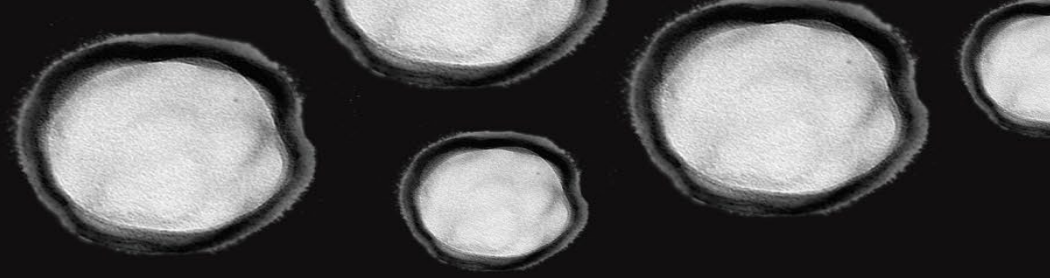

INSTITUTO DE TECNOLOGÍA QUÍMICA

Conversion and Storage of Energy

Jose M. Serra
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EXCELENCIA SEVERO OCHOA

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Enabling components and technologies for decarbonized industry

Energy Efficiency
CO_2 capture
Circularity
Electrification
H_2 production
Low C-footprint fuels

Smart Catalysts

Electrochemical Cells

Smart Electric Heating

Smart Separations

Gasification & Pyrolysis

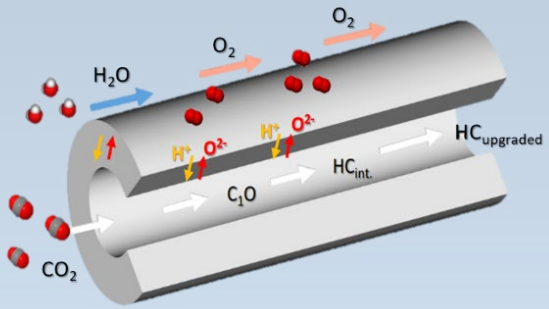
Heat Exchangers

Solar Heating & Cycles

Conversion and Storage of Energy
https://itqmembranes.itq.webs.upv.es/

Catalytic membrane reactors

Catalytic membrane reactors couple chemical reactions with membrane separation technology providing compact systems with improved performance (selectivities and/or yields). We pay special attention to the design of cutting-edge membrane reactors but also to test the reactors performance and long-term stability for the next generation of renewable fuel and chemicals production, and CO_2 valorization systems.

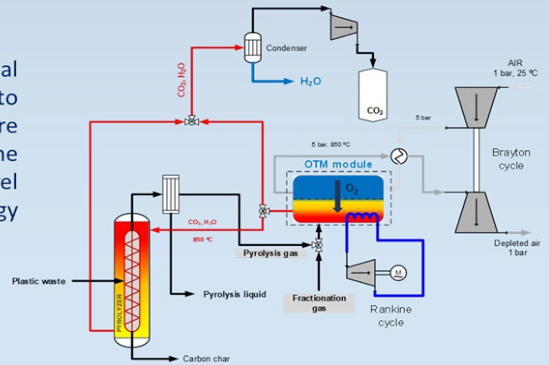


Membrane technology

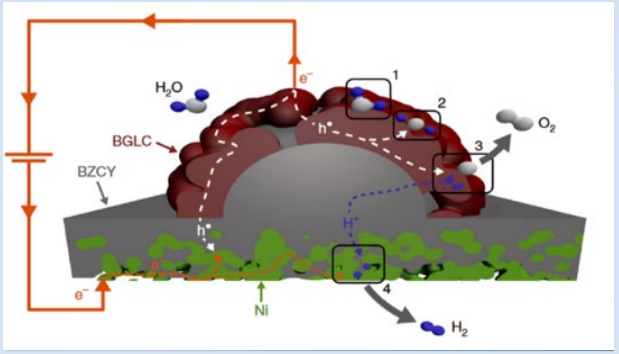
We have wide expertise on the production and characterization of mixed ionic electronic conducting membranes at bench and prototype scales. These high temperature membranes would find application where high purity oxygen or hydrogen is required.

Process intensification

With the intensification of chemical processes, we employ engineering tools to obtain substantially cleaner, safer, and more sustainable technologies. We focus on the design, simulation and optimization of novel processes and units with increased energy efficiency.

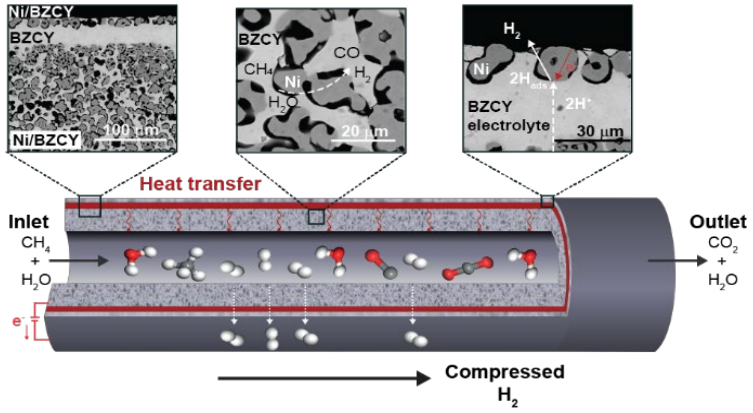


Electrochemical conversion & storage devices



Fuel cells and electrolysers are electrochemical devices that directly convert/store the chemical energy into/from electrical energy. In particular, we focus on the fabrication and characterization of Solid oxide fuel/electrolyser cells (SOFC/SOECs) and Protonic ceramic fuel/electrolyser cells (PCFC/PCECs)

KERIONICS



nature materials — ARTICLES

https://doi.org/10.1038/s41563-019-0388-2

Mixed proton and electron conducting double perovskite anodes for stable and efficient tubular proton ceramic electrolysers

Einar Vøllestad[1,2], Ragnar Strandbakke[1], Mateusz Tarach[2], David Catalán-Martínez[2], Marie-Laure Fontaine[2], Dustin Beeaff[4], Daniel R. Clark[1,4], Jose M. Serra[2,3] and Truls Norby[1]*

Hydrogen production from water electrolysis is a key enabling energy storage technology for the large-scale deployment of intermittent renewable energy sources. Proton ceramic electrolysers (PCEs) can produce dry pressurized hydrogen directly from steam, avoiding major parts of cost-driving downstream separation and compression. However, the development of PCEs has suffered from limited electrical efficiency due to electronic leakage and poor electrode kinetics. Here, we present the first fully operational $BaZrO_3$-based tubular PCE, with 10 cm^2 active area and a hydrogen production rate above 15 Nml min^{-1}. The novel steam anode $Ba_{0.95}Gd_{0.15}La_{0.15}Co_2O_{6-\delta}$ exhibits mixed p-type electronic and protonic conduction and low activation energy for water splitting, enabling total polarization resistances below 1 Ω cm^2 at 600 °C and Faradaic efficiencies close to 100% at high steam pressures. These tubular PCEs are mechanically robust, tolerate high pressures, allow improved process integration and offer scale-up modularity.

nature energy — ARTICLES

https://doi.org/10.1038/s41560-020-00720-6

Hydrogen production via microwave-induced water splitting at low temperature

J. M. Serra[1,2]✉, J. F. Borrás-Morell[1,2], B. García-Baños[2], M. Balaguer[1], P. Plaza-González[2], J. Santos-Blasco[1], D. Catalán-Martínez[1], L. Navarrete[1,2] and J. M. Catalá-Civera[2]✉

Supplying global energy demand with CO_2-free technologies is becoming feasible thanks to the rising affordability of renewable resources. Hydrogen is a promising vector in the decarbonization of energy systems, but more efficient and scalable synthesis is required to enable its widespread deployment. Here we report contactless H_2 production via water electrolysis mediated by the microwave-triggered redox activation of solid-state ionic materials at low temperatures (<250 °C). Water was reduced via reaction with non-equilibrium gadolinium-doped CeO_2 that was previously in situ electrochemically deoxygenated by the sole application of microwaves. The microwave-driven reduction was identified by an instantaneous electrical conductivity rise and O_2 release. This process was cyclable, whereas H_2 yield and energy efficiency were material- and power-dependent. Deoxygenation of low-energy molecules (H_2O or CO_2) led to the formation of energy carriers and enabled CH_4 production when integrated with a Sabatier reactor. This method could be extended to other reactions such as intensified hydrocarbons synthesis or oxidation.

RESEARCH

REPORT — CATALYSIS

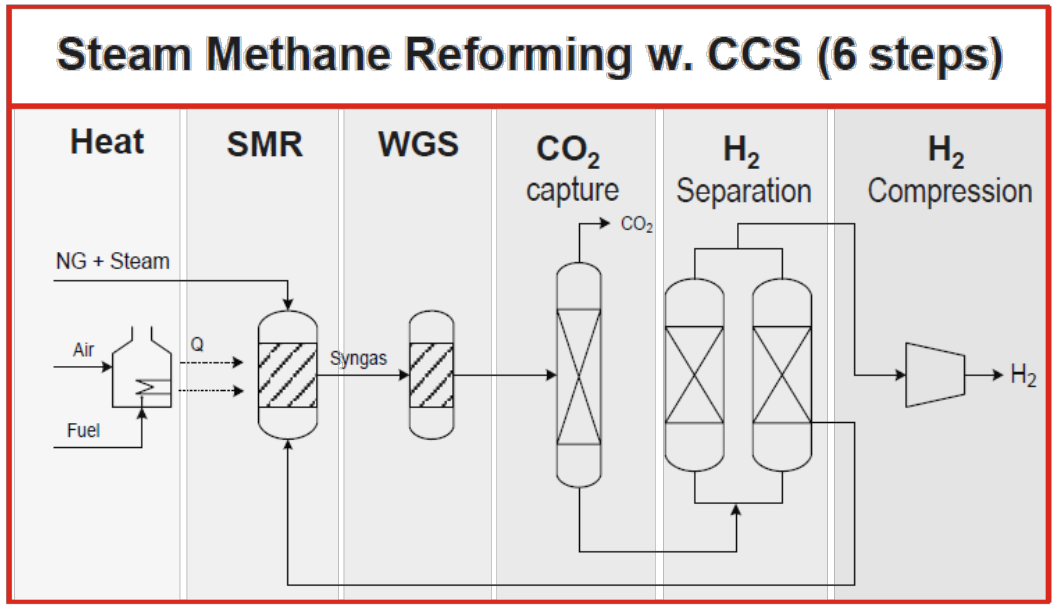
Clark *et al.*, *Science* **376**, 390–393 (2022) 22 April 2022

Single-step hydrogen production from NH_3, CH_4, and biogas in stacked proton ceramic reactors

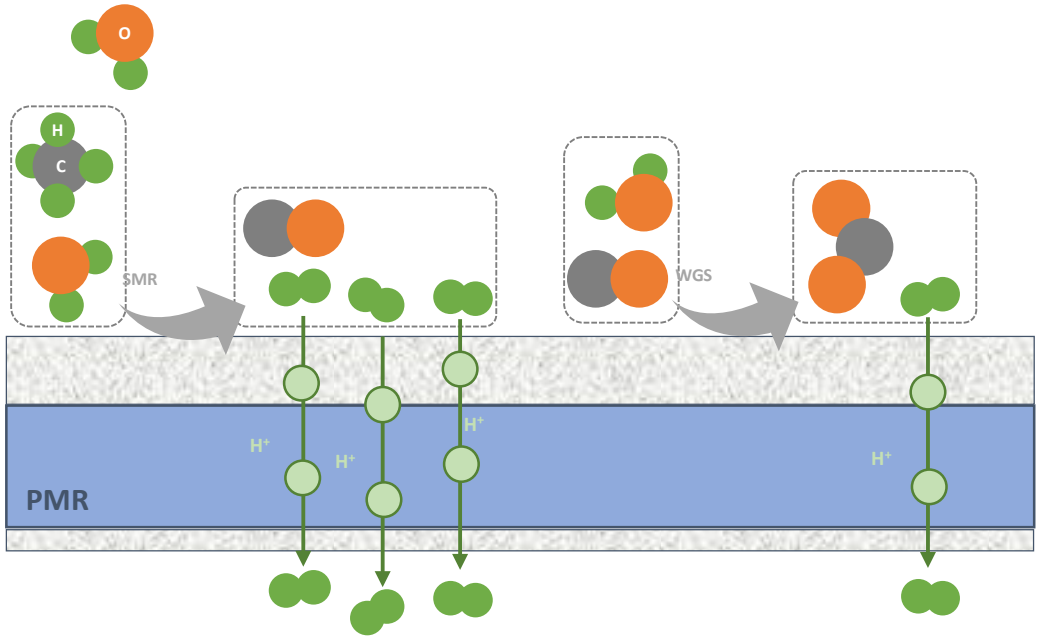
Daniel Clark[1], Harald Malerød-Fjeld[1], Michael Budd[1], Irene Yuste-Tirados[1,2], Dustin Beeaff[1], Simen Aamodt[1], Kevin Nguyen[1], Luca Ansaloni[3], Thijs Peters[3], Per K. Vestre[1], Dimitrios K. Pappas[1], María I. Valls[4], Sonia Remiro-Buenamañana[4], Truls Norby[2], Tor S. Bjørheim[1], Jose M. Serra[4]*, Christian Kjølseth[1]*

Proton ceramic reactors offer efficient extraction of hydrogen from ammonia, methane, and biogas by coupling endothermic reforming reactions with heat from electrochemical gas separation and compression. Preserving this efficiency in scale-up from cell to stack level poses challenges to the distribution of heat and gas flows and electric current throughout a robust functional design. Here, we demonstrate a 36-cell well-balanced reactor stack enabled by a new interconnect that achieves complete conversion of methane with more than 99% recovery to pressurized hydrogen, leaving a concentrated stream of carbon dioxide. Comparable cell performance was also achieved with ammonia, and the operation was confirmed at pressures exceeding 140 bars. The stacking of proton ceramic reactors into practical thermo-electrochemical devices demonstrates their potential in efficient hydrogen production.

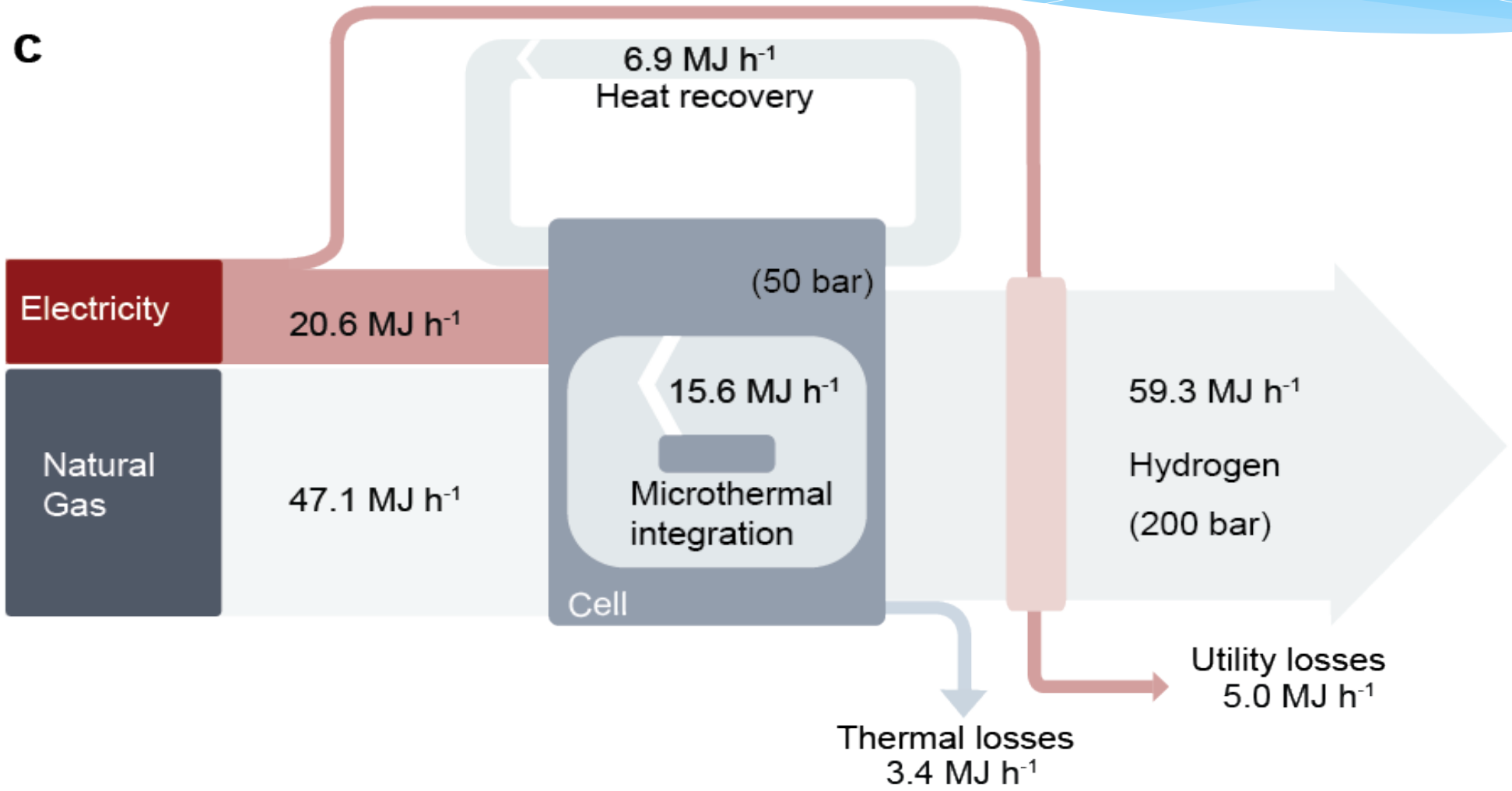
Electrified Membrane Reformer (eMR)



Process step reduction



Proton Membrane Reformer (PMR) – Energy Balance



H. Malerød-Fjeld et al., *Nature Energy,* **2**, p. 923–931 (2017)

Proton Membrane Reformer (PMR) – Efficiency

Hydrogen from natural gas with carbon capture

>90%

energy efficiency

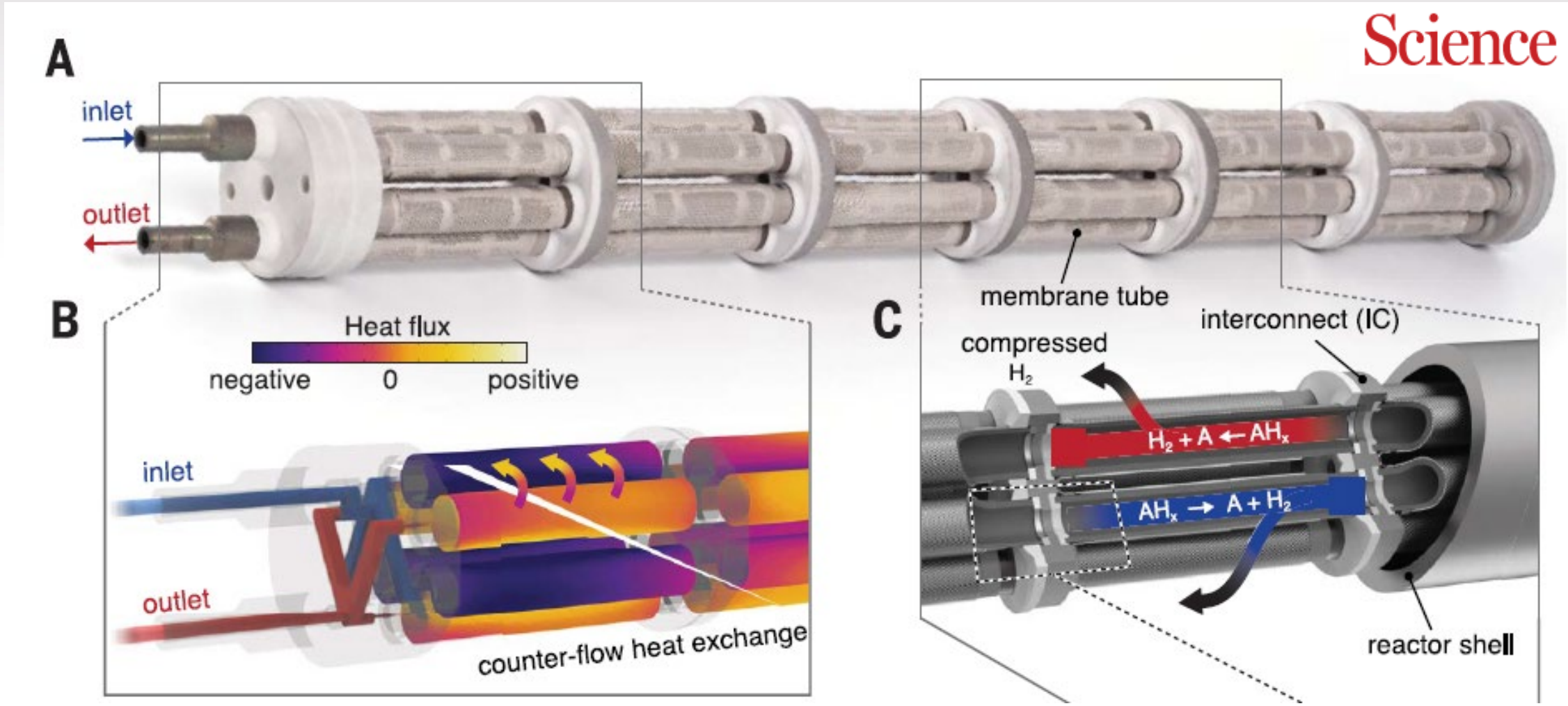
natural gas + electricity → compressed H_2 and CO_2

SOC – Electrified Reforming with Capture

- High current densities (1-4 A/cm^2)
- High-pressure operation – 50 bar (150 tested)

D. Clark et. al, Science 376 (2022) p. 390-393

Single-step hydrogen production from NH_3, CH_4, and biogas in stacked proton ceramic reactors



CoorsTek Membrane Sciences

IMQ

Direct electrocatalytic conversion of CO_2 into chemical energy carriers in a co-ionic membrane reactor

AIM: Set-up a technology for direct synthesis of carbon-neutral jet fuels from CO_2 using renewable energy and electrochemical catalytic membrane reactors. Bench-testing targets a 500 W multi-tubular system.

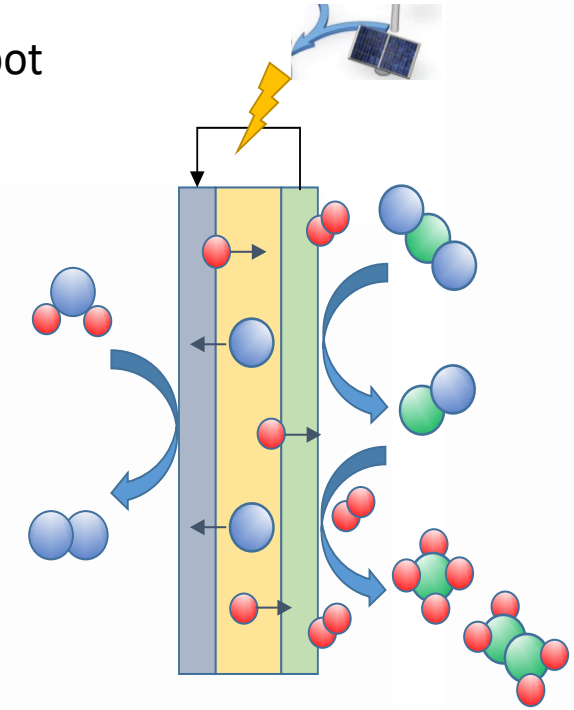
- Single-step electrolysis and one-pot catalytic conversion.
- Operating conditions:
  T = 350-450 °C and > 25 bar.

Product:
Jet fuel

Efficiency:
> 85%

Full integration:
compact sized reactor

Final TRL:
5



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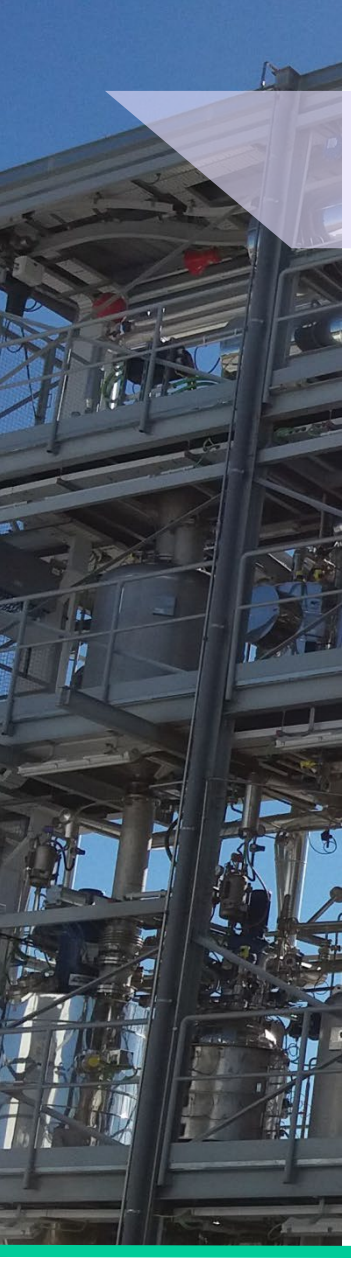
RWTH Aachen University
HERA
Shell
ArcelorMittal
SINTEF
CEMEX
九州大学 Kyushu University
Universitas Amoiensis

https://ecocoo.eu

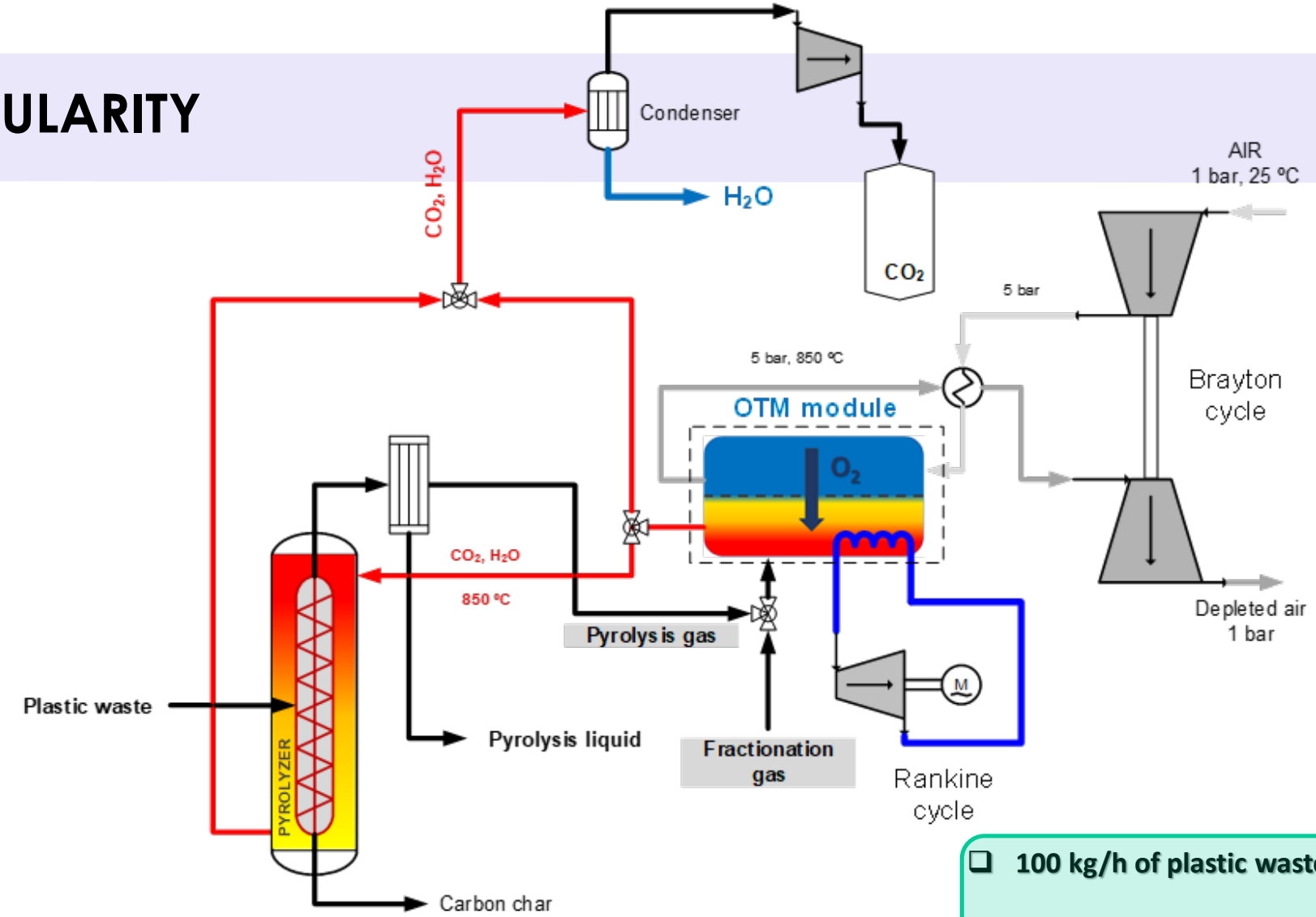
H2020-LC-SC3-2018-NZE-CC | Duration: May 2019 – May 2023 | **EC funding**: 3.9 M€

This project has received European Union's Horizon 2020 research and innovation funding under grant agreement Nº 838077.

SPIRE – Sustainable Process Industry through Resource and Energy Efficiency



CIRCULARITY



- **100 kg/h of plastic waste is treated.**
- The **O_2 demand is** around **20.5-26.5 m_3/h.**

This project has received European Union's Horizon 2020 research and innovation funding under grant agreement N° 820770.

MINISTERIO DE CIENCIA E INNOVACIÓN

FINANCIADO POR LA UNIÓN EUROPEA
Next Generation EU

ESPAÑA PUEDE.

GREENRUPTIVE™

MAKING NET ZERO EMISSIONS REAL

CSIC

Fundación General CSIC

PTI+Transener Initiative (Valencia)

PTI+ TRANS-ENER+
Alta Tecnología Clave en la Transición en el Ciclo Energético

Motivación

Nuestra vocación es ayudar con nuestro *know-how* y capacidades experimentales a la industria a DESARROLLAR SOLUCIONES

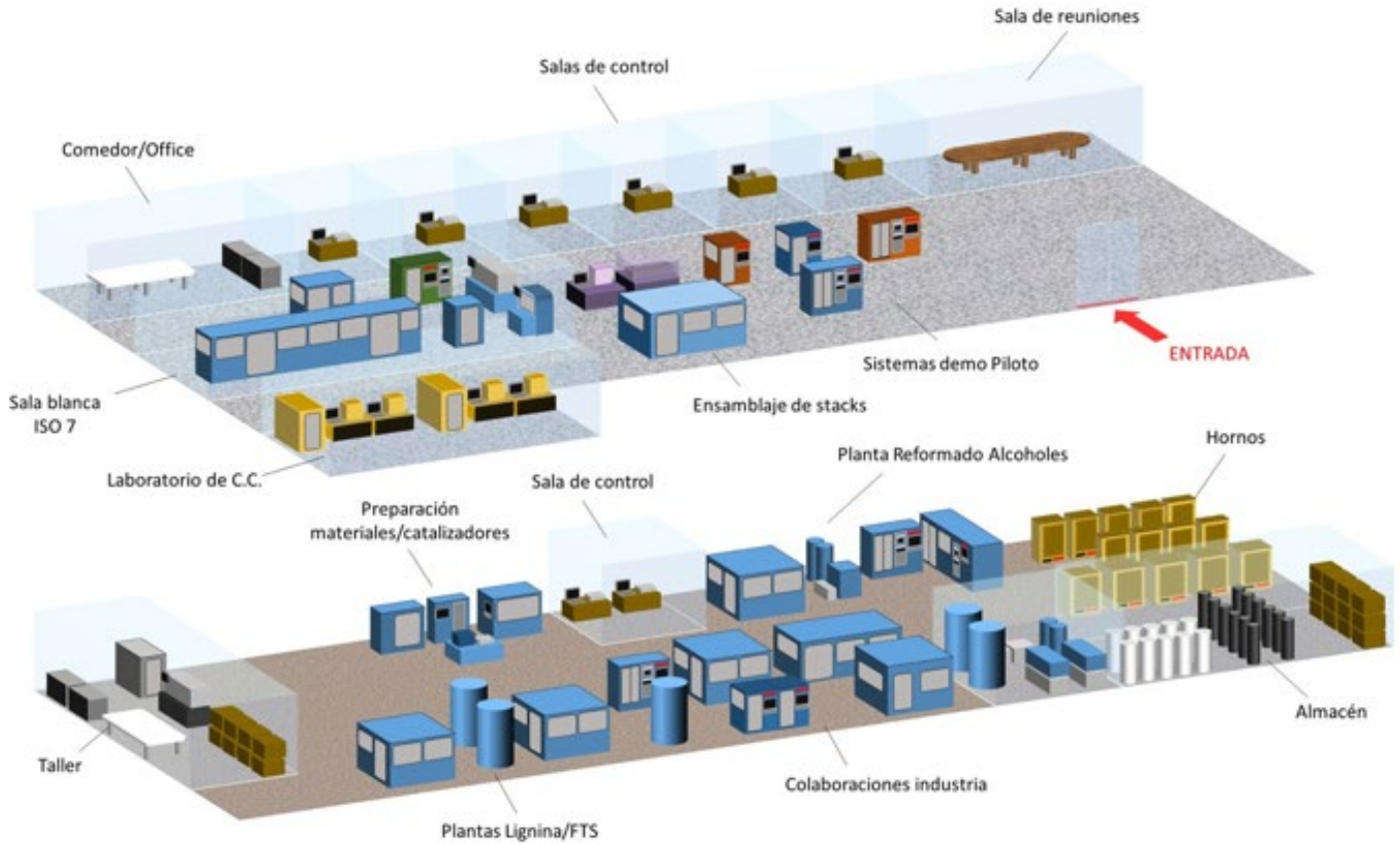
- Proyectos piloto de desarrollo e innovación avanzados (TRL-5 a TRL-9)
- Start-ups/spin-off

MISIÓN

- CREAR UN **ECOSISTEMA** ABIERTO, INNOVADOR Y COLABORATIVO
- PROMOVER EL DESARROLLO DE SOLUCIONES Y PRODUCTOS ALINEADOS CON LOS **RETOS INDUSTRIALES** QUE PLANTEA LA ECONOMÍA DE IMPACTO ZERO ENERGÉTICO
- IMPULSAR LA **ESPECIALIZACIÓN** COMO SEÑA DE IDENTIDAD Y PRINCIPAL VENTAJA COMPETITIVA DE UNA INDUSTRIA SOSTENIBLE Y COMPETITIVA
- ATRAER, RETENER Y DESARROLLAR AL MEJOR **TALENTO**

Capacidades clave y Tecnologías

H_2 - e-fuels – Biofuels - Green Steel - Green Ceramics/Cement
Electrificación de procesos - Reactores electroquímicos
Capturas (CCUS, DACC, BECCS) - emisiones negativas
Reciclado de corrientes industriales y residuos bio/agro/RSU/EDARs



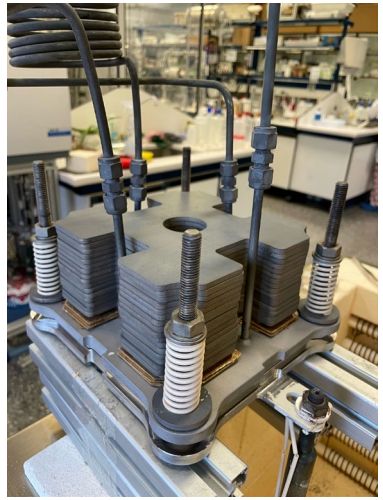
Pilotos programados
Línea piloto de fabricación de celdas SOC/membranas*
Línea piloto de ensamblado de stacks SOC
Unidades testeo (BoP) (co-)electrolizadores x 3
Reformador electrificado NG/biogas/FG con captura x2
Reformador electrificado etanol con captura x 2
Unidad testeo Generador de O2 oxicombustión
Línea de fabricación de catalizadores
Piloto generador de H2 por tecnología microondas
Reactor de reducción con H2 en metalurgia
Reactor de conversión de CO2 (Fischer-Tropsch)
Gasificador/pirol. waste/biomas HC o H2 y captura CO2
Unidad de co-electrólisis y síntesis de hidrocarburos

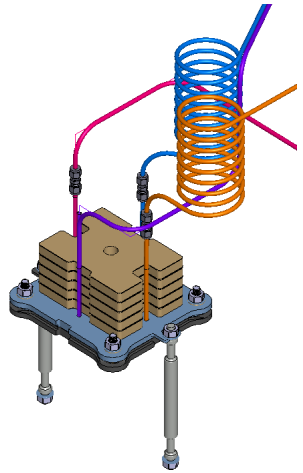
LÍNEAS PILOTO

Capacidades clave: Ejemplos

LINEAS DE FABRICACIÓN DE CELDAS SOC/ MEMBRANAS / BATERÍAS

LINEAS DE MONTAJE DE STACK, MÓDULOS Y REACTORES



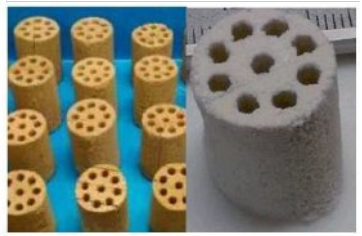


BANCOS DE VALIDACIÓN DE TECNOLOGÍAS CLAVE Y PILOTOS (TRL5 – TRL9)

LÍNEAS DE PRODUCCIÓN Y ESCALADO DE MATERIALES, CATALIZADORES y REACTORES

Selective Laser Sintering

Direct Ink Writing (DIW)



Actividades y Servicios

- Proyectos demostrativos (TRL-5 a TRL-9)
- Incubación Start-ups/spin-off
- Formación y especialización
- Campañas de Innovación abierta
- Jornadas específicas
- Value-chain matching (Corporates, EBTs, R&D)
- Consecución de subvenciones específicas
- Inversores