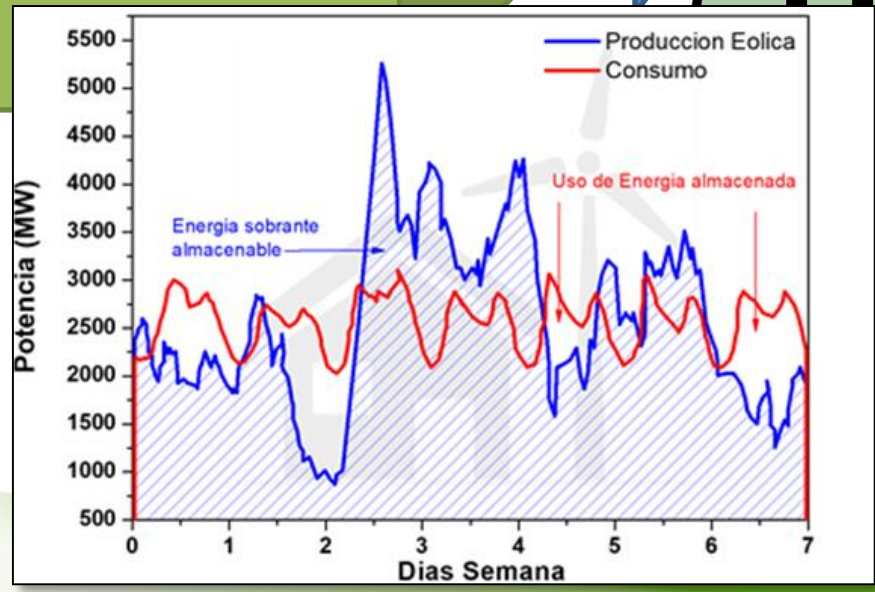
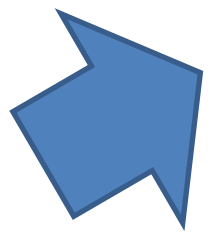
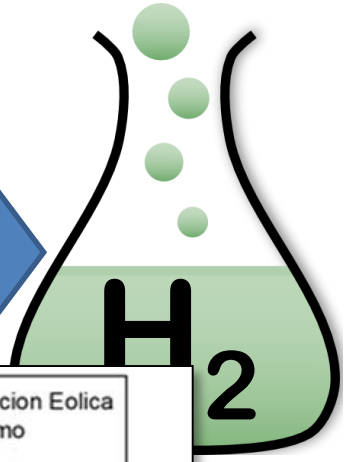
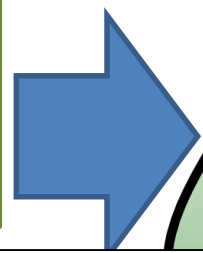
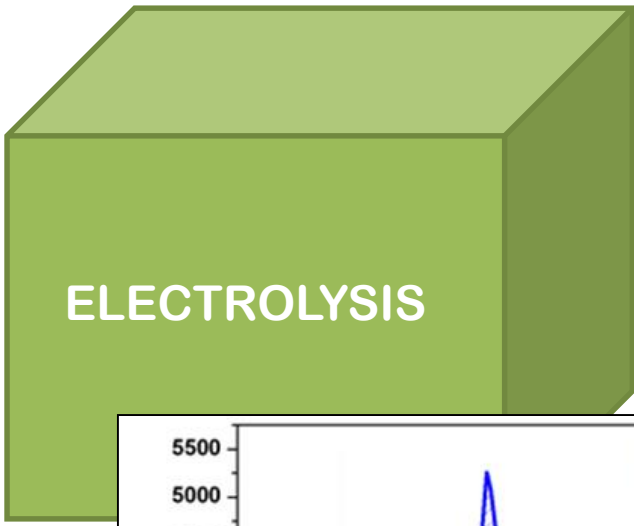
- **Market orientation**, focusing on technology development, new products and new technical solutions for energy sector companies active in the same fields as IREC's established lines of action.
- **Long-term research** into different aspects of the established lines of action. It will not initially aimed at the market but at generating knowledge amongst groups and areas in the Institute itself, with possible long-term commercial projection in mind.



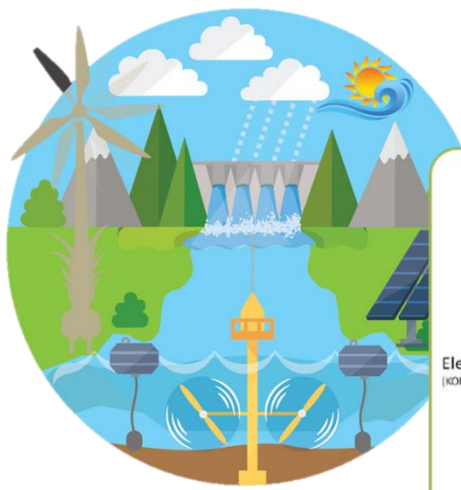
POWER TO GAS OR CHEMICAL STORAGE



POWER TO GAS OR CHEMICAL STORAGE



POWER TO GAS OR CHEMICAL STORAGE



Alkaline (AC)

a)

Electrolyte (KOH)

Cathode (Ni, Fe, Co...)

Diaphragm (NiO, asbestos...)

Anode (Ni, c-PL...)

$T=50-80\text{ }^{\circ}\text{C}$

b)

Polymeric (PEMC)

a)

Proton exchange membrane

Cathode

Anode

$T=50-80\text{ }^{\circ}\text{C}$

b)

Solid Oxide (SOC)

a)

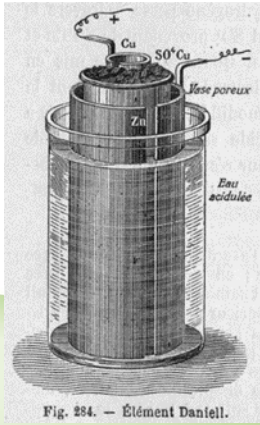
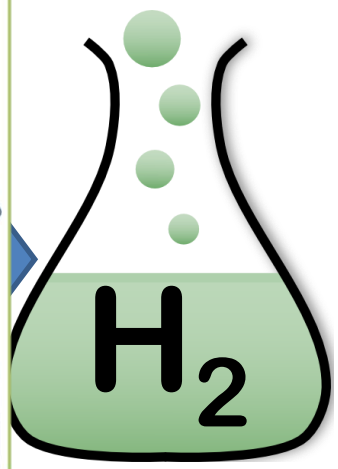
Oxygen ion exchange membrane

Anode

Cathode

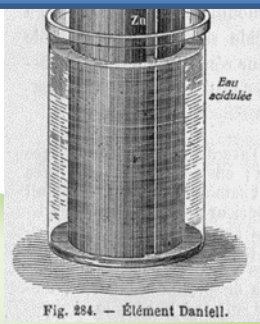
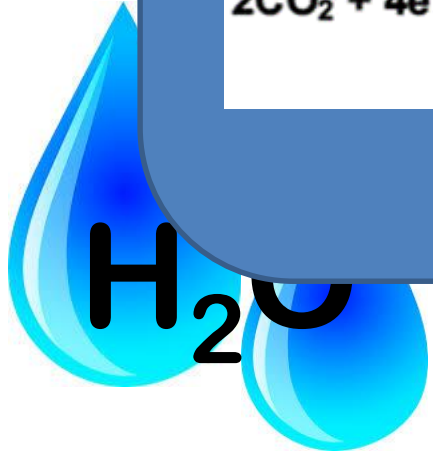
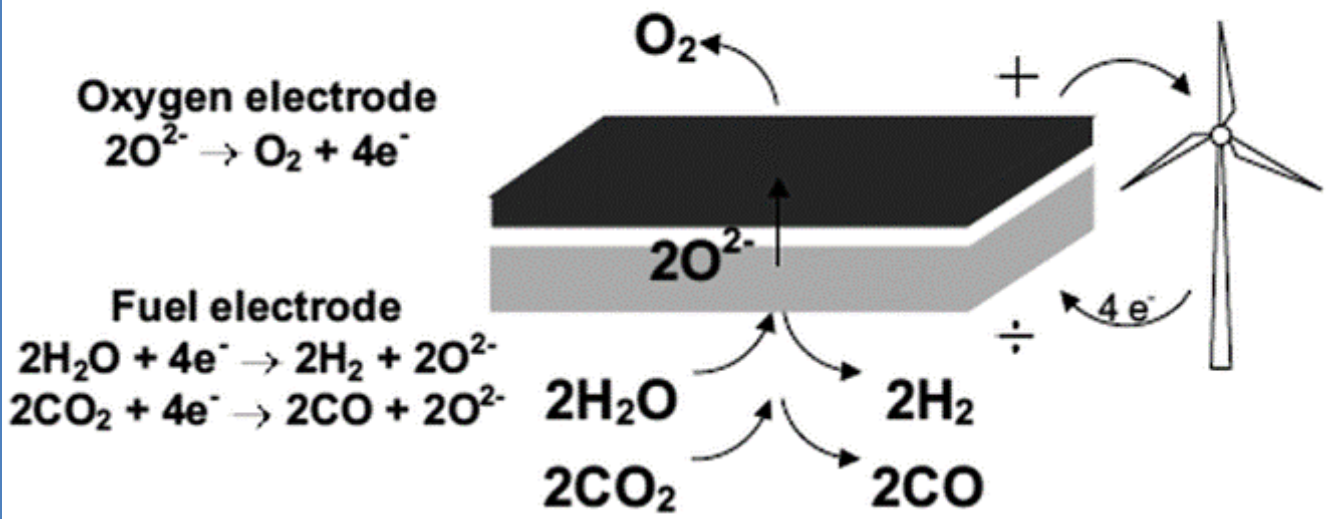
$T=700-800\text{ }^{\circ}\text{C}$

b)

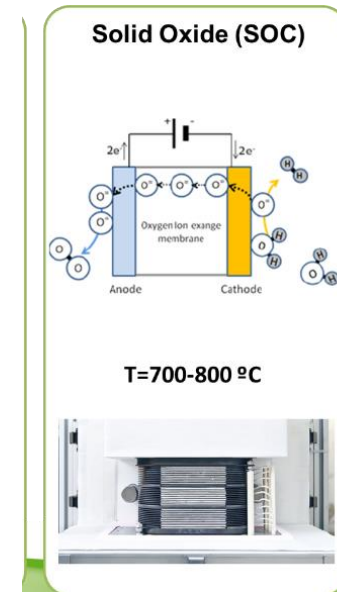
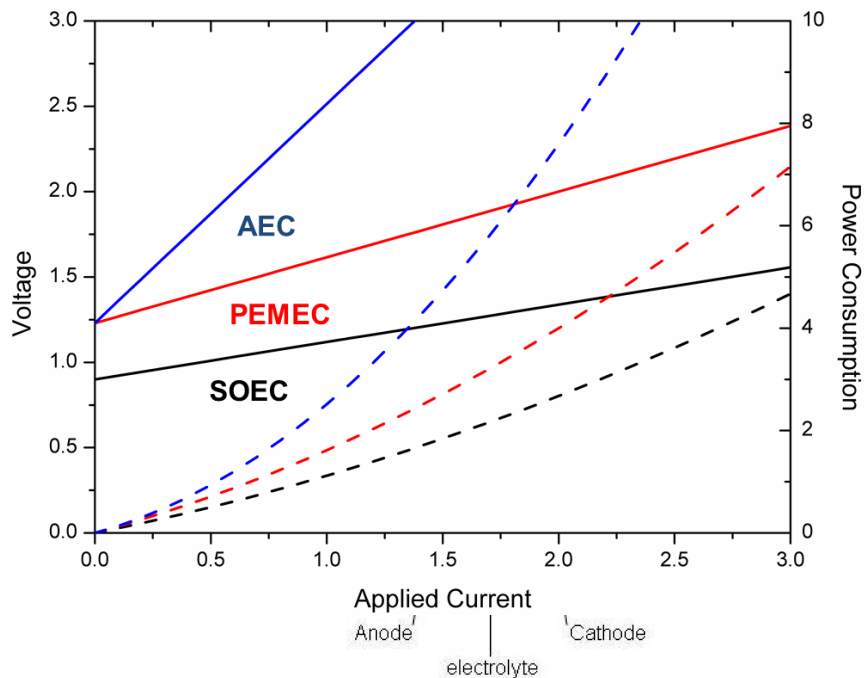




Solid Oxide Electrolysis Cell (SOEC)



WHAT IS A HIGH TEMPERATURE ELECTROLIZER?

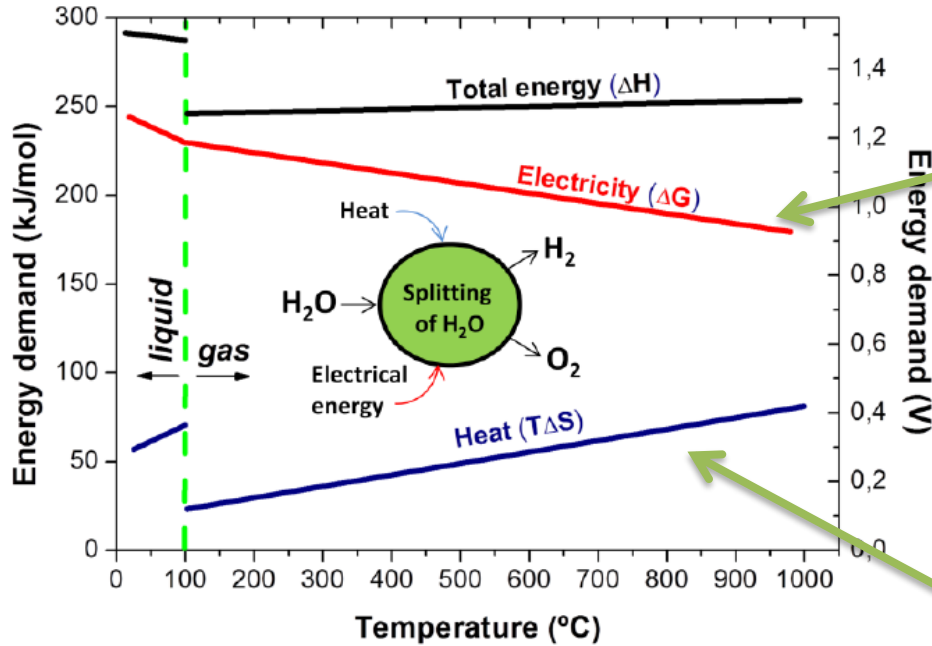


Thermodynamic advantage

Lower resistances

Higher efficiency

THERMODYNAMIC ADVANTAGES OF WORKING AT HIGH TEMPERATURES



Lower power consumption if the heat demand is satisfied

Higher efficiency

>80-90%

Who provides the heat demand?

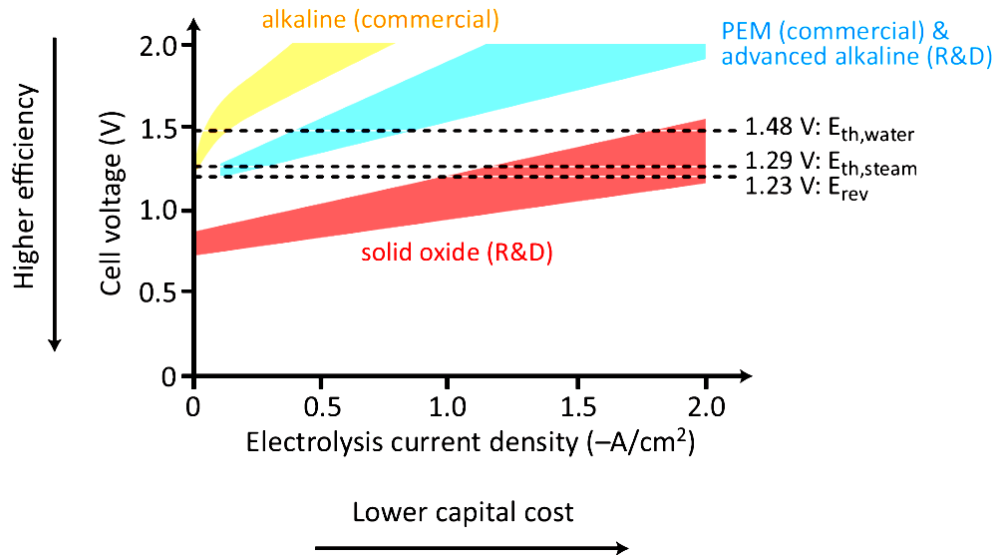
- 1) Temperature source (coupling)
- 2) Joule effect for non-ideal cells:

Faraday

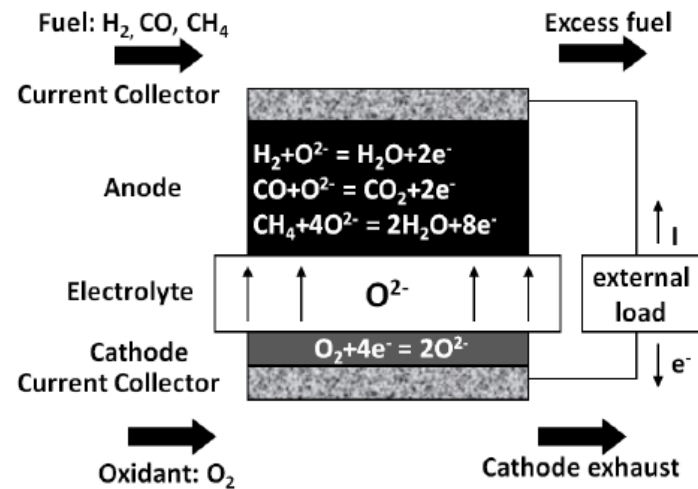
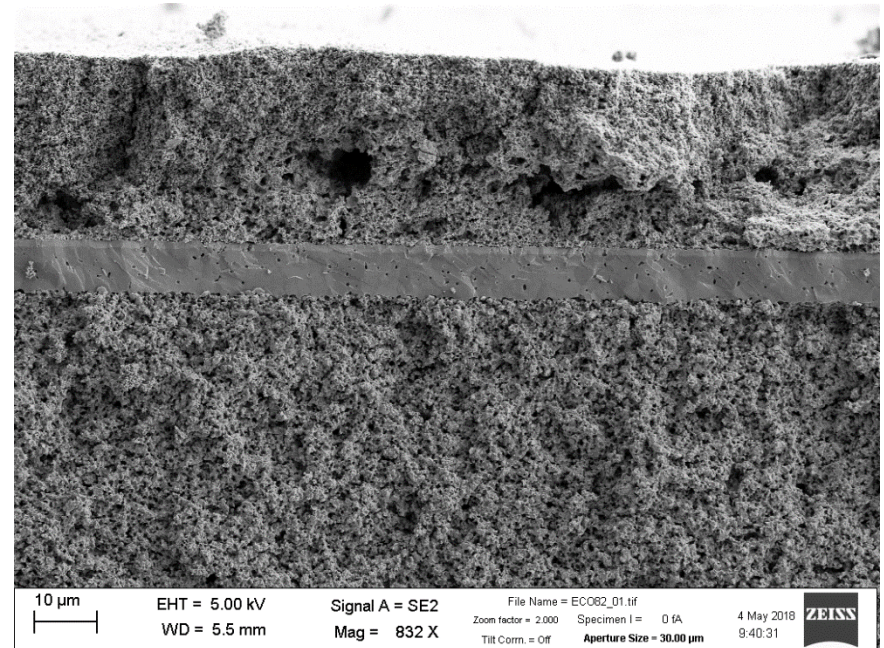
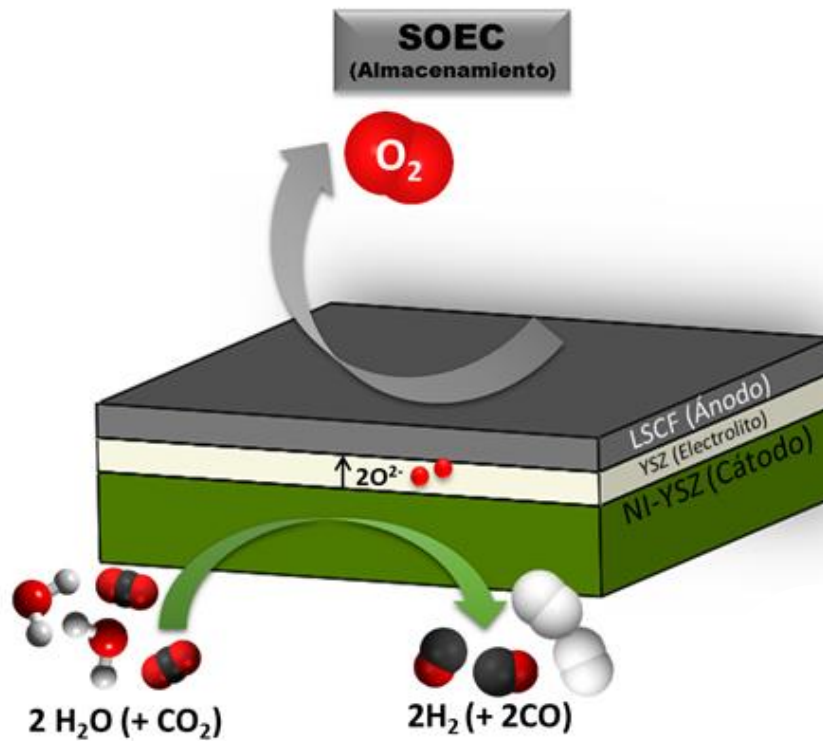
$$Q_{\text{Joule}} = E_{\text{ov}} I = E_{\text{ov}} z F = (E_{\text{cell}} - E_{\text{rev}}) z F$$

$$Q = T\Delta S$$

$$E_{\text{tn}} = \frac{\Delta H}{zF}$$



HOW IT WORKS



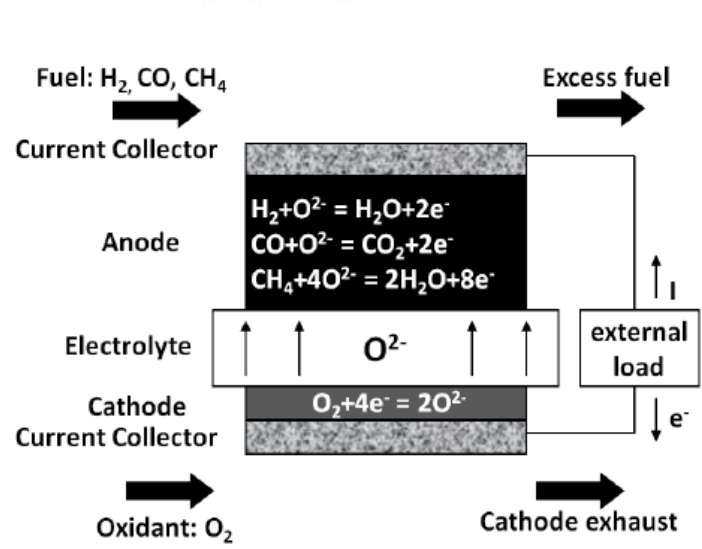
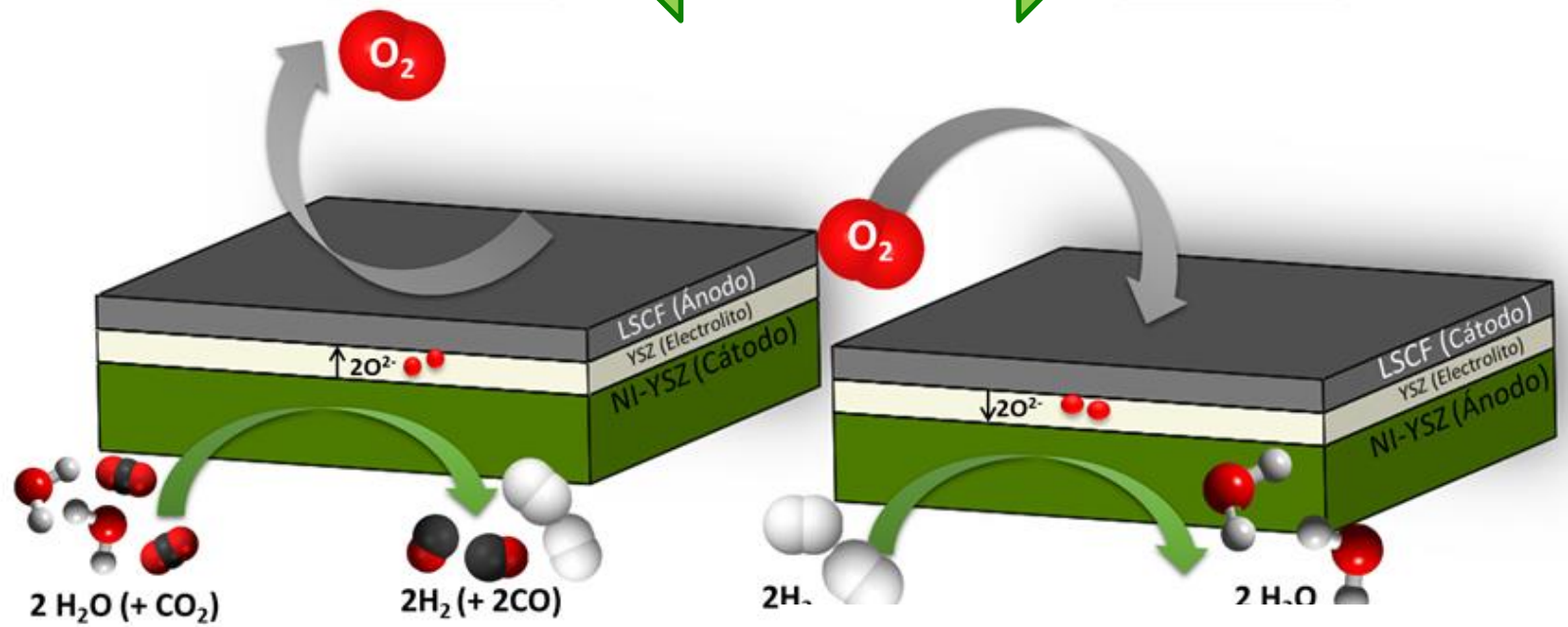
SOFC

HOW IT WORKS

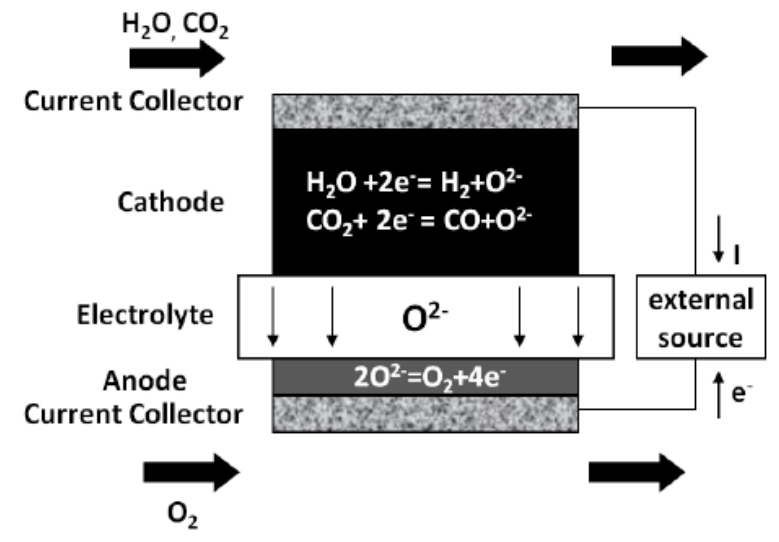
SOEC
(Almacenamiento)

REVERSIBLE CELLS

SOFC
(Generador)

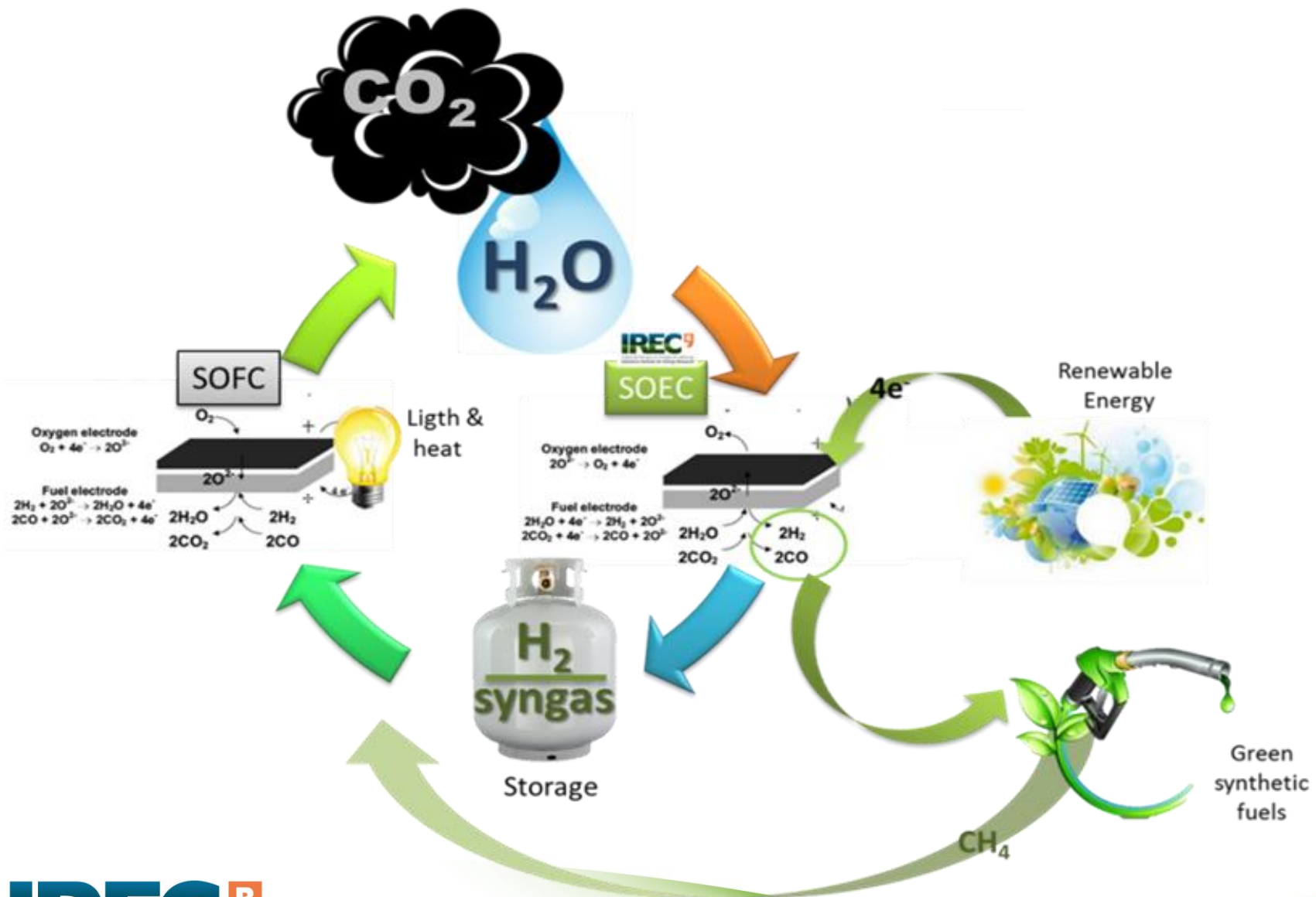


SOFC



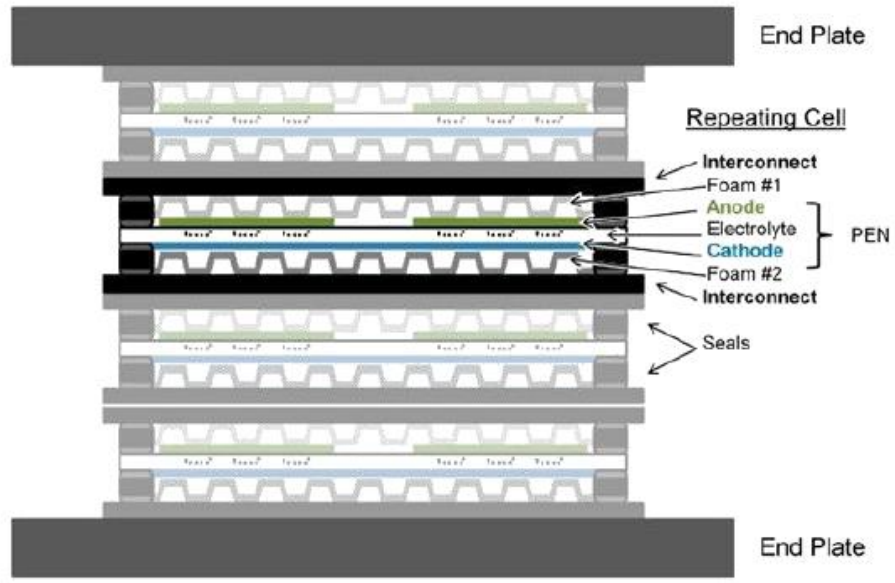
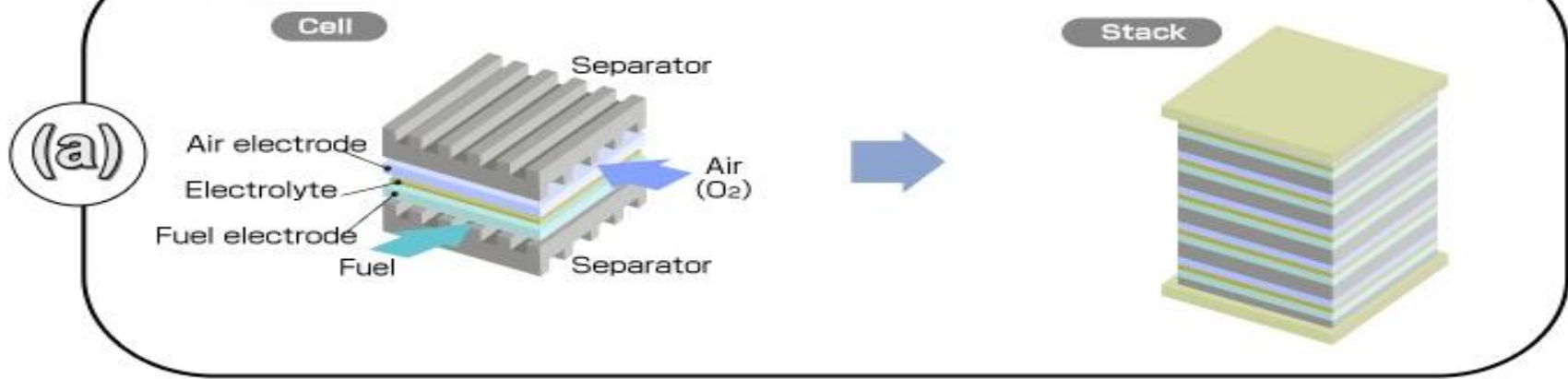
SOEC

THE CYCLE OF THE SOC TECHNOLOGY

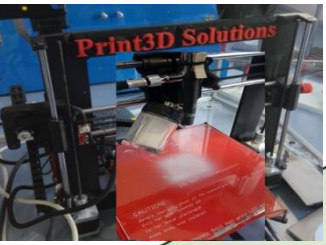
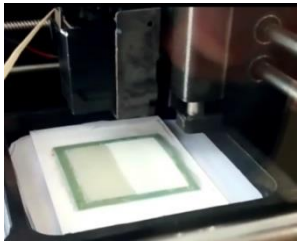
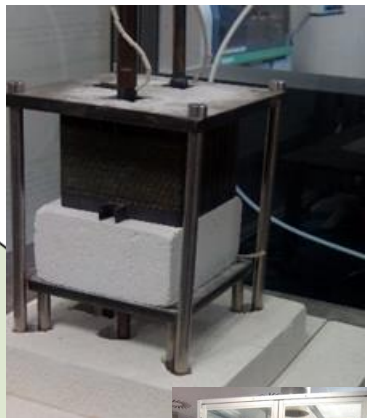
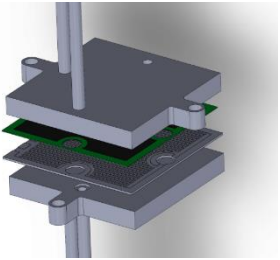
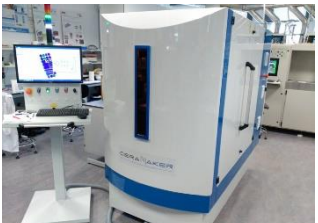
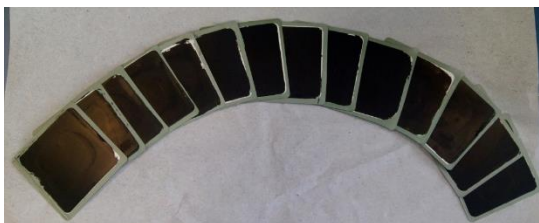


STANDARD CONFIGURATIONS

Planar configuration



Our Potential in IREC

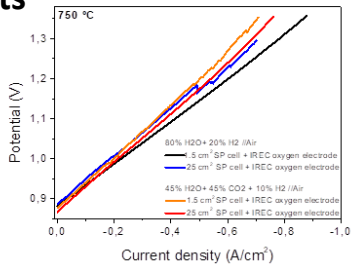


Scale-up
Fabrication methods

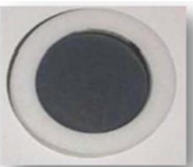
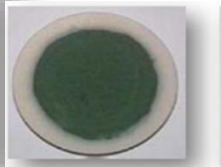
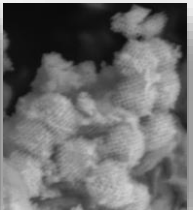
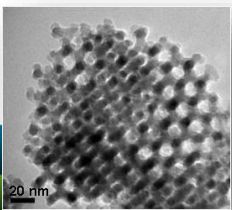
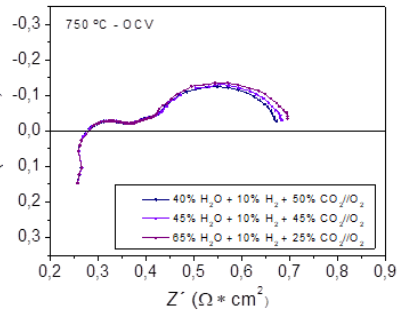
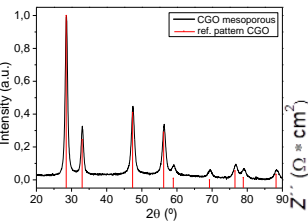
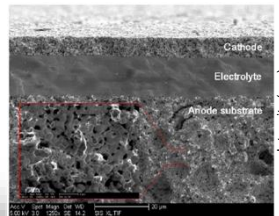
Stack and System
(kW)

Degradation tests

Electrochemical and
microstructural
characterisation



Development of new materials

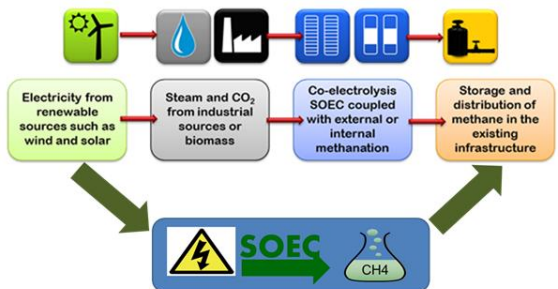


Power To Gas Active Projects



ECo

- **Title:** Efficient Co-Electrolyser for Efficient Renewable Energy Storage
- **Goal:** Develop and validate a highly efficient co-electrolysis process for conversion of excess renewable electricity into distributable and storable hydrocarbons via simultaneous electrolysis of steam and CO₂ through SOEC

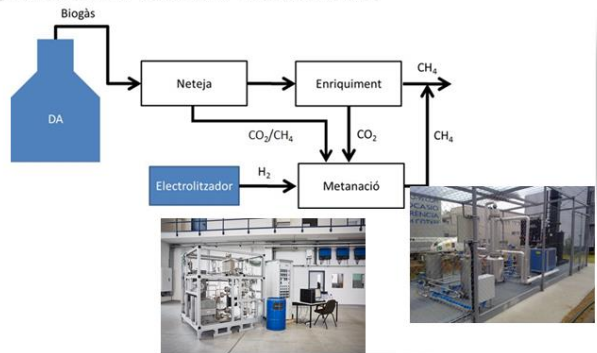


- **Role of IREC:** Development of a new SOEC technology
- **Partners:**



COSIN (RIS3)

- **Title:** Scalable Processes for the Fabrication of Intermediate Temperature Solid Oxide Fuel Cell Stacks for Auxiliary Power Units
- **Goal:** This project aims to develop Intermediate Temperature Solid Oxide Fuel Cell (IT-SOFC) technology addressed to the automotive and energy sector. Special attention will be paid in massive synthesis of non-conventional materials and scalability of manufacturing processes for cells and interconnects.

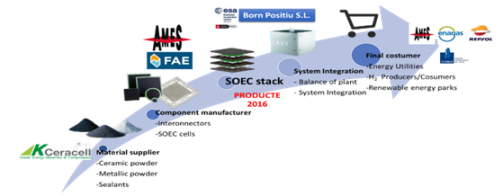


- **Role of IREC:** Technology developer and scientific coordination
- **Partners:**



FETEN (PRODUCTE)

- **Title:** Fabrication of High efficiency electrolyser system for energy storage. FETENS
- **Goal:** The energy produced by renewable sources during the low spot energy prices periods would be used to reduce H₂O+CO₂ to synthetic gas) and smartly couple the two major energy infrastructures of our modern society, i. e. gas and electricity networks,



- **Role of IREC:** Technology developer and scientific coordination



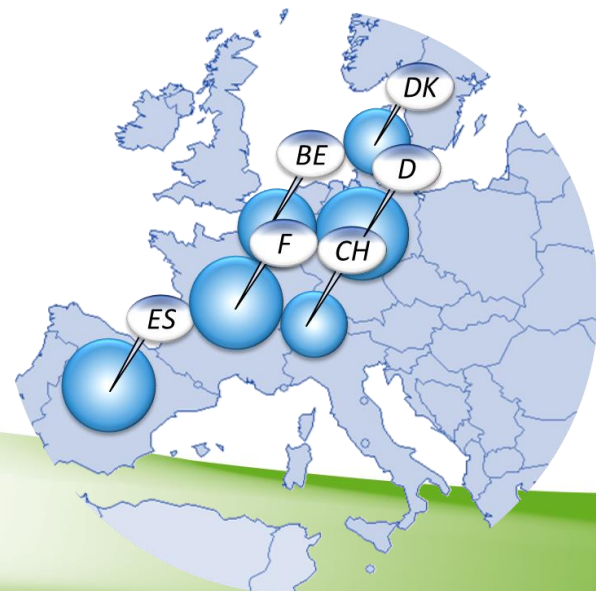
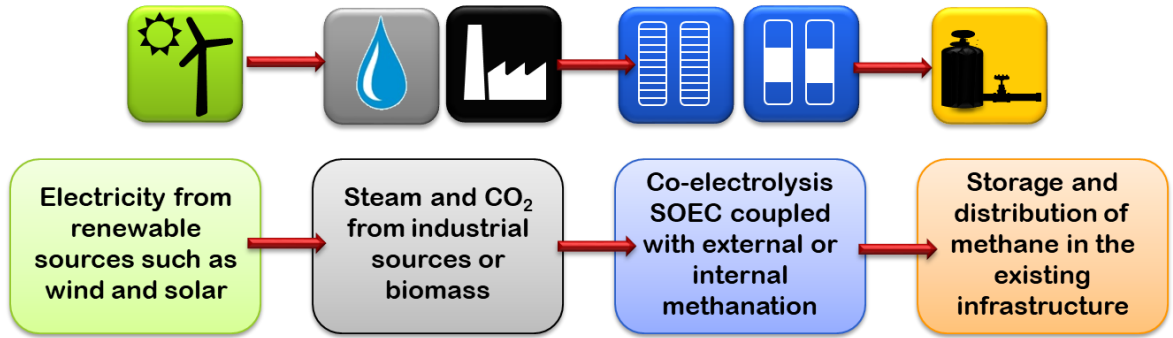
The Eco Project



 @eco_soec

Project objective

- The overall goal of *Eco* is to develop and validate a highly efficient co-electrolysis process for conversion of excess renewable electricity into distributable and storable hydrocarbons via simultaneous electrolysis of steam and CO₂ through SOEC (Solid Oxide Electrolysis Cells) thus moving the technology from technology readiness level (TRL) 3 to 5.



| | |
|--|---|
| Technical University of Denmark |  |
| Commissariat à l'Énergie Atomique et aux énergies alternatives |  |
| European Institute for Energy Research |  |
| École polytechnique fédérale de Lausanne |  |
| Catalonia Institute for Energy Research |  |
| HTceramix |  |
| LABORELEC/ENGIE |  |
| Enagás |  |
| VDZ gGmbH |  |

The Eco Project



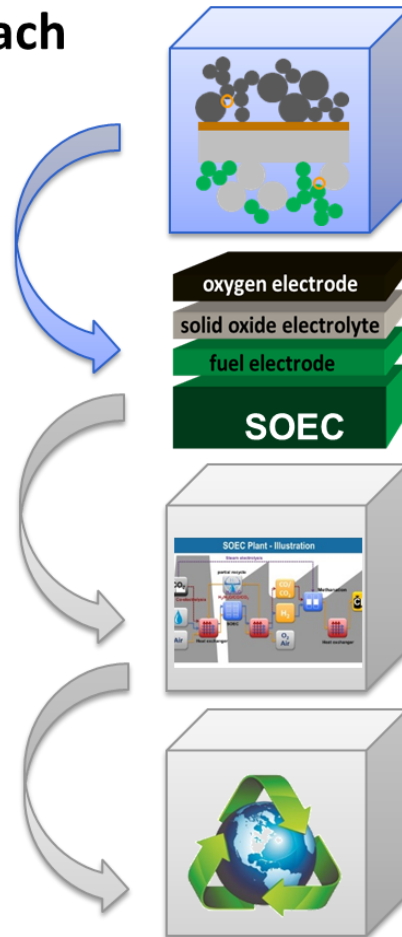
 @eco_soec

Eco Scientific approach

Co-electrolysis
process power
to gas

Techno-economic
benefits

Life cycle
assessment



Improved SOEC
electrodes

Improved SOEC
cells & stacks

SOEC system
SOEC plant

SOEC application
cases

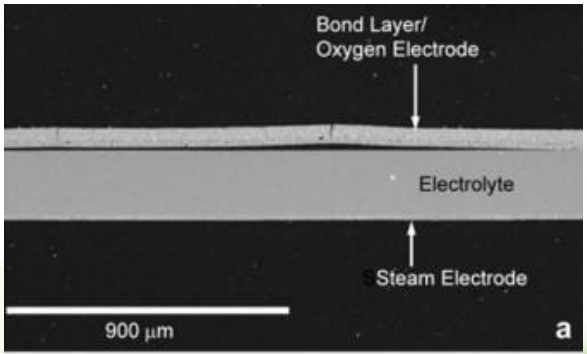
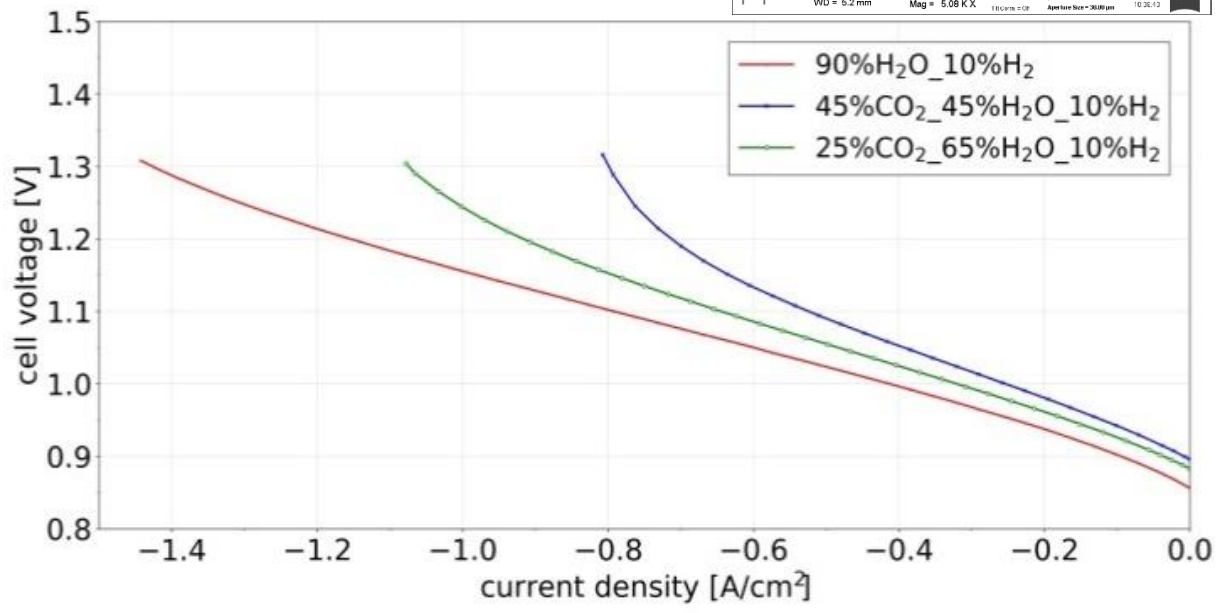
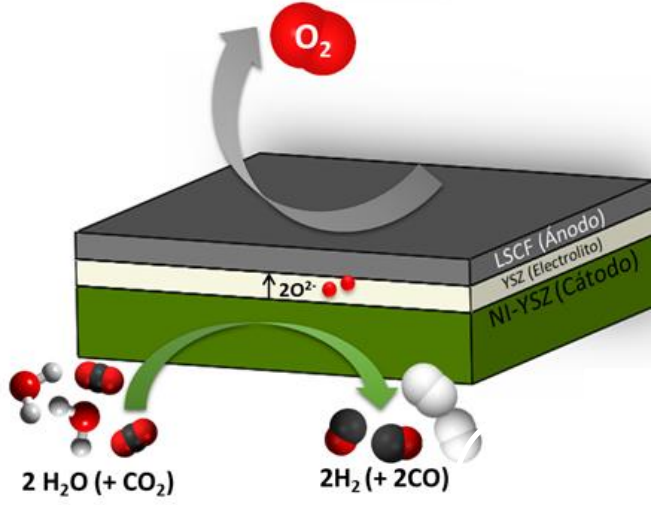
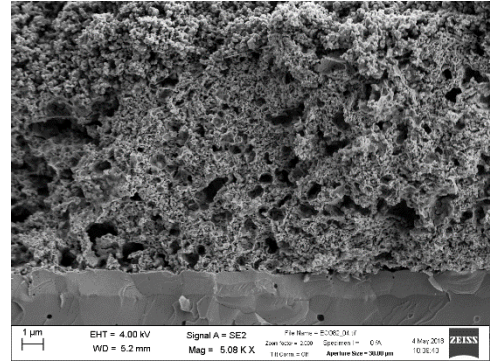
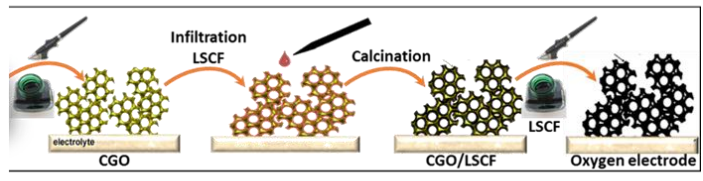
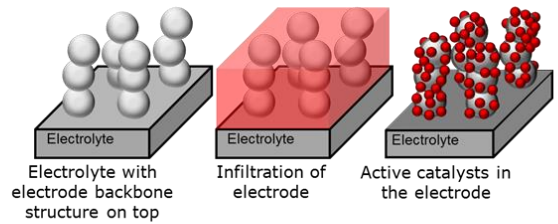
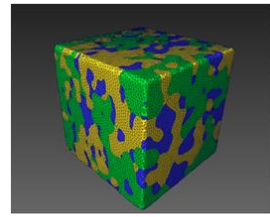
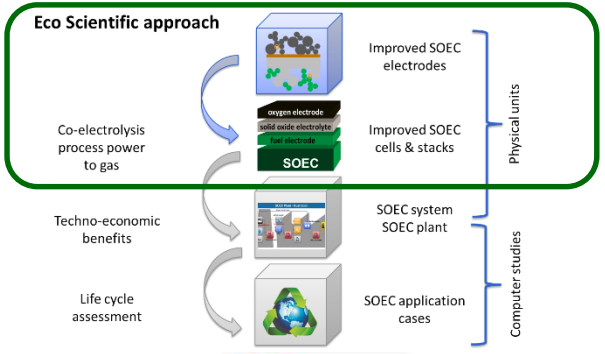
Physical units

Computer studies

The Eco Project



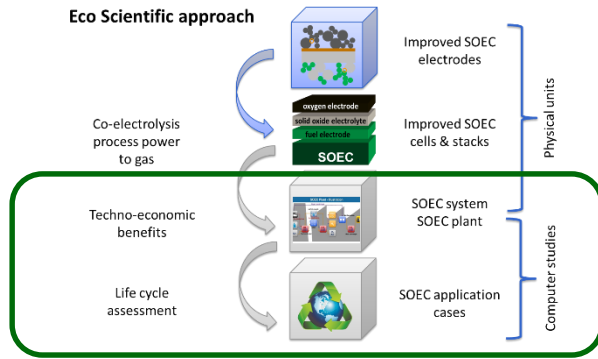
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The Eco Project

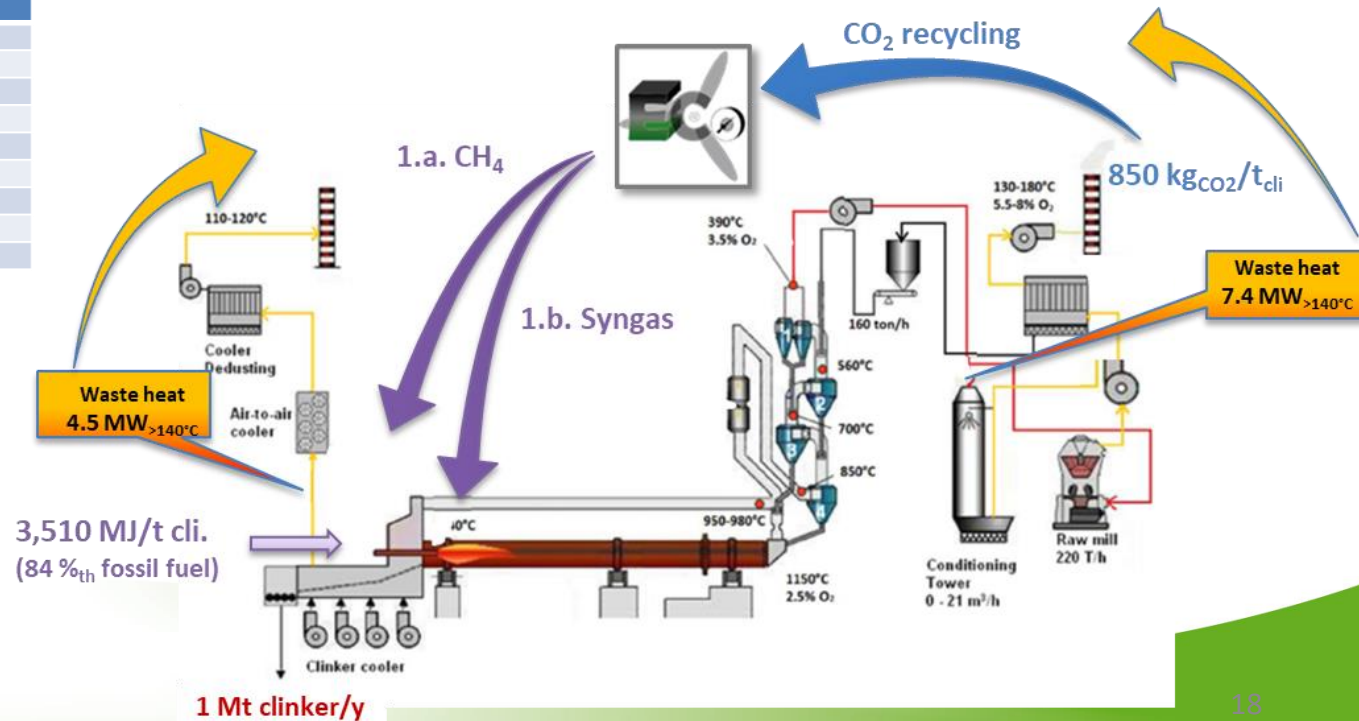


@eco_soec



Case of Study 1: Enhancing sustainability of cement production

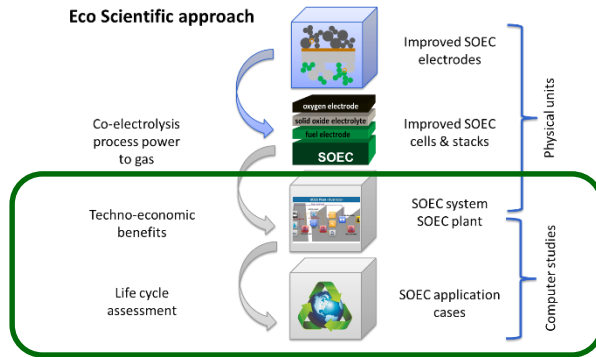
| | |
|-------------------------------------|---|
| Production capacity | 1 Mt clinker / y |
| Operating time | 330 j/yr – 24h/d |
| Clinker/cement factor | 0.752 |
| CO ₂ emission | |
| Gross CO ₂ per t clinker | 850 kgCO ₂ /t _{cli} |
| Fuel | |
| Specific fuel energy demand | 3,510 MJ/t cli |
| Fossil fuel share | 84% _{th} |
| Alternative fuels | 10.2% _{th} |
| Biomass | 5.8% _{th} |



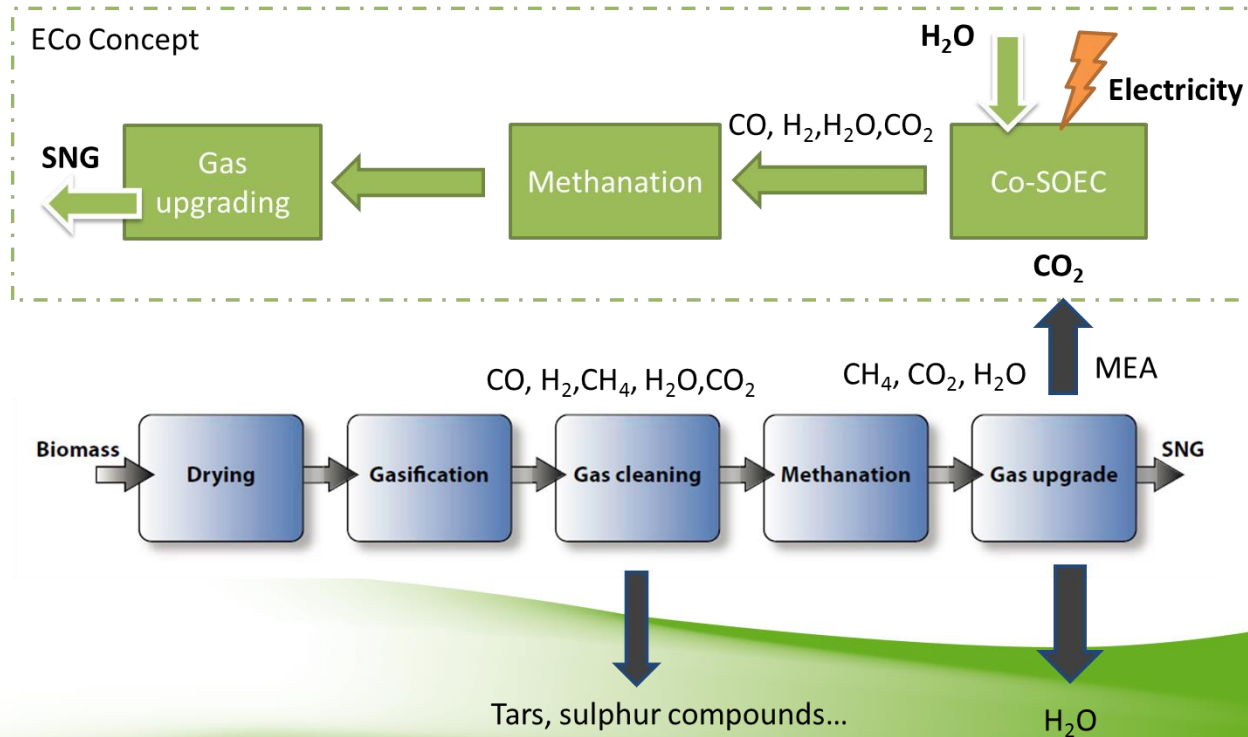
The Eco Project



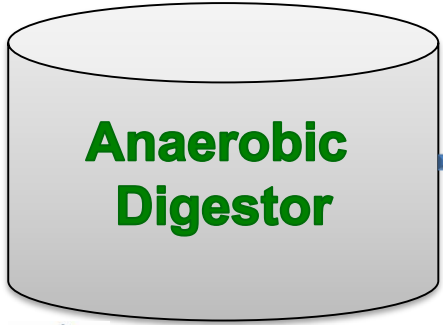
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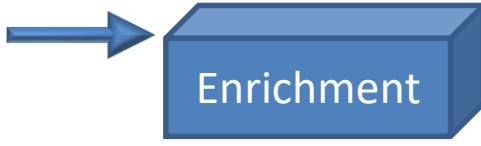
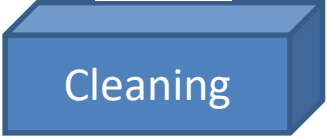
Case of Study 2: Enhancing biomass gasification plant with CO₂ utilization



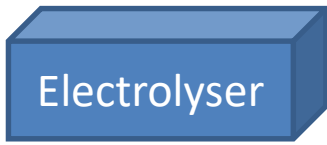
The CO₂Sin Project



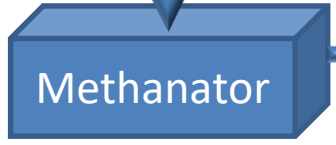
BioGas



gasNatural fenosa



H₂

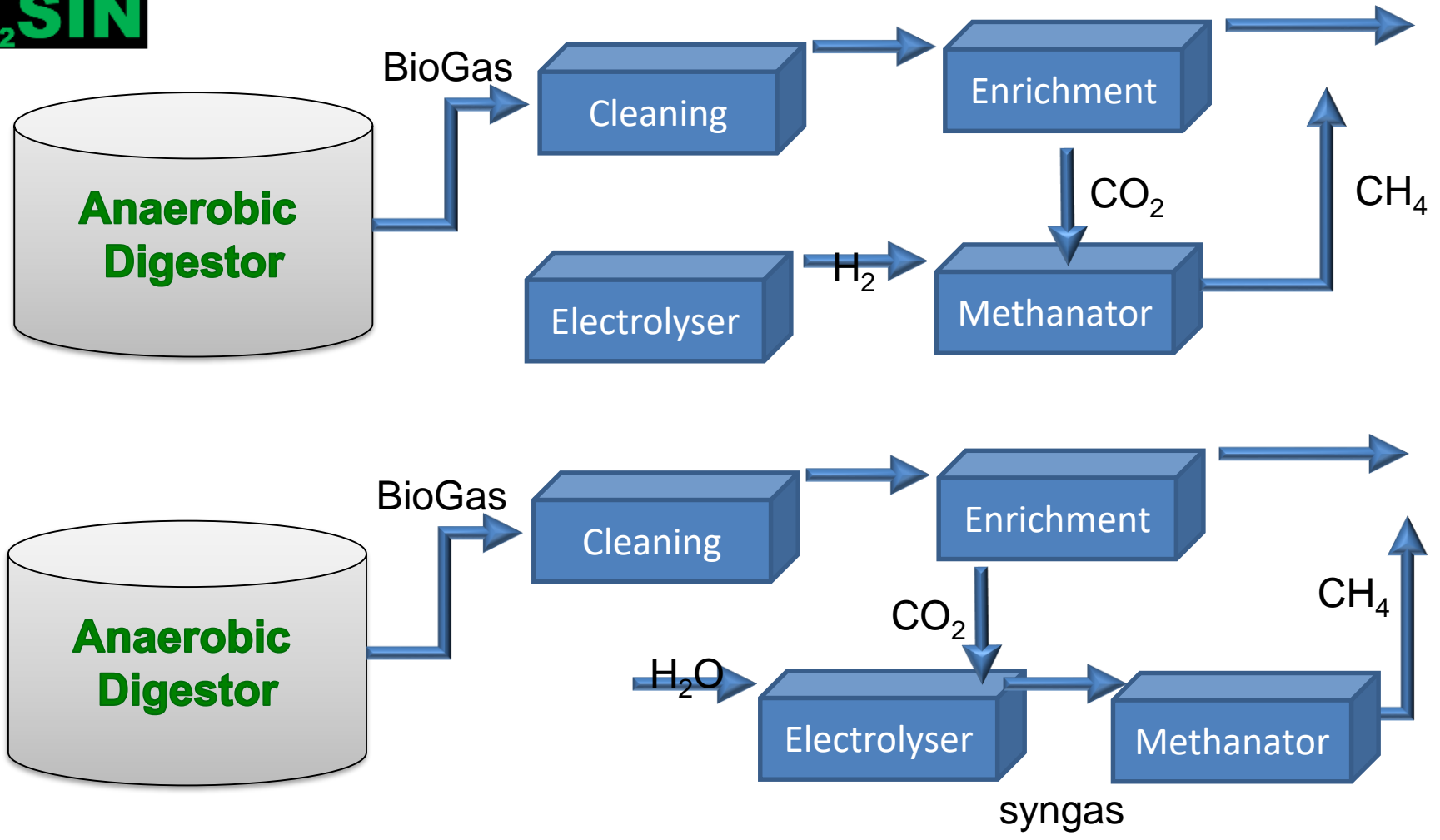


CO₂

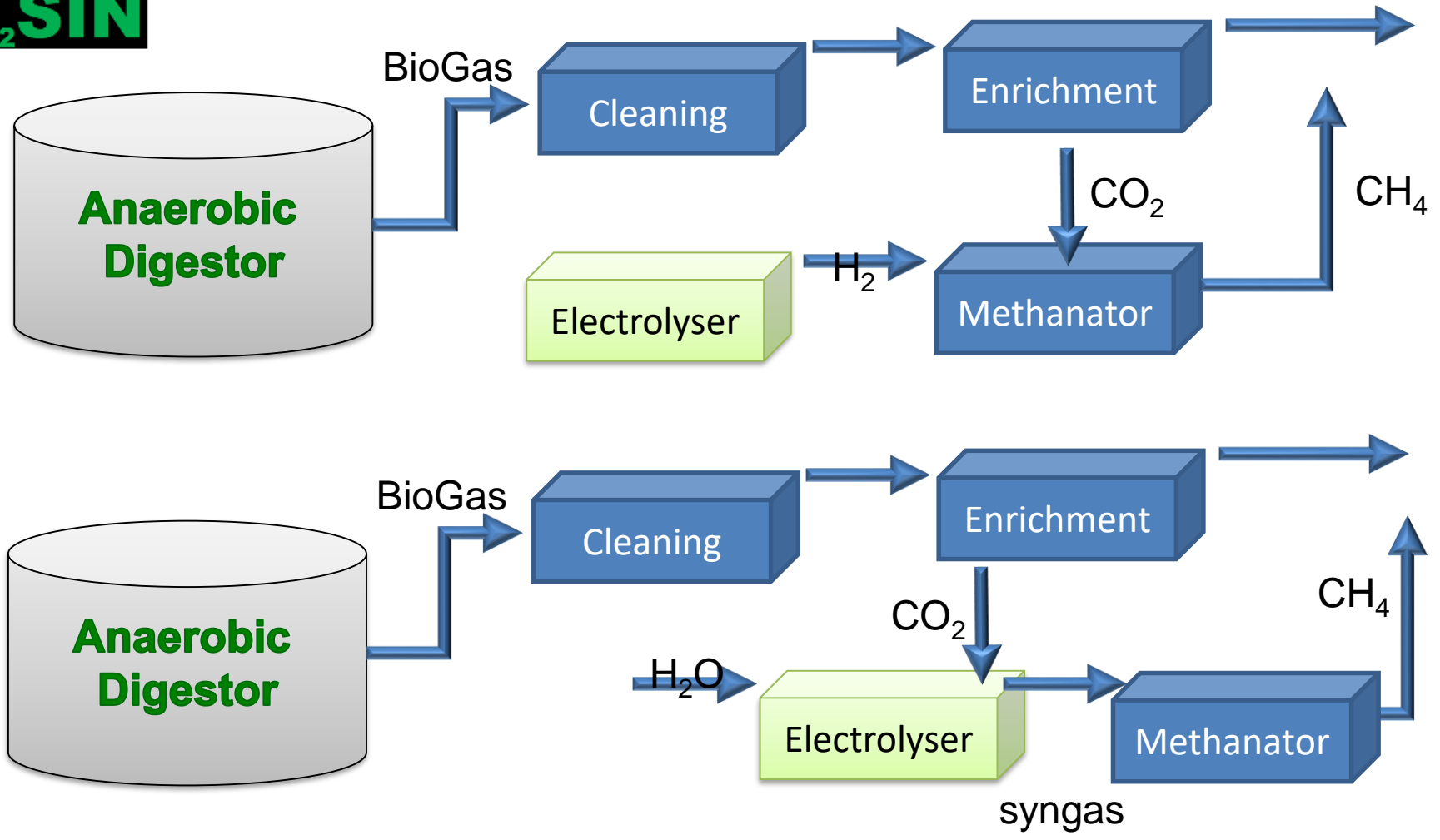
CH₄



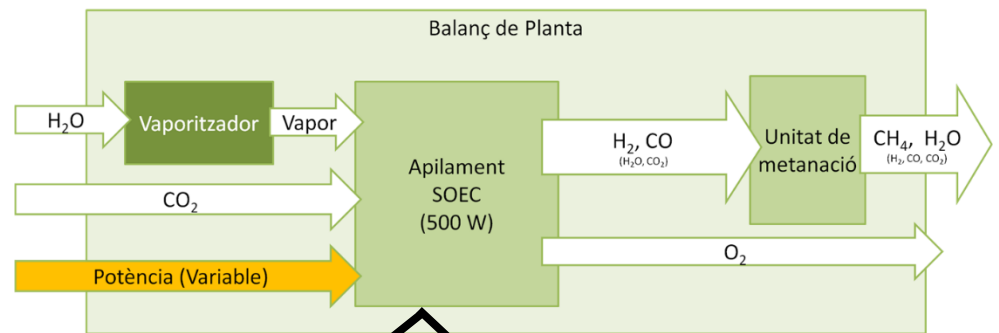
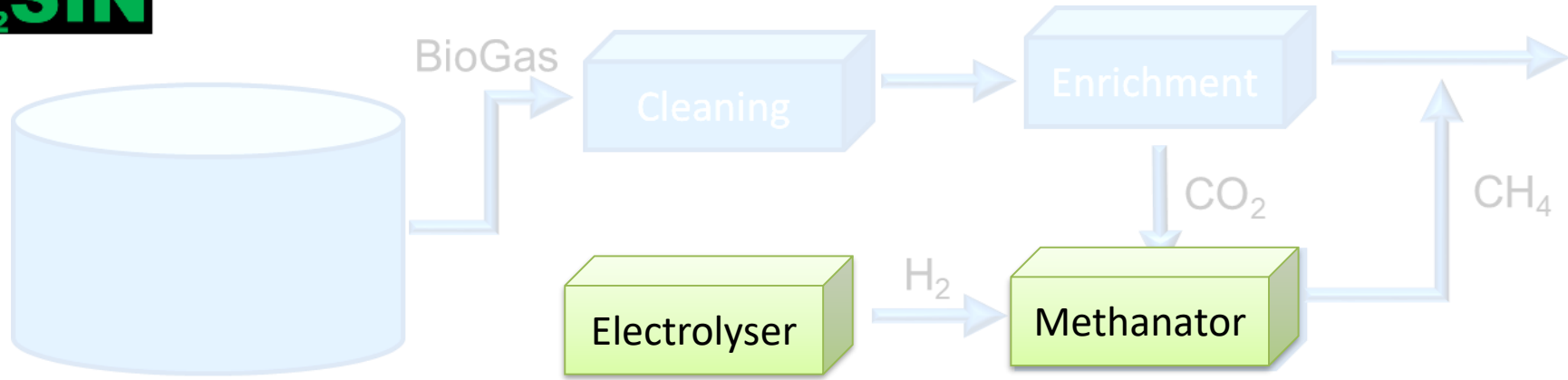
The CO₂Sin Project



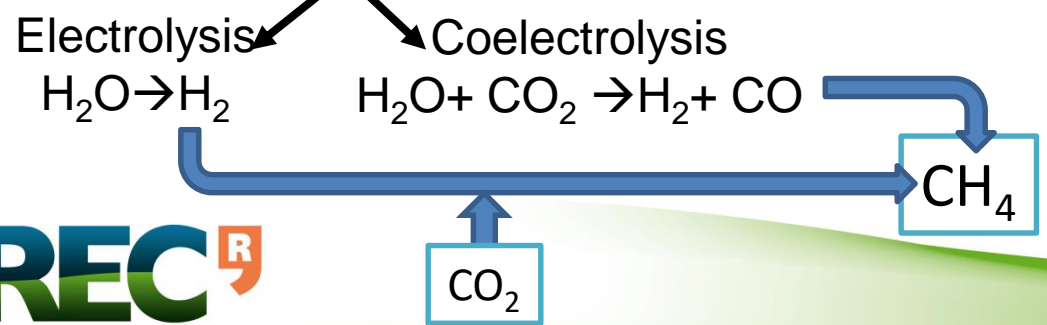
The CO₂Sin Project



The CO₂Sin Project

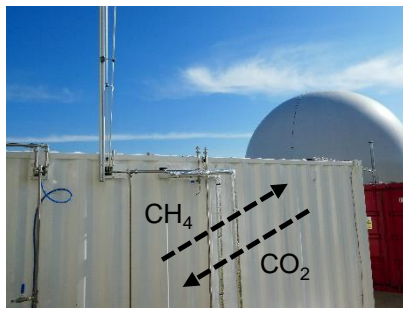
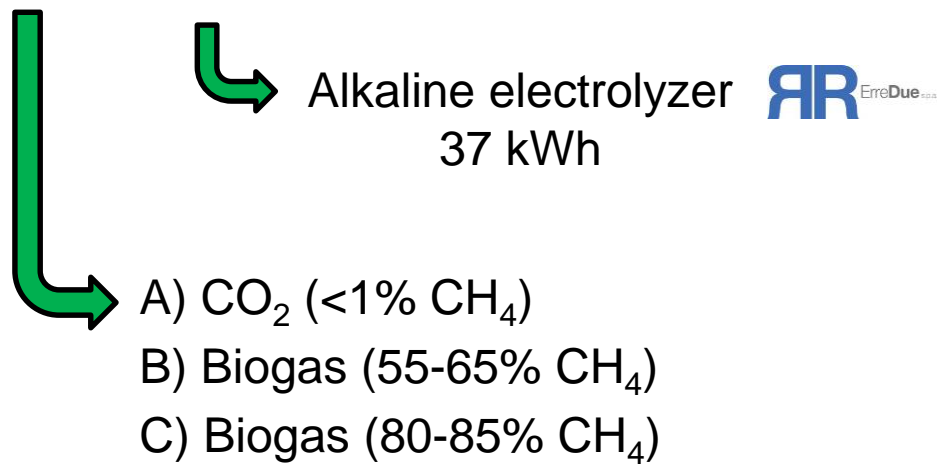
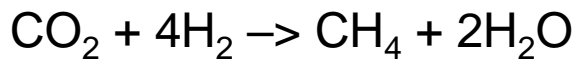


| Objectius quantitatius del projecte | Requisits del sistema final |
|---|-----------------------------|
| Potència injectada | 0.5 kW |
| Combustible d'entrada | Aigua (i CO ₂) |
| Eficiència faràdica | >90% |
| Eficiència conversió electricitat a gas | >75% |
| Ritme de producció de H ₂ | 8 mols H ₂ /h |
| Relació CO:H ₂ en co-electròlisi | 2:1 |





10 Nm³/h



CO₂ source

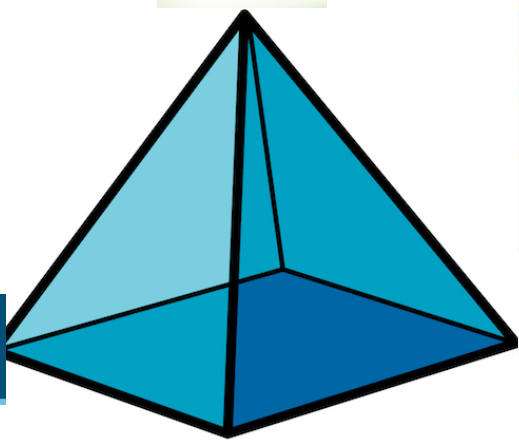
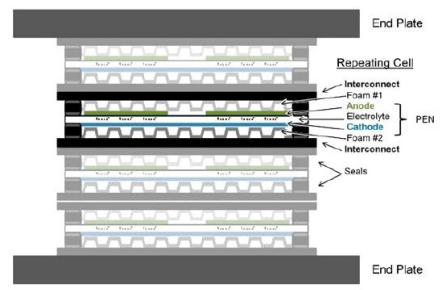


H₂S cleaning

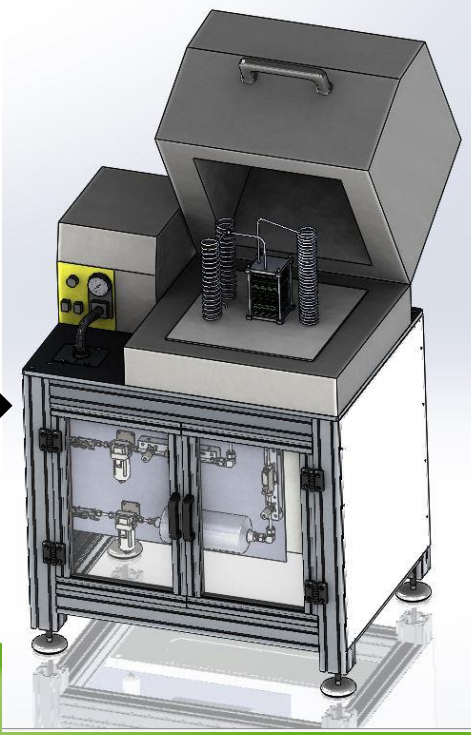
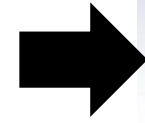
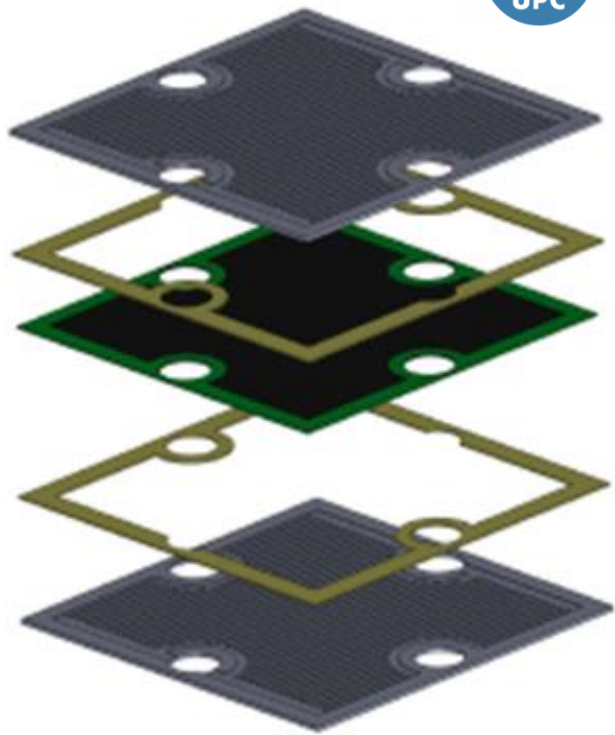
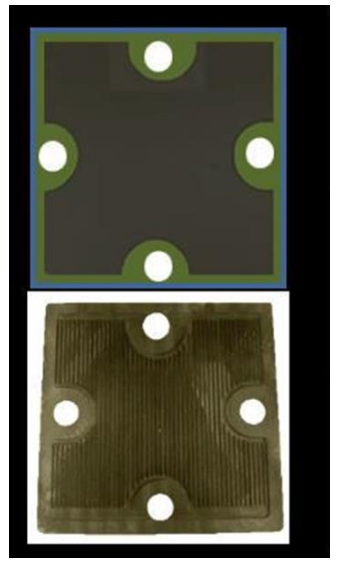
The CO₂Sin Project



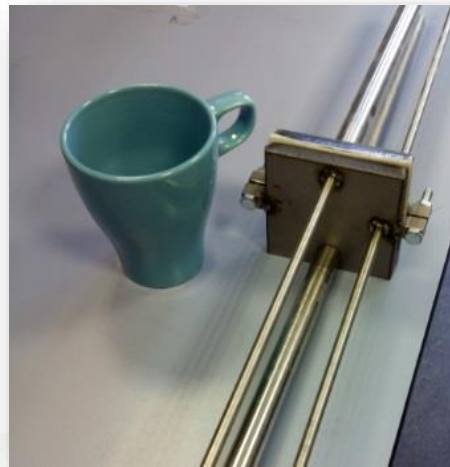
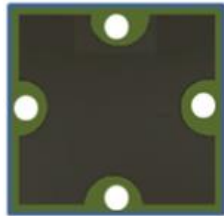
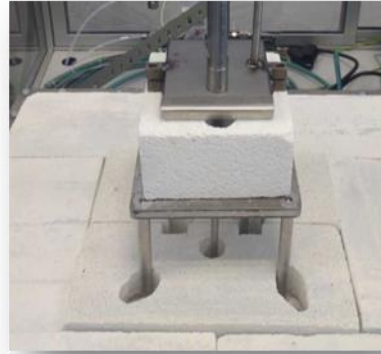
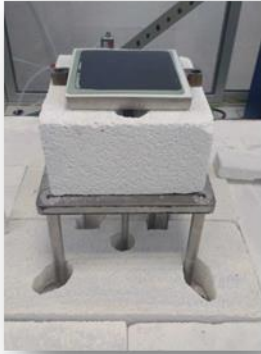
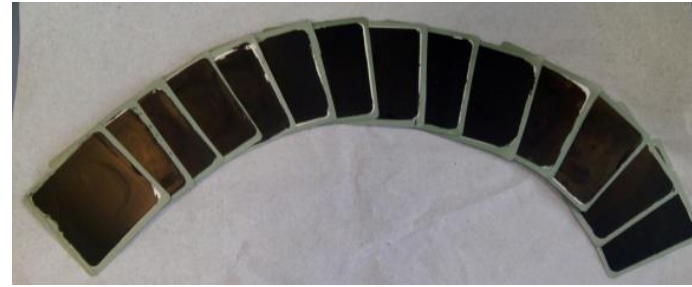
CO₂SIN



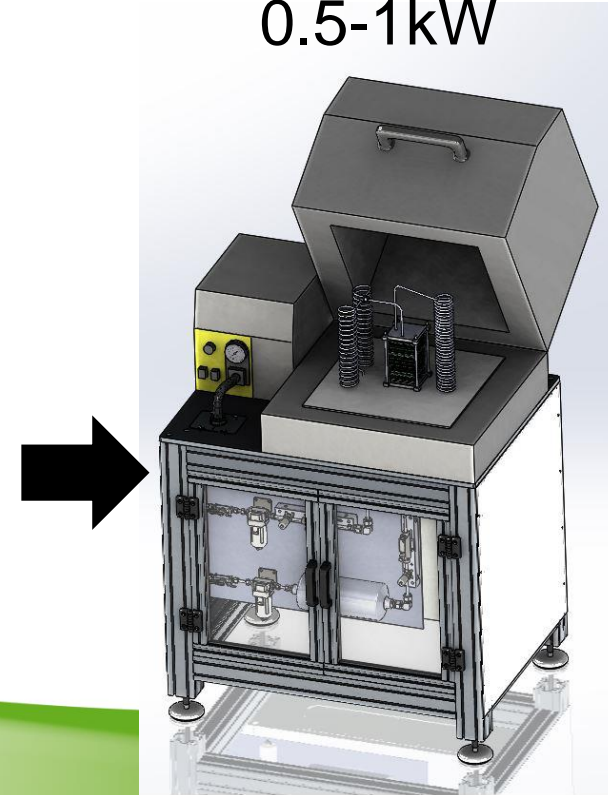
0.5-1kW



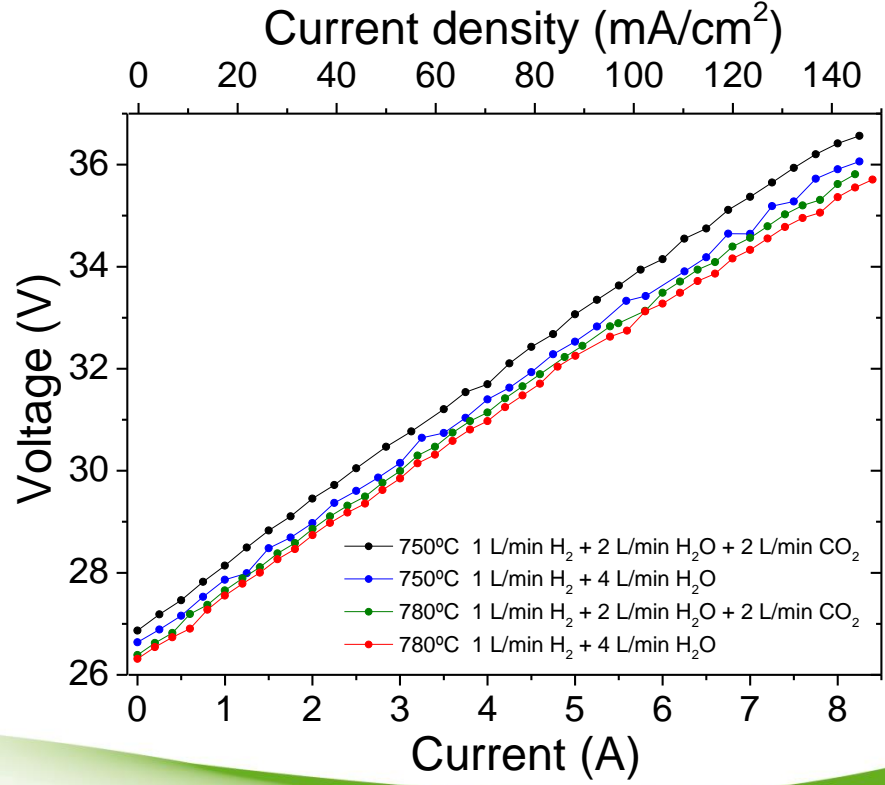
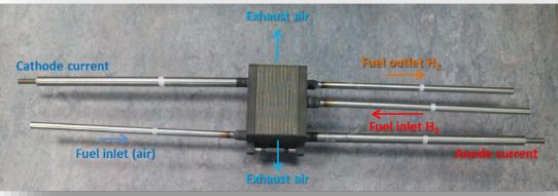
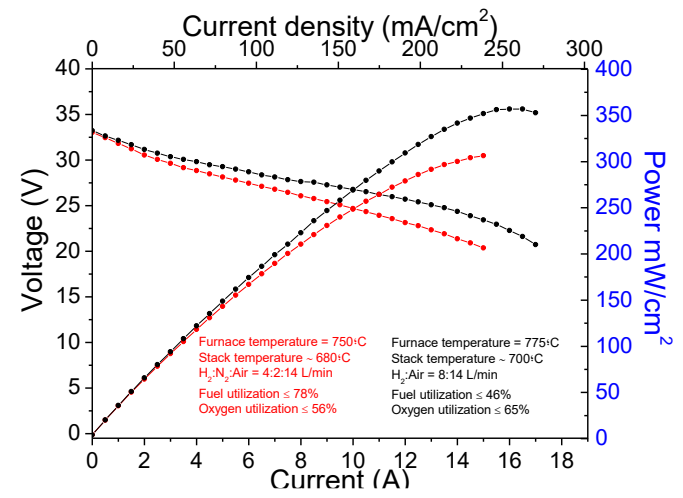
The CO₂Sin Project



0.5-1kW



The CO₂Sin Project



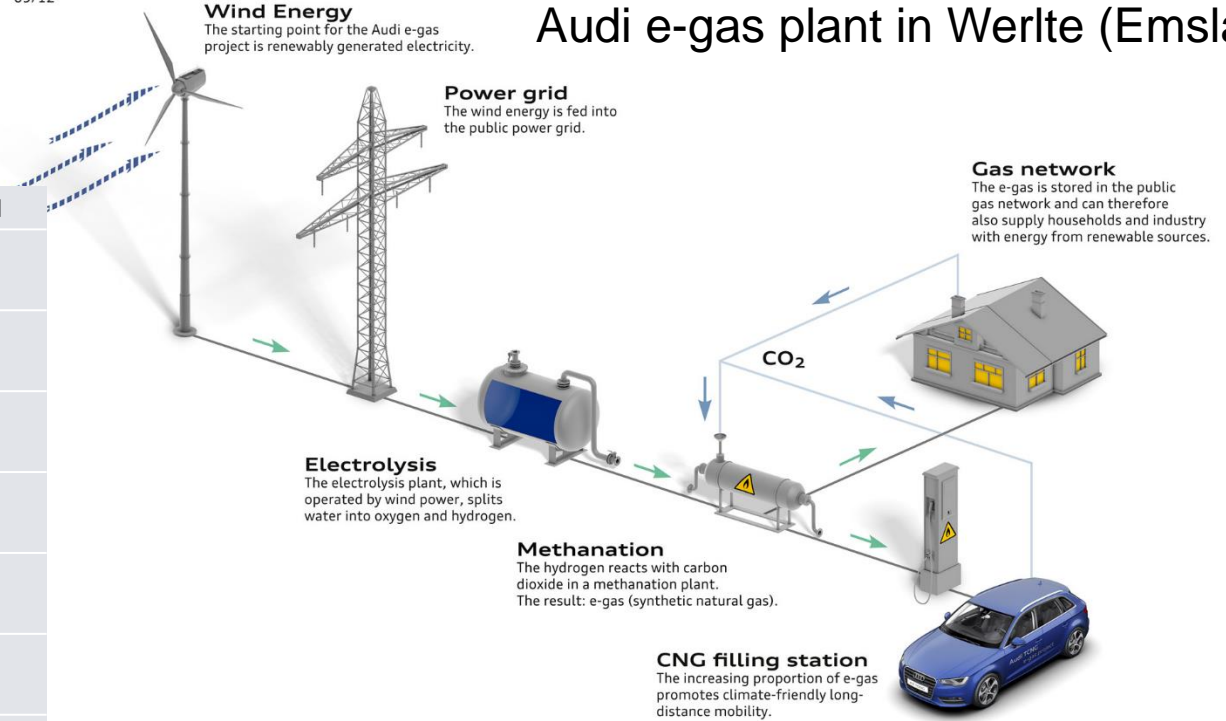
Max. production rate of H₂ = 106 L/h F.U. (H₂O conversion) = 44%

Audi A3 TCNG

09/12

Audi e-gas plant in Werlte (Emsland)

| | |
|---|---|
| Project status | Project completed |
| Typical system size Energy | Capacity of natural gas grid |
| Typical system size Output | 6 MW |
| Volumetric energy density | Identical to natural gas grid |
| Efficiency AC/VN CH4 | 54% +/- 3% |
| Service life of the system | > 20 years |
| Typical discharge time | 30 seconds |
| Typical period between storage and withdrawal | Variable due to high amount of gas power stations in the grid |
| Example application areas | Adjustable at will (power conversion at any place in the grid) |
| Project duration | Supply of synthetic methane from excess power for mobility purposes. Use of the PtG plant for control power. |





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UNIÓN EUROPEA
“Una manera de hacer Europa”

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