

**SOLAR
HYDROGEN
PRODUCTION VIA
PHOTOELECTRO-
CATALYSIS**

REPSOL TECHNOLOGY LAB



REPSOL

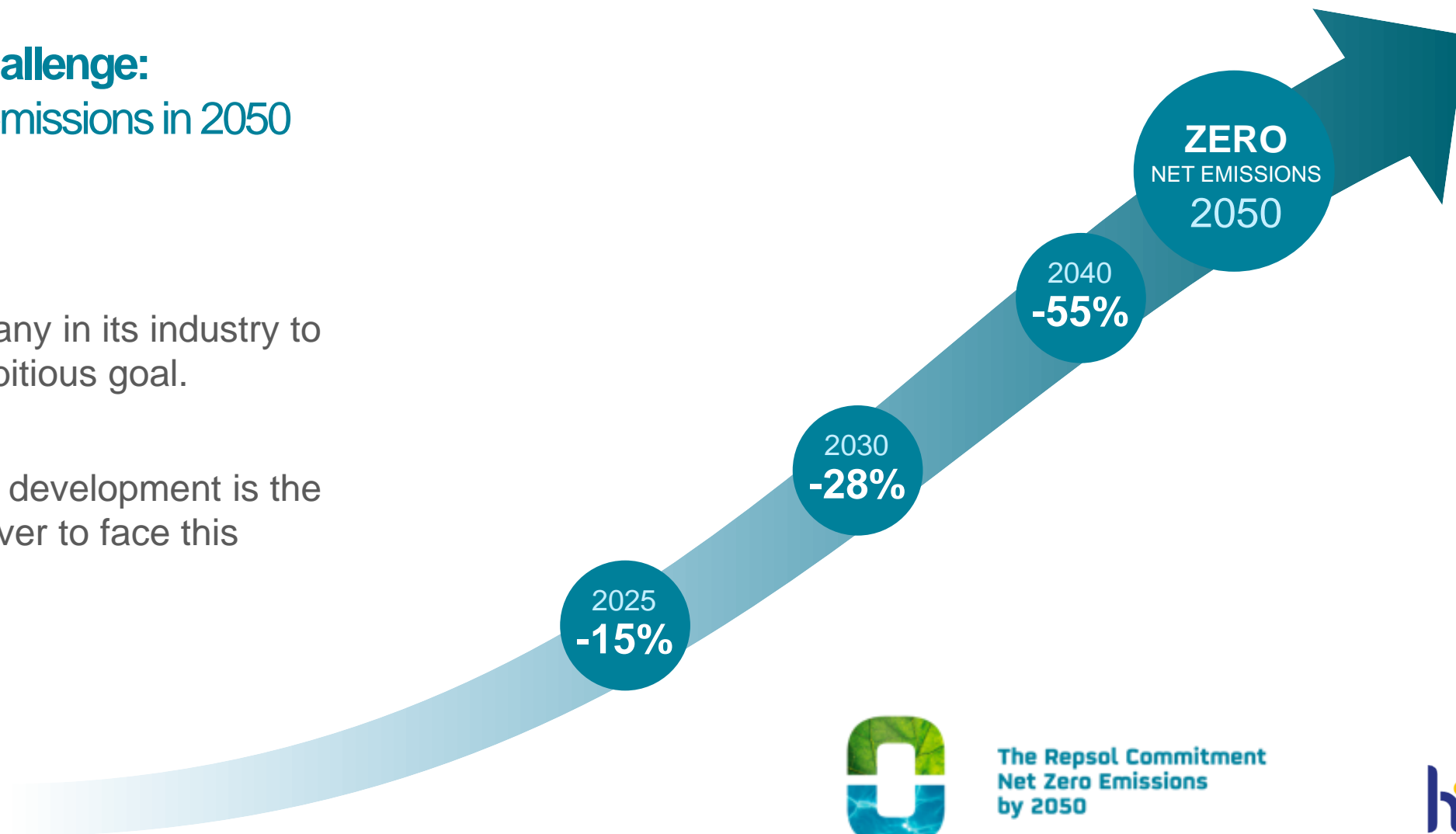
Background and strategy



Repsol challenge:
Net zero emissions in 2050

First Company in its industry to set this ambitious goal.

Technology development is the essential lever to face this challenge.



The Repsol Commitment
Net Zero Emissions
by 2050



Repsol Technology Lab

Open innovation model



Repsol Technology Lab

#RepsolTechLab
#RepsolVenturing

Our **R&D**

233

experts
of 17 nationalities

+ 64 million
euros invested
in 2021

CAPABILITIES
In multiple fields such as:

- # Advanced Mobility
- # Bio-Energy and Low Emissions
- # Advanced Mathematics
- # Geophysics
- # Process Design

+50.000 m²
dedicated to innovation around the world

REPSOL DEEP TECH
Fund

Endowed with

50 million €

for investment in startups

Investment in
20 startups
with disruptive technologies

OPEN INNOVATION
Our door is open to innovation in the Energy Sector

9 new
patents
families
registered in 2021

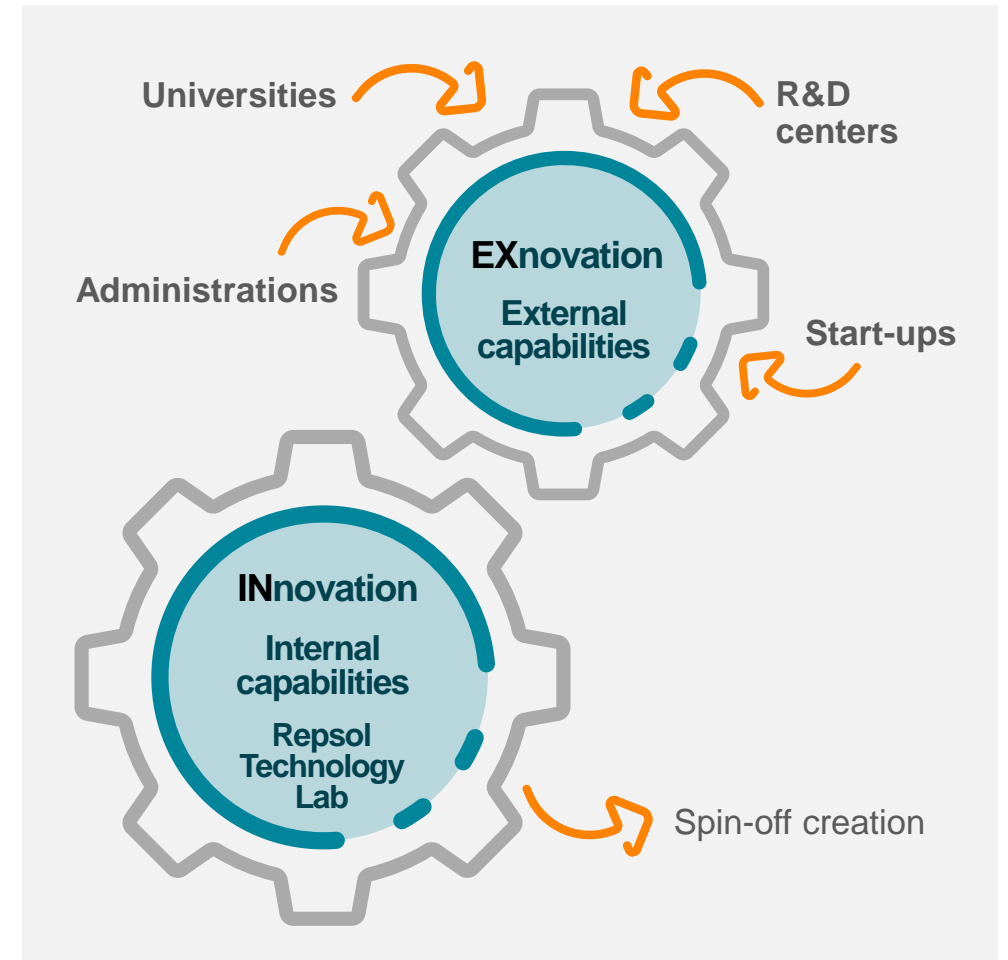
We are focused on working
70 NEW
TECHNOLOGY PRODUCTS

We provide more than
180
technology solutions

+200 alliances
with partners around the world...

...to **transform the energy sector**

+20 Specialized laboratories
and **35** pilots plants

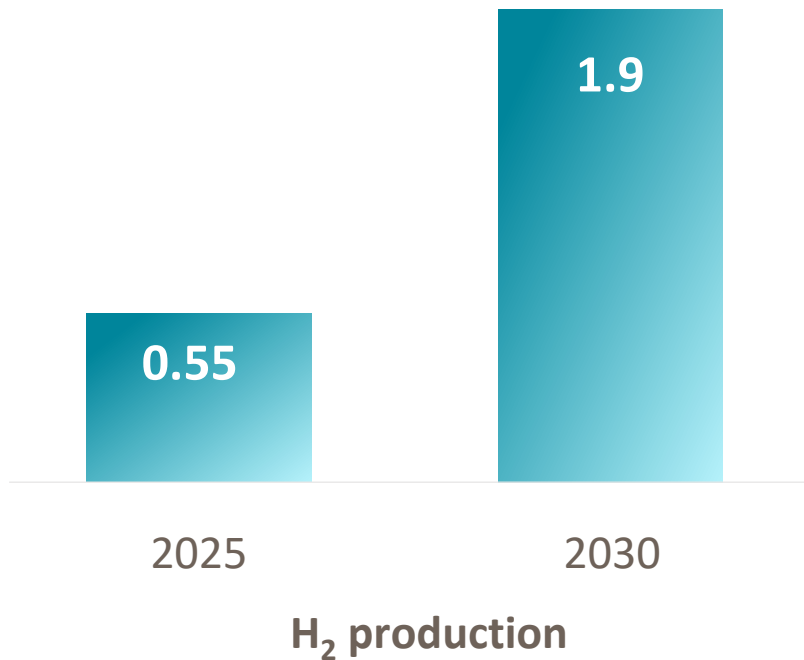


REPSOL

Hydrogen strategy



Renewable H₂ capacity, GW_{eq}



Combining different technologies

Power generation

- New electric generation and storage to feed electrolysers

HYDROGEN PRODUCTION

- New plants to produce biogas from waste
- New plants to produce renewable H₂ from water electrolysis.
- New technologies development: Joint Development Agreement with Enagás to develop photoelectrocatalysis for hydrogen production. From 2021, SUNRGYZE.

Final Uses

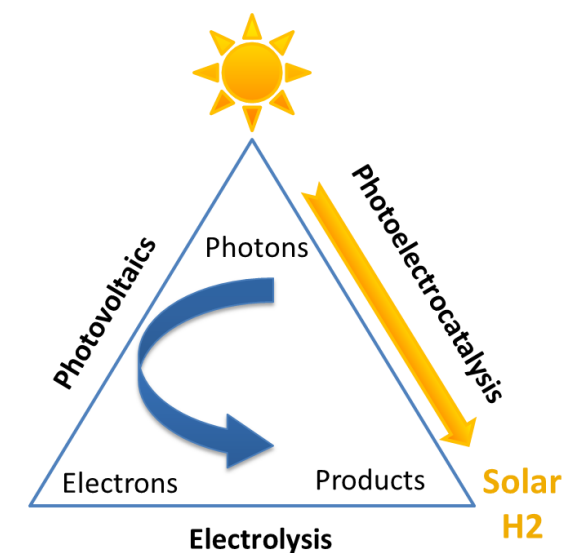
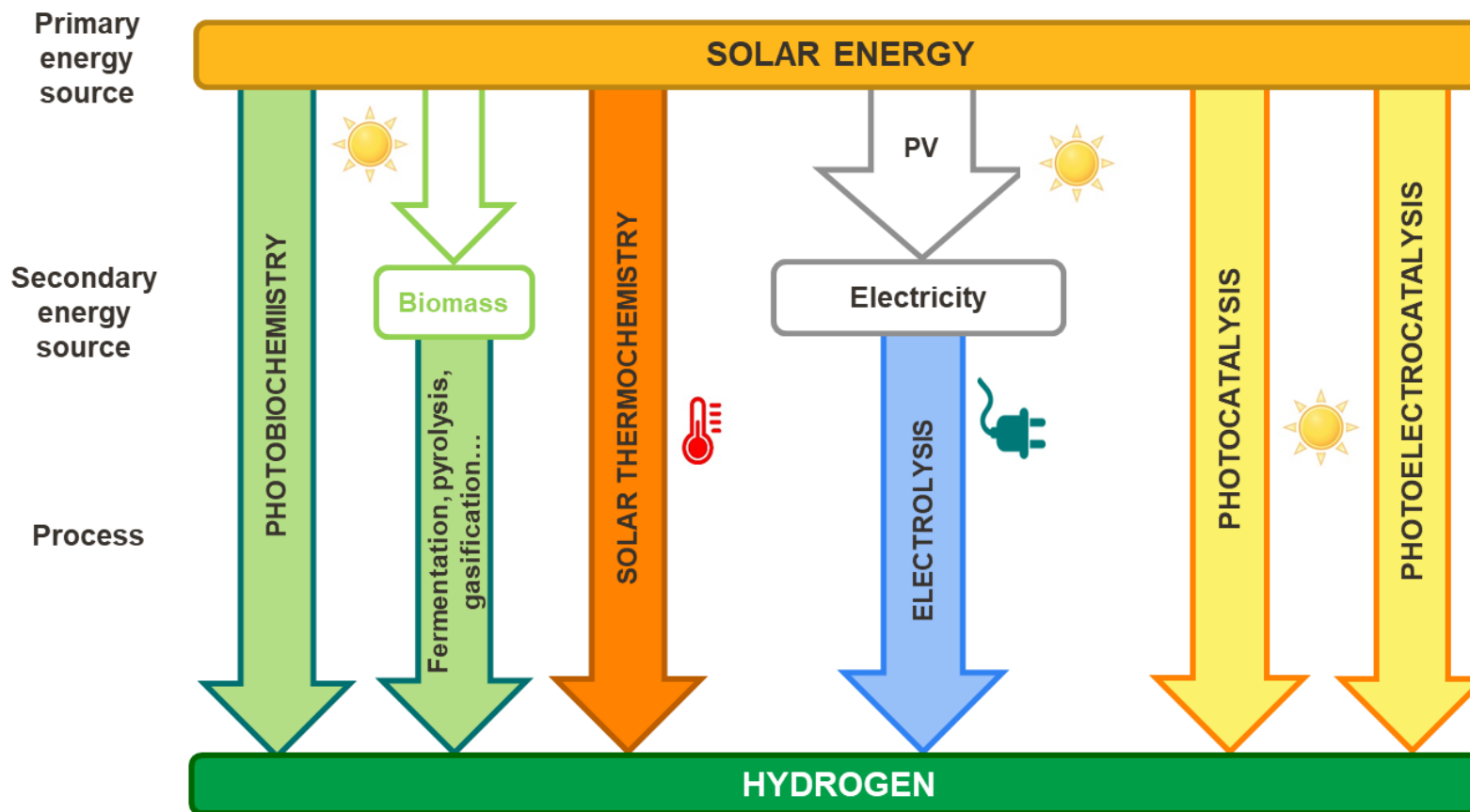
- Demo plant for e-fuels production (~8.000 l/day) announced in Bilbao together with Aramco

Repsol leads



Hydrogen production

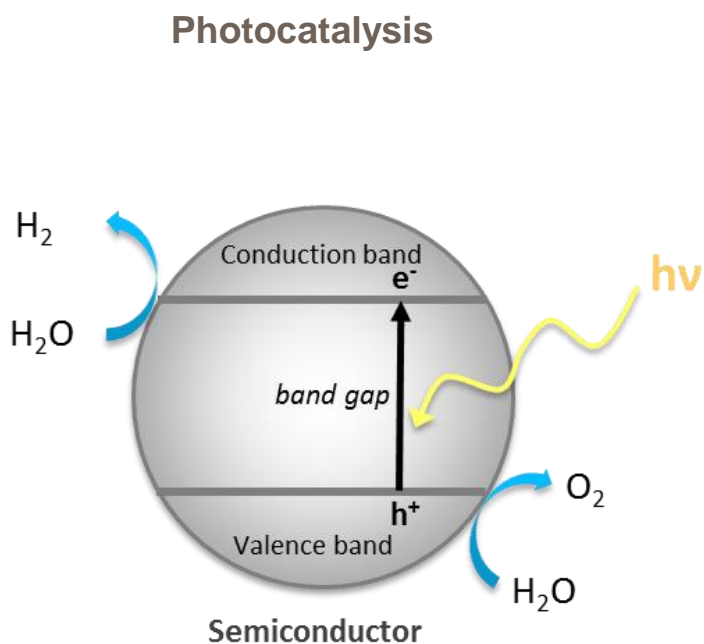
From solar energy



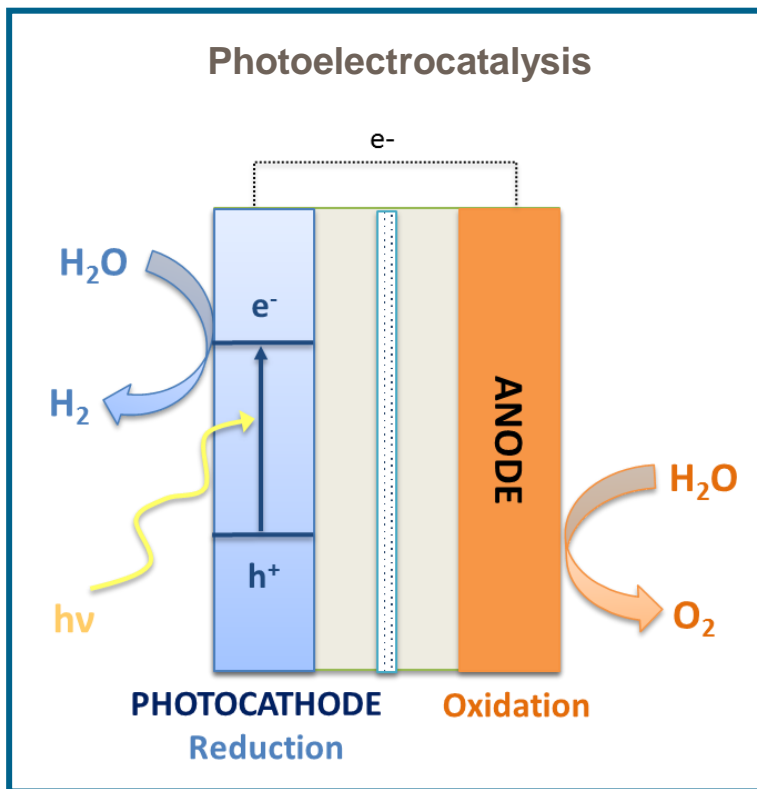
Hydrogen production

Water photoelectrocatalysis – from sunlight to hydrogen

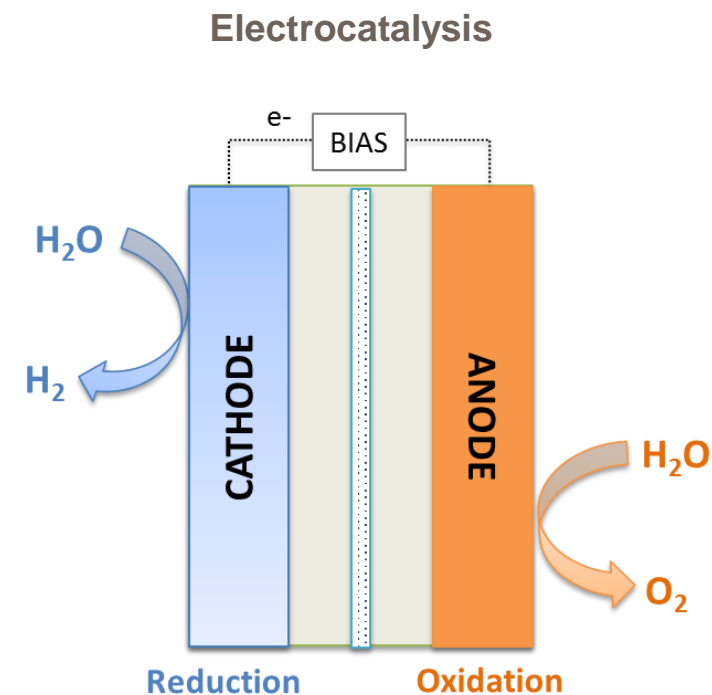
Based on the interaction between radiation and a semiconductor, the photoelectrocatalytic process consists on the direct conversion of solar energy into hydrogen in one-step and one-device.



Direct conversion of solar energy.
Current STH < 2%



Direct conversion of solar energy.
STH > 14%



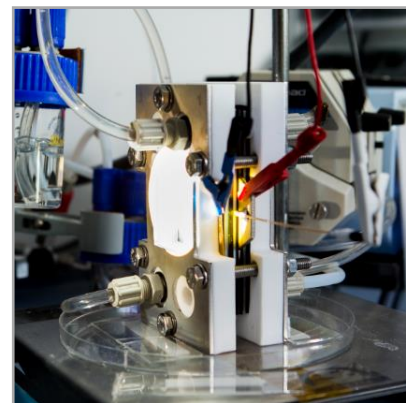
Two steps process.
Global STH efficiency = 8-12%.

Hydrogen production

Photoelectrocatalysis in REPSOL



- **Photoelectrochemical technology (PEC) development in Repsol from 2012:** with the direct action of solar radiation, in a single step and in a single device.
- **Repsol-Enagás Joint Development Agreement:** signed in 2018
- **Proprietary technology:** three families of patents, with 65 patent applications filed in 30 countries, 47 have already been granted.
- **Integrated process:** integration leads to higher efficiency and lower CAPEX compared to the two-stage process
- **Modular technology:** facilitating scaling and industrialization.
- **Use of abundant materials and low cost.** High potential to become a competitive process for the production of renewable hydrogen.
- **Pilot plant** operating at Repsol TechLab for more than 4000h.
- **Sunrgyze:** NewCo constituted in April 2021 with the aim of valuing technology, and accelerating development, industrialization and commercialization with the entry of new investors.



Hydrogen production

Photoelectrocatalysis in REPSOL



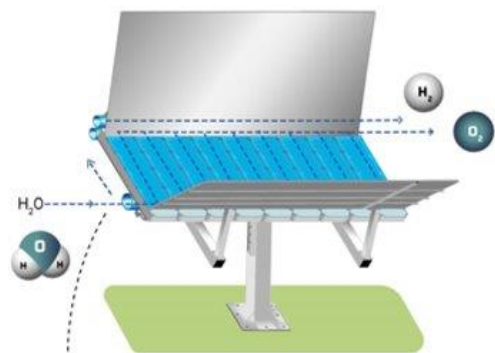


PILOT PLANT

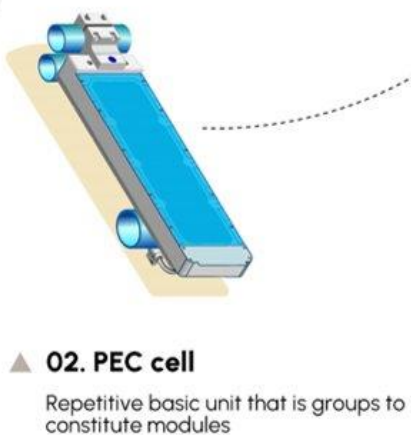
m² scale

2019 - 2021



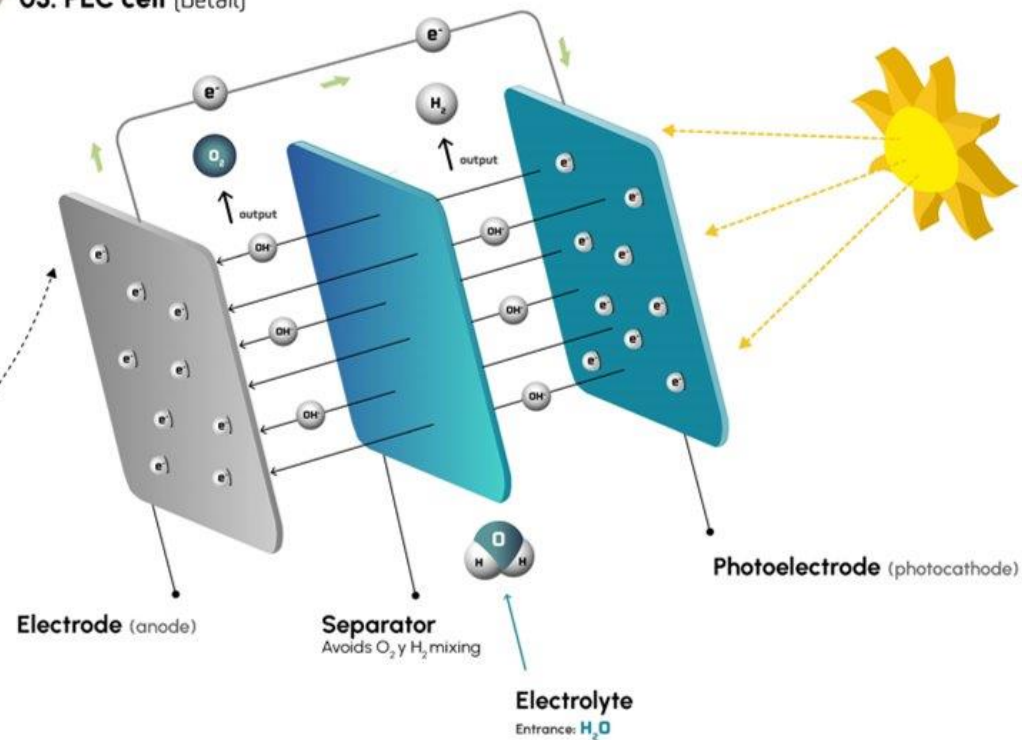


▲ **01. Module PEC**
with sun concentration



▲ **02. PEC cell**
Repetitive basic unit that is groups to constitute modules

▼ **03. PEC cell (Detail)**





IREC
Institut de Recerca en Energia de Catalunya
Catalonia Institute for Energy Research



magrana



Universitat d'Alacant
Universidad de Alicante



Ha
FUNDACIÓN PARA EL
DESARROLLO DE LAS NUEVAS
TECNOLOGÍAS DEL HIDRÓGENO
EN ARAGÓN



Hydrogen production

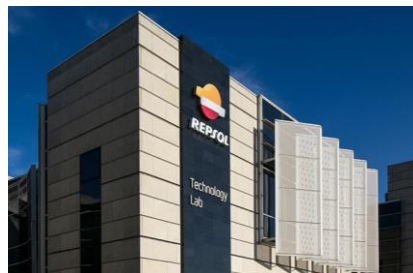
Photoelectrocatalysis in REPSOL



PILOT PLANT

m² scale

2019 - 2021



- Based at **Repsol Technology Lab**, located in Móstoles (Madrid).
- More than **4,000 operation hours**
- **STH > 14%**
- Experimental **validation of technology under real conditions.**
- Performance measured across **operational parameter ranges.**
- **Bias-free process** with possibility of continuous operation with connection to grid.

Hydrogen production

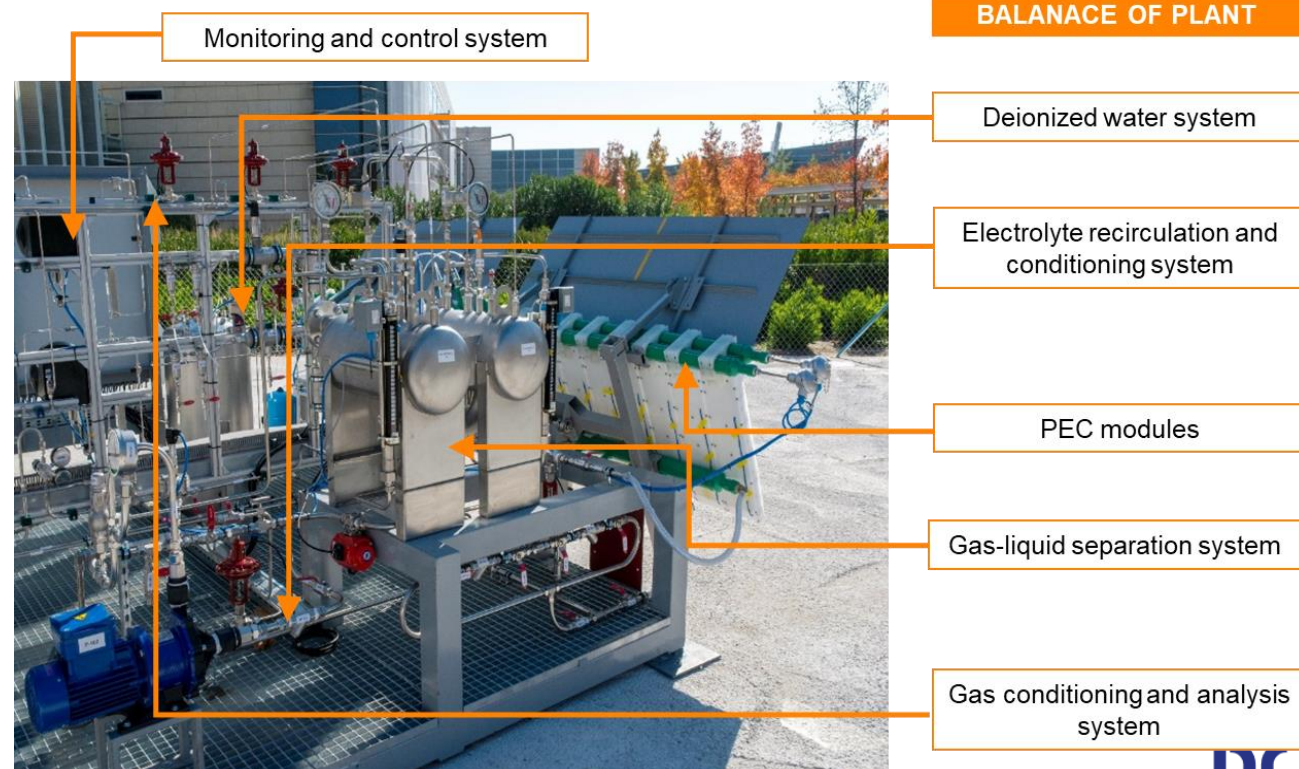
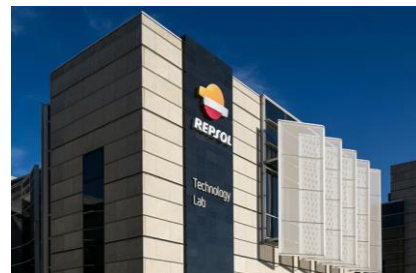
Photoelectrocatalysis in REPSOL



PILOT PLANT

m² scale


2019 - 2021



Hydrogen production

Photoelectrocatalysis in REPSOL



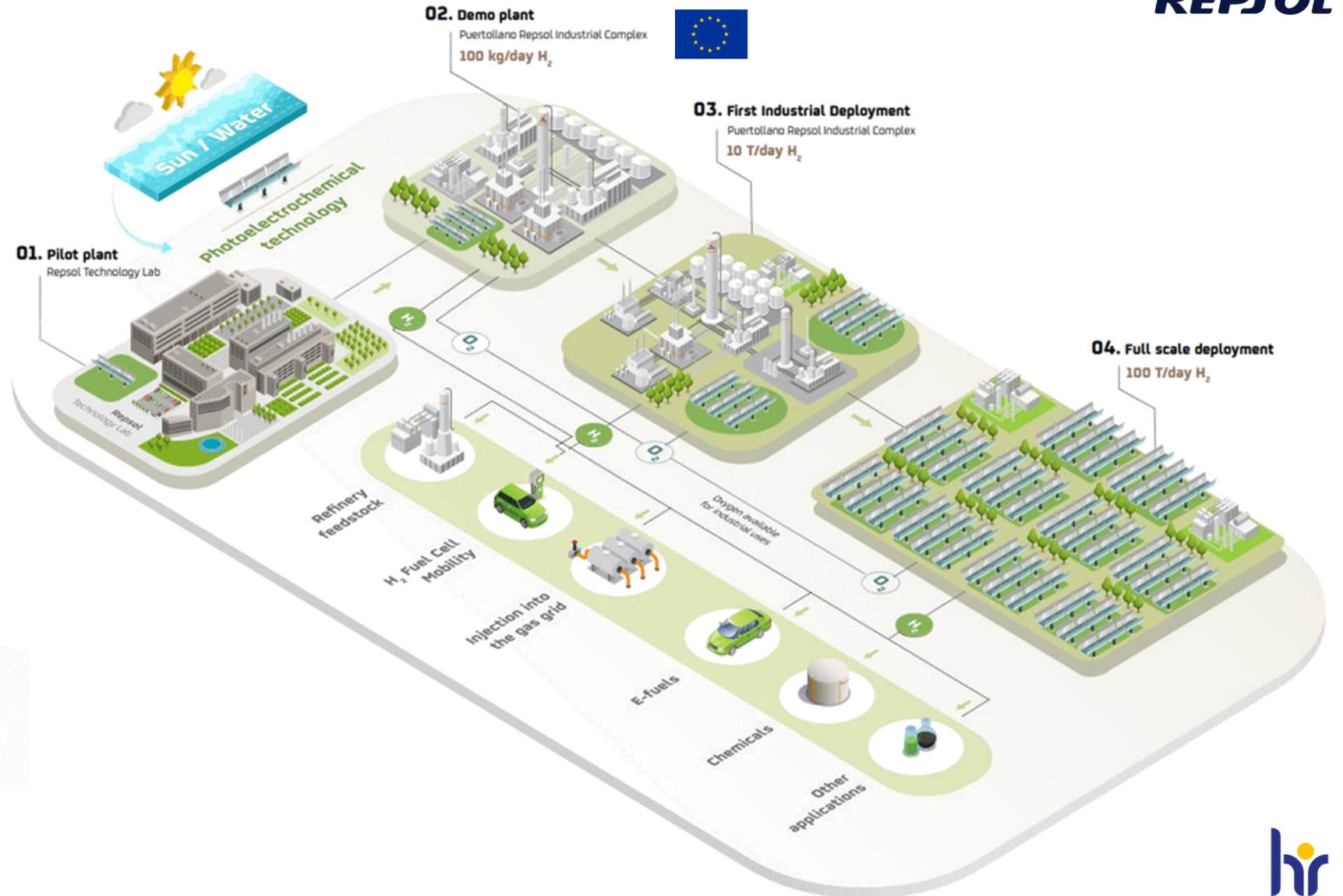


DEMO PLANT

Ha scale

2021 - 2025





Hydrogen production

Photoelectrocatalysis in REPSOL





DEMO PLANT

Ha scale

2021 - 2025





- Repsol's Industrial Complex at Puertollano is **one of the biggest industrial sites in Spain, with a hydrogen consumption of around 80,000 tonnes/year.**
- Puertollano Industrial Complex counts on the **needed land and utilities** and with a **solid experience** to contribute to the development, construction and operation of the Demo plant.
- Puertollano will enable the **demo plant connection to real applications.**
- Puertollano shows **highly favourable environmental conditions for solar applications, with an annual irradiance estimated at 1.83 MWh/m²** (69% direct radiation and 31% diffuse radiation).

Renewable hydrogen

Key messages



- Hydrogen is an energy vector that will play a key role in the decarbonization of the economy.
- Technology development is an essential lever to face this challenge.
- Renewable hydrogen can be produced from solar energy via different indirect and direct routes.
- Photoelectrocatalysis allows direct conversion of solar energy into chemical energy in an integrated process.
- Photoelectrocatalysis, under development, is expected to be a competitive alternative in the medium and long term.
- Repsol and Enagás development, initiated at Repsol Technology Lab and proved at pilot plant scale, continue with Sunrgyze, with a demo plant planned to be located in Puertollano I.C.



REPSOL

Technology Lab

from ideation to real business

#RepsolTechLab