

4-7 NOVEMBER 2024
ROTTERDAM, THE NETHERLANDS

 GET2024

HYDROGEN & ENERGY STORAGE

CONFERENCE

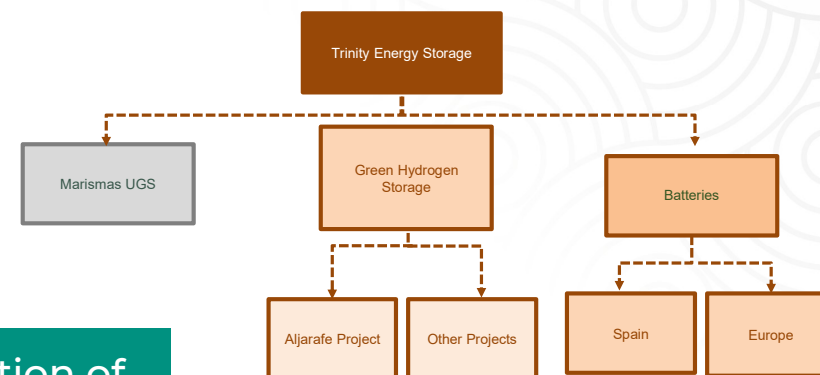
**UNDERGY: GREEN HYDROGEN STORAGE
IN A DEPLETED GAS FIELD IN SPAIN**

Trinity Energy Storage- Cristina Yuste

TRINITY ENERGY STORAGE (TES): INTRODUCTION



- Trinity Energy Storage is an energy company focused on renewable energy storage.
- Operation of regulated Marismas UGS, and several gas fields in the Aljarafe area.



The company began its activity in 2022, with the acquisition of Petroleum Oil & Gas España, S.A. (Naturgy Energy Group)

Strategic objectives:

- Natural Gas Storage: Increase Marismas UGS capacity maintaining good relationship with local community.
- Underground Hydrogen Storage: Develop Aljarafe Project
- Battery storage: Trinity is promoting several projects in Spain and Europe.



TRINITY ENERGY STORAGE: Aljarafe Project



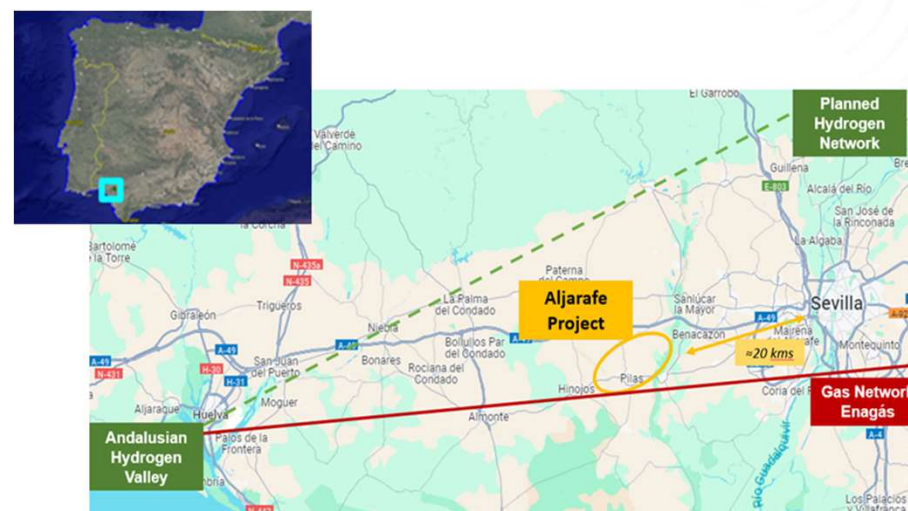
- Firm commitment to the energy transition: reach 2050 with a 100% renewable energy generation mix and net of zero emissions, partially established in the Spanish 2024 Integrated National Energy and Climate Plan (PNIEC).

	2030	2050
Emission Reduction vs 1990	32%	32%
Final Energy from Renewable Sources	48%	100%
Electricity from Renewable Sources	81%	100%

PNIEC: Spain's Integrated National Energy and Climate Plan, 2024

Main Company Objective:

- **Aljarafe project development:** Conversion of the depleted gas fields located in the Aljarafe area (San Juan, Palancares and La Cerca), into UHS.
- Energy Storage Capacity: 550 GWh equivalent to 14,000 tons H₂.
- Strategically located.



UNDERGOING TRINITY RESEARCH PROJECTS

Projects at National Level

2021-2024

UNDERGY (UNDERground enerGY)

Technologies for the Development of Seasonal Renewable Energy Storage using Green Hydrogen integrated in an efficient energy system

2022-2025

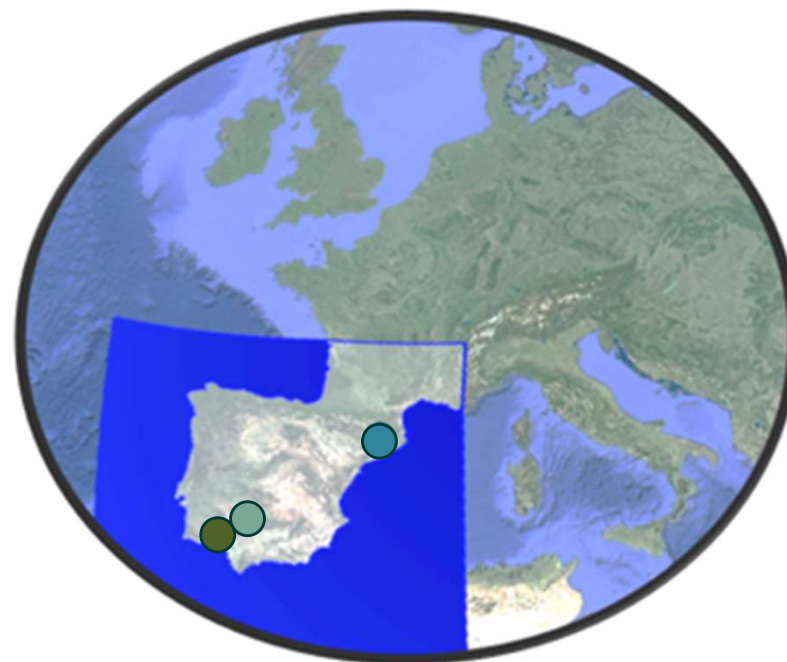
UES365: Underground Energy Storage 365 days/year

Investigation of systems of seasonal underground energy storage from renewable energy sources using I-CAES, BIO-CAES and green hydrogen as vectors to balance and maintain the Spanish electricity system.

2024-2027

PureH2: H2 Purification from Salt Caverns

Development a H2 purification solution, based on different membranes, at the exit of future H2 storage in salt caverns.



Plan de Recuperación, Transformación y Resiliencia



UNDERGOING TRINITY RESEARCH PROJECTS

European Level: EUH2STARS

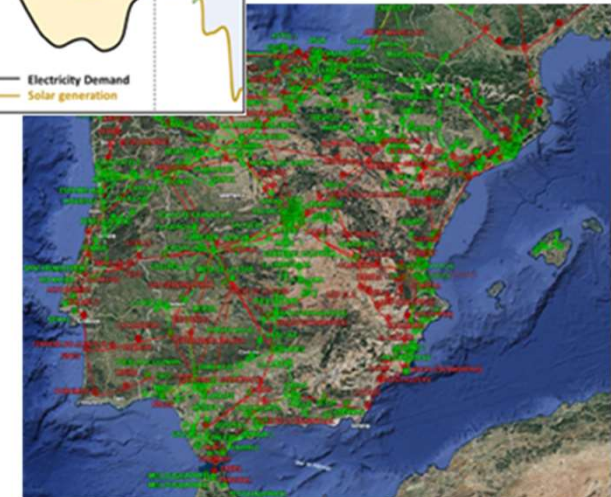
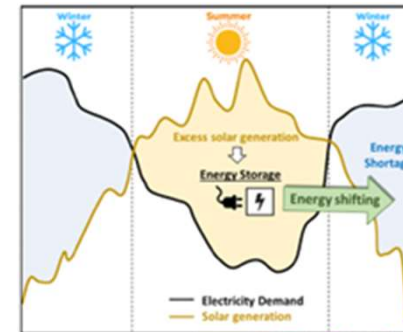
- Supported by the Clean Hydrogen Partnership with a funding of ~ 20 million euros , for the large-scale demonstration of underground hydrogen storage.
- January 2024 to September 2029.
- Consortium made up of twelve partners from five countries.
- Investigation of storage of H₂ in porous reservoirs up to a TRL of 8 (Certified System), by performing four complete injection-extraction cycles of pure hydrogen in the "demonstrator" storage Rubensdorf (Austria), operated by the consortium leader (RAG).
- The information obtained in the demonstrator will feed the rest of the project's:
 - Netherlands (Shell, deep deposit case)
 - Hungary (HGS, intermediate depths) and
 - Spain (Trinity, shallow sites). Aljarafe Project.



UNDERGY: UNDERground energy

- The project (<https://undergy.eu/>) reflects the need for a large-scale storage system to manage electricity curtailment and provide security of energy supply. It assess the viability of underground green hydrogen storage in Spain, including an estimation of the potential volume, and including the construction of an efficient energy management system model.
- Consortium of five companies with expertise in all hydrogen value chain, led by Gas Natural Comercializadora (Naturgy Group) and six research centres.
- 3,5 M€ fund of the Centre for Industrial and Technological Development (CDTI) with Next Generation EU Funds.

UNDERGY ^{H₂}



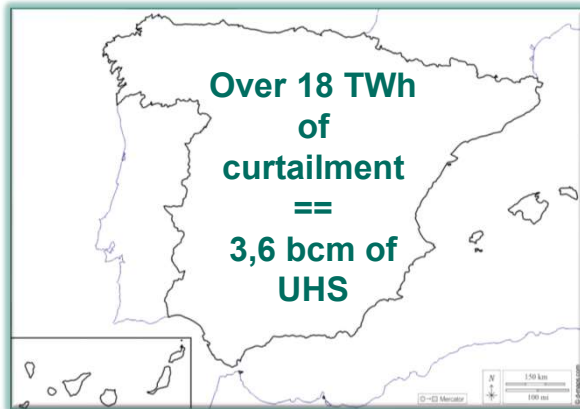
PROJECT INDICATORS

Proof of compliance



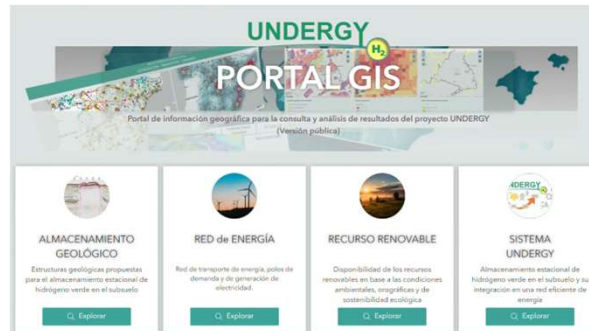
KPI 1: HARNESS CURTAILMENT

Identify UHS capacity in Spain to harness up to 70% of curtailment estimated by 2030.



KPI 2: GIS, BASIS OF EFFICIENT MANAGEMENT SYSTEM

Elements to include in the Geographic Information System tool.



KPI 3: OPTIMIZATION OF COST OF STORAGE

Reduction over reported Bloomberg reference.

Target: LCOS = 1\$/Kg of H₂

	Gaseous state			
	Salt caverns	Depleted gas fields	Rock caverns	Pressurized containers
Main usage (volume and cycling)	Large volumes, months-weeks	Large volumes, seasonal	Medium volumes, months-weeks	Small volumes, daily
Benchmark LCOS (\$/kg) ¹	\$0.23	\$1.90	\$0.71	\$0.19
Possible future LCOS ¹	\$0.11	\$1.07	\$0.23	\$0.17
Geographical availability	Limited	Limited	Limited	Not limited

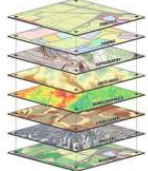
Source: Bloomberg NEF. Benchmark levelized cost of storage (LCOS) at the highest reasonable cycling rate.



UNDERGY: Divided in six Activities

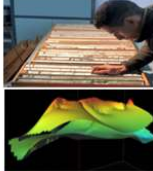


Activity 1 (WP1)
SPAIN'S UNDERGROUND STORAGE CAPACITY FOR GREEN H2



- ❑ Evaluation of the underground storage capacity of Spain for Green Hydrogen.
- ❑ Mapping and distribution analysis based on a Geographic Information System (GIS).


Activity 2 (WP2)
HYDROGEN STORAGE FEASIBILITY ASSESSMENT OF A GAS FIELD



- ❑ Geological characterization of a depleted gas field.
- ❑ Mineral reactivity, chemical reactions and in situ methanation.
- ❑ Static and dynamic models.
- ❑ Existing gas wells VS New H2 wells.




Activity 3 (WP3)
ELECTROLYSIS



- ❑ Modular design for the production of green Hydrogen.
- ❑ Renewable energy and available water utilization

Activity 4 (WP4)
SURFACE FACILITIES RESEARCH




- ❑ Reuse of existing surface facilities and equipment.
- ❑ Management of gases and effluents.
- ❑ New installations and engineering.



TECNICAS REUNIDAS




Activity 5 (WP5)
RISK ANALYSIS / CO2



- ❑ Environmental impact aspects.
- ❑ CO2 supply.

Activity 6 (WP6)
INTEGRATED EFFICIENT ENERGY MANAGEMENT SYSTEM



- ❑ Analysis of energy generation, transmission and demand scenarios for 2030 and 2050. SIG database.
- ❑ Renewable generation, surpluses and reduction of emissions.
- ❑ Needs, potential and integration of seasonal storage.
- ❑ Efficient management of the energy market.

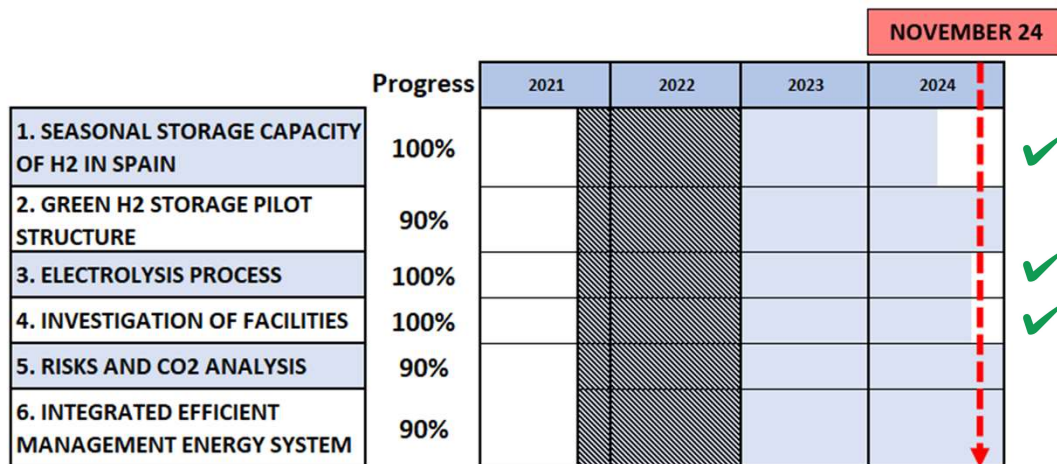


UNDERGY: Project Schedule



Started in October 2021,

Closed to termination, planned in December 2024:



Trinity is mainly focused on

- Activity 1 related with the estimation of the total UHS volume capacity of Spain
- Activity 2, which assesses the conversion of Palancares depleted gas field at laboratory scale, as UHS.

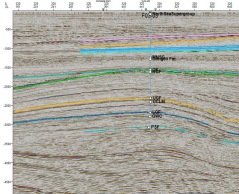
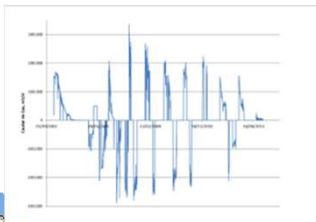
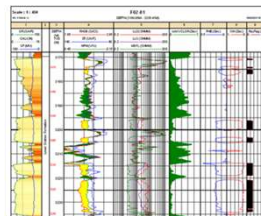
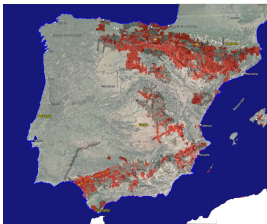
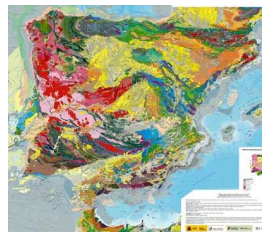


ACTIVITY 1: Estimation of Green H2 seasonal storage capacity



Geology
Seismic Coverage

- Well Data
- Production Data
- Existing Facilities



FINAL OBJECTIVE:

Estimation of Potential Underground Hydrogen Storage capacity in Spain



Depleted Gas Fields



Porous Reservoirs



Salt Caverns



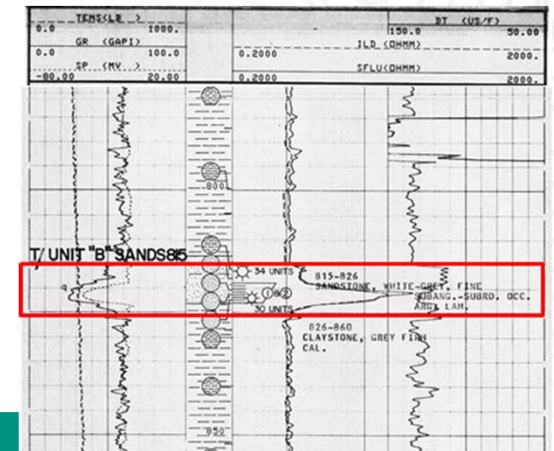
ACTIVITY 2: Assessment of Palancares as UHS



Main Objective:

Validate conversion of Palancares depleted gas field, as Underground Hydrogen Storage at laboratory scale.

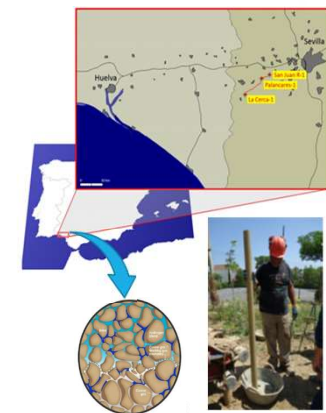
- Fluids and rocks reactivity (reservoir and seal) at reservoir P and T.
- Investigate bacteria activity
- Construction of reservoir simulation models
- Operational scenarios and possible upscaling for analogous deposits.



PALANCARES AS UHS IN FIGURES (*)

Total NET Production, NMm ³	TOTAL Hydrogen Storage Capacity, NMm ³ /ton H ₂	Operating H2 Storage Capacity, NMm ³ /ton H ₂	Max. Extraction /Injection Rate, m ³ /d
125,5	130 /10.000	56,4 / 5.000	500,000 / 600,000

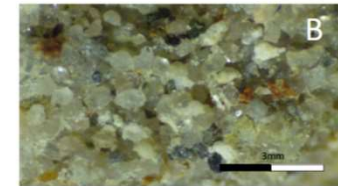
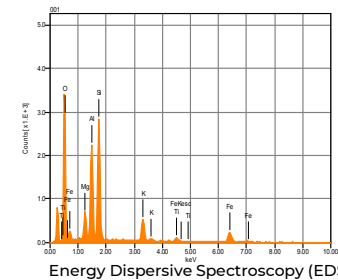
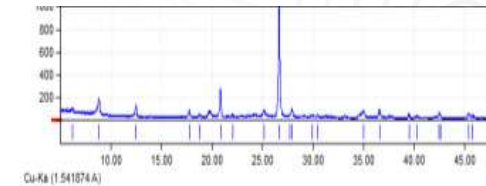
(*) Estimated Figures



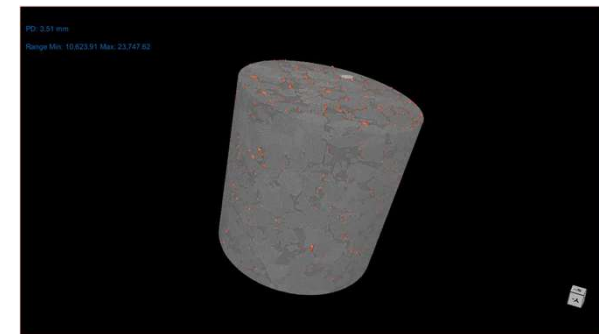
ACTIVITY 2: Assessment of Palancares as UHS

Geochemical reactions and microbiological activity

- **Geological characterization of 6 reservoir and 6 seal rock samples**
 - Non-destructive analytical techniques (Digital scanner and XRF, SM and IR sensors)
 - Destructive analysis (XRD, SEM)
- **2 years of multiapproach experiments (1 month exposure experiments)**
 - 3 reactors x 4 plates, over 500 analysis
- **Tested Atmospheres (80 Bar and 55° C)**
 - H₂ atmosphere
 - H₂ / CH₄ mixtures
 - N₂ and CH₄ control tests
- **Pre & post exposure analysis**
 - XRD, total geochemistry and SEM
 - BET surface area and porosity
 - Permeability and Leakage Pressure tests
 - Brine geochemical composition, pH and conductivity
 - Gas chromatography
- **Biological reactivity**
 - Incubation of brine samples
 - Tested atmospheres: H₂, H₂/CH₄, and H₂/CH₄/CO₂
 - Microbials growth condition study



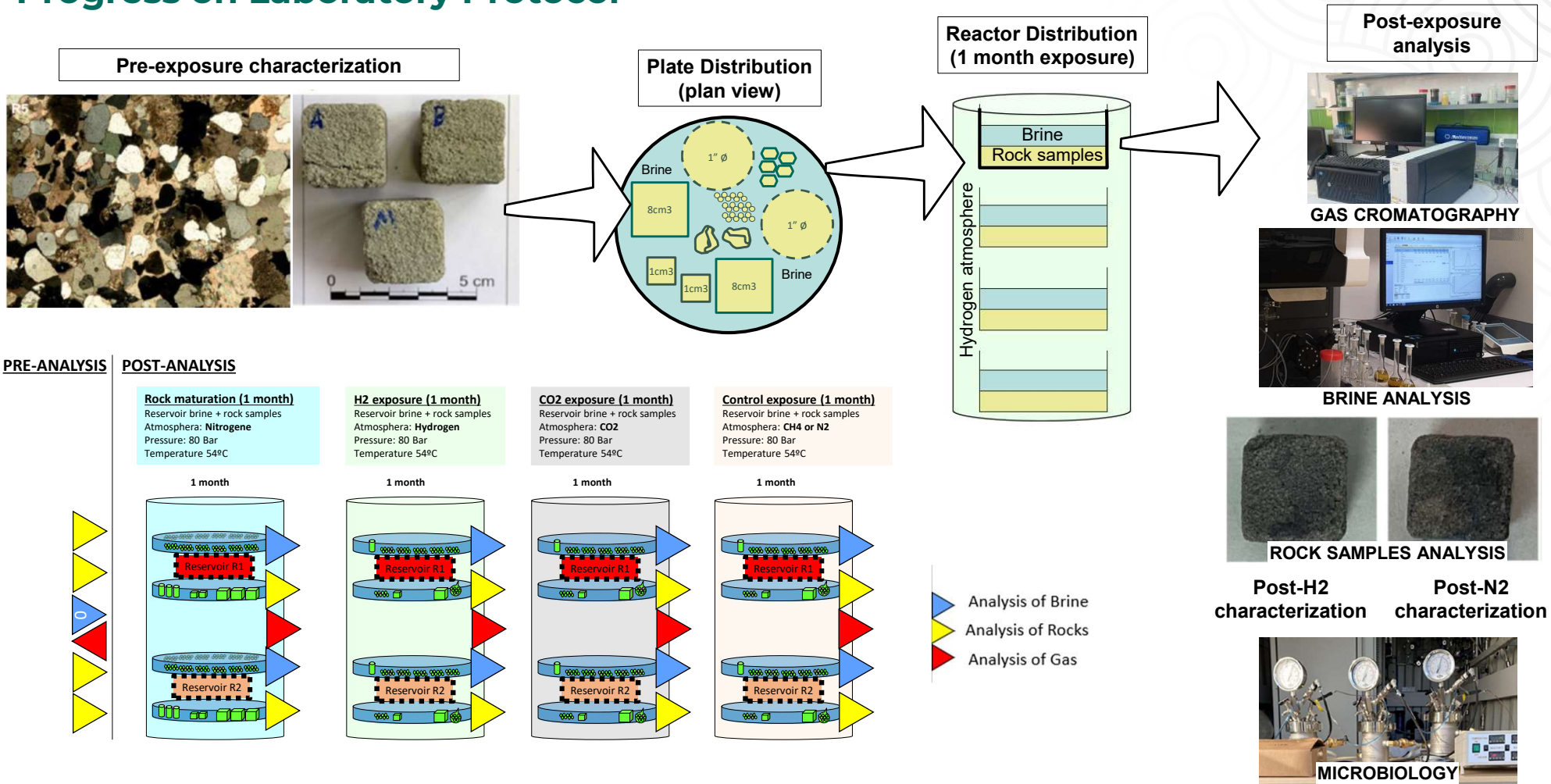
Transmitted Light Optical Microscope



XR Computed Microtomography

ACTIVITY 2: Assessment of Palancares as UHS

Progress on Laboratory Protocol



ACTIVITY 2: Assessment of Palancares as UHS

Preliminary Results from Laboratory Experiments



Extremely low intrinsic permeability verified the containment capacity of the existing seal rock

No evidence of reactivity that alters the sealing capacity and reservoir properties of the analyzed rocks.

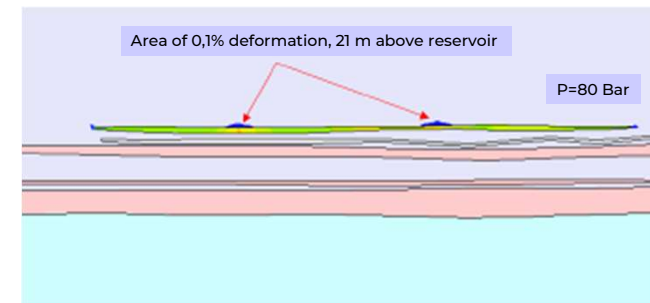
Microbiological processes continues under investigation

Geomechanical model indicates deformation extends to a maximum distance of 21 m above reservoir at operational pressure (80 Bar)

SCANNING ELECTRON MICROSCOPE EVALUATION (SEM-EDS)
pre-exposure (left) vs post-exposure (right) to H₂ for 1 month



Composición (SEM-EDS): Filossilicato (chamosita), foraminifero, cuarzo, carbonatos.

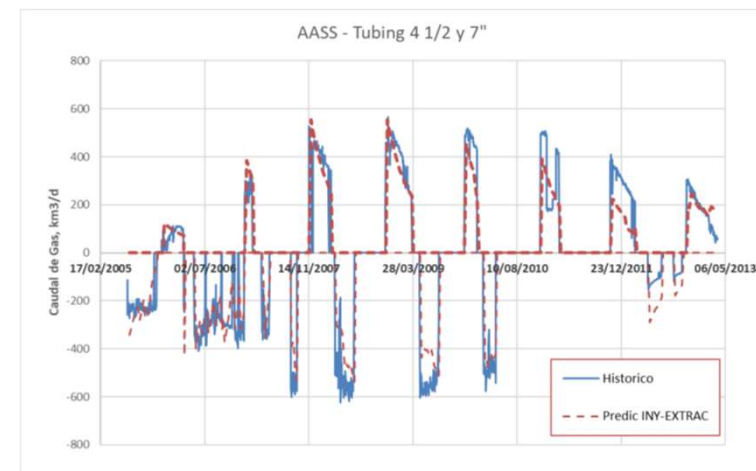
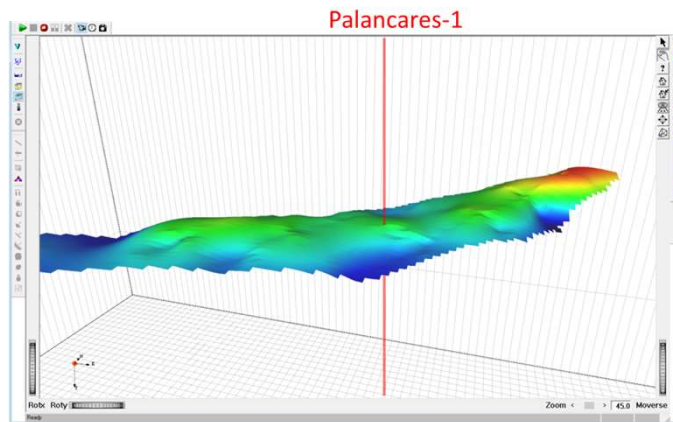


ACTIVITY 2: Assessment of Palancares as UHS



Static and dynamic reservoir model

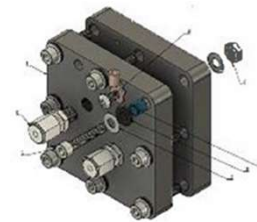
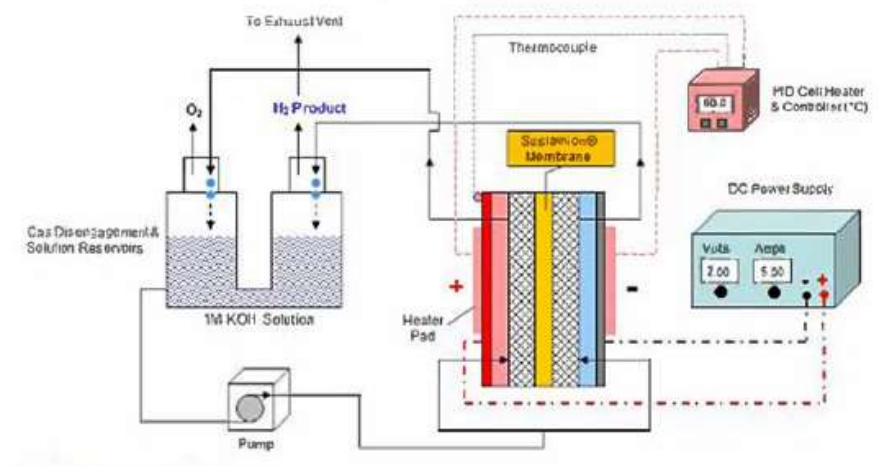
- 3D structural model (Kingdom Suite and Petrel)
- Static petrophysical model (Gocad)
- Geomechanical model by finite elements (Flac30)
- 4D-History Match dynamic reservoir model (Petex for CH₄ and in progress on t-Navigator for H₂)
- Comprehensive 4D model with optimal operating scenarios (Tough)



ACTIVITY 3: Electrolysis Process



- Analysis at laboratory scale of PEM, AEM and SOEC stacks operation for optimizing:
 - o Water treatment management for electrolyser rejection water reduction
 - o Configuration of the power system: direct connection of renewable generation source and the stack
 - o Mode of operation: frequent starts and stops
- Water resource analysis of the surroundings
- Conceptual design of a 20 MW plant with PEM electrolysis technology.



ACTIVITY 4: Assessment of Surface Facilities

- Validation of existing components of surface facilities at Palancares site in mixing scenarios up to 20% hydrogen and natural gas.
- Laboratory tests to better understand behaviour of existing materials at two points considered representative to assess hydrogen embrittlement and the feasibility of being used in the presence of mixtures with up to 100%.
- Integration of hydrogen production plant (related to activity 3) and additional hydrogen separation plant using membranes within existing facilities.



Palancares Infrastructure Material



Carbon Membranes



High Pressure Equipment (95 Bar)

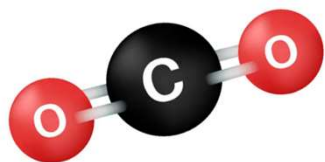
ACTIVITY 5: Risk Analysis and CO₂

UNDERGY ^{H₂}

ayterra
soluciones y proyectos SL



Basis for the design of the monitoring network to implement.



Identification and assessment of sources of CO₂, for potential in-situ metanization. Technical and economic feasibility analyses for capturing and transporting CO₂ from the emitting sources, and assessment of the environmental impact of this process.

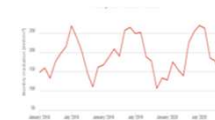


ACTIVITY 6: Integrated Efficient Energy Management System Model

UNDERGY 

Naturgy 

SPAIN: Monthly Solar Irradiation Estimates and PV Geographical Information



- Construction of the integrated energy model combining renewable generation, main consumption regions and seasonal storage of green H2 to fulfil the very high decarbonization objectives of Spain.
- Basis: Scenarios defined in the National Energy Plan that sets Spanish objectives for 2030 in terms of climate, in terms renewable potential, expected demand and different, and definition of storages sites.
- Construction of Geographic Information System compiling information from all activities of Undergy.



The screenshot shows the 'UNDERGY PORTAL GIS' website. At the top, it features the 'UNDERGY H2' logo and the text 'PORTAL GIS'. Below this, a subtitle reads 'Portal de información geográfica para la consulta y análisis de resultados del proyecto UNDERGY (Versión pública)'. The main content area is divided into four columns, each with a circular icon and a title: 1. 'ALMACENAMIENTO GEOLÓGICO' with an icon of a geological structure and the subtitle 'Estructuras geológicas proouestas'; 2. 'RED de ENERGÍA' with an icon of wind turbines and the subtitle 'Red de transporte de energía, polos de'; 3. 'RECURSO RENOVABLE' with an icon of a sunset and the subtitle 'Disponibilidad de los recursos'; 4. 'SISTEMA UNDERGY' with an icon of a storage tank and the subtitle 'Almacenamiento estacional de'.





Thank you very much

