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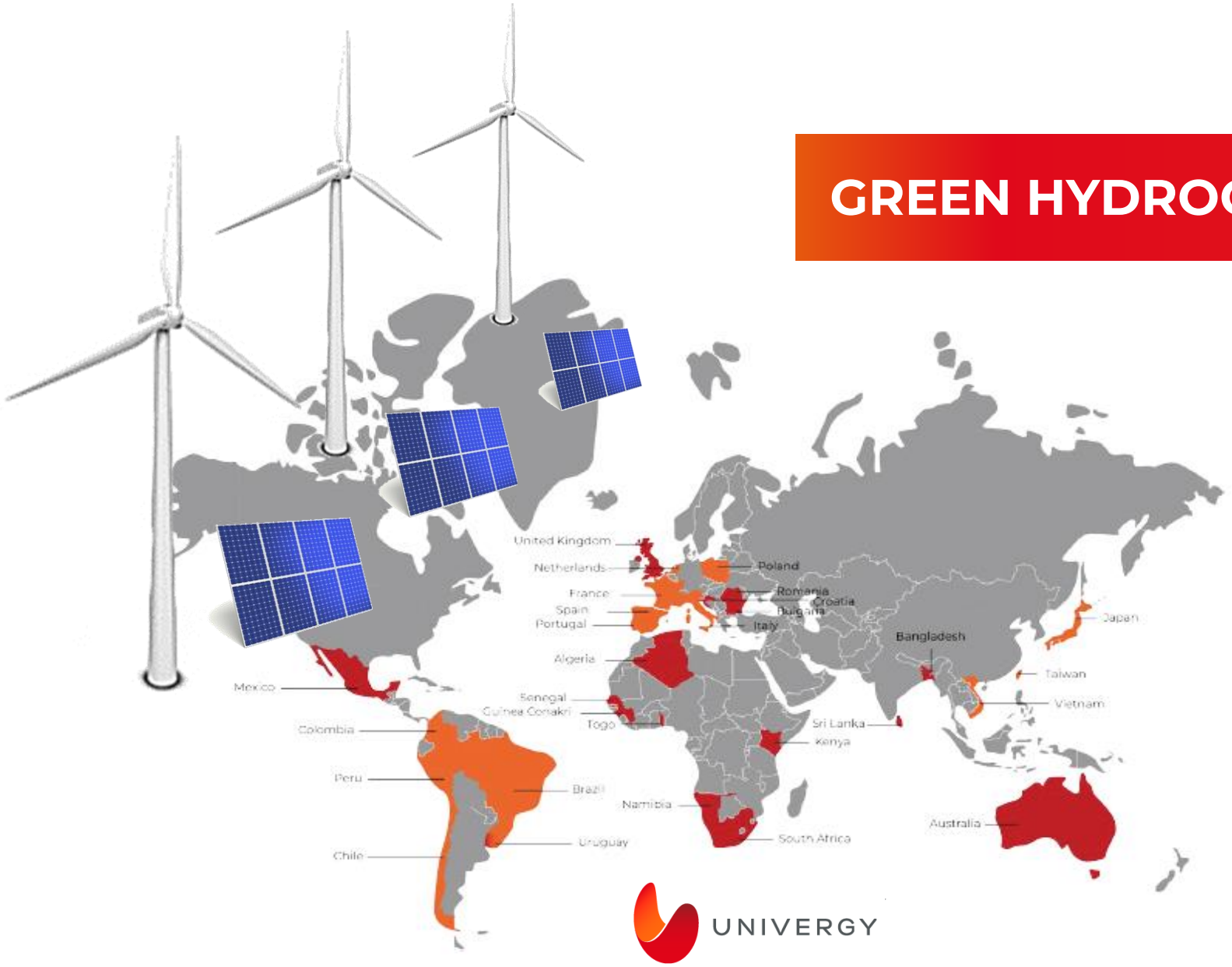

GREEN HYDROGEN & DECARBONIZATION

Present & Future

EA4EPQ

20th International Conference on Renewable Energies and Power Quality (ICREPQ'22)

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EXECUTIVE SUMMARY

PRESENT & FUTURE OF H2 IN ENERGY TRANSITION

- True **Magnitude of "Decarbonization Challenge"**:
  - More than 75% of current energy consumption comes directly from burning fossil fuels.
  - **3 on every 4 KW** currently consumed **should be replaced** with alternative sources.
- **Renewable energies are part of the solution** but:
  - There is no sun/wind every where and every time.
  - They have a quite relevant impact (environmental and space impacts).
  - We need to build up ways to Store and Transport a hugh amount of renewable energies.
- **Hydrogen** and related molecules (NH3, CH3OH, biokerosenes,…) **will play a relevant role in green energy store and distribution**.
- **Hydrogen production at scale is feasible and** will be **competitive in costs**. Hydrogen costs will not be a show stopper.
- **Hydrogen technology** due to its modularity **will cover both local or centralized production applications**.

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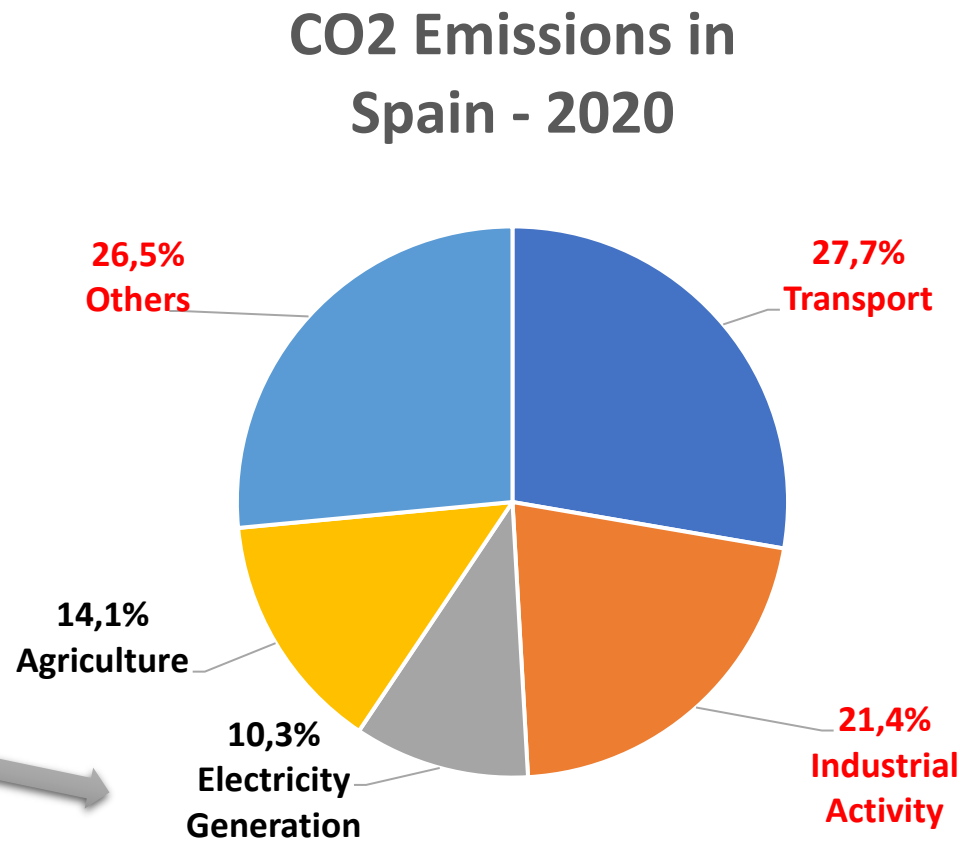
DECARBONIZATION CHALLENGE

TRUE MAGNITUDE OF THE PROBLEM

- We should implement **alternatives for Transport, Industry and Home applications**.
- R**eplacing Carbon or Natural Gas Power Stations** with Renewable sources **is not enough**.

Just 10,3 % of CO_2 emissions **comes from electricity generation.**



SOURCE: MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y RETO DEMOGRÁFICO.

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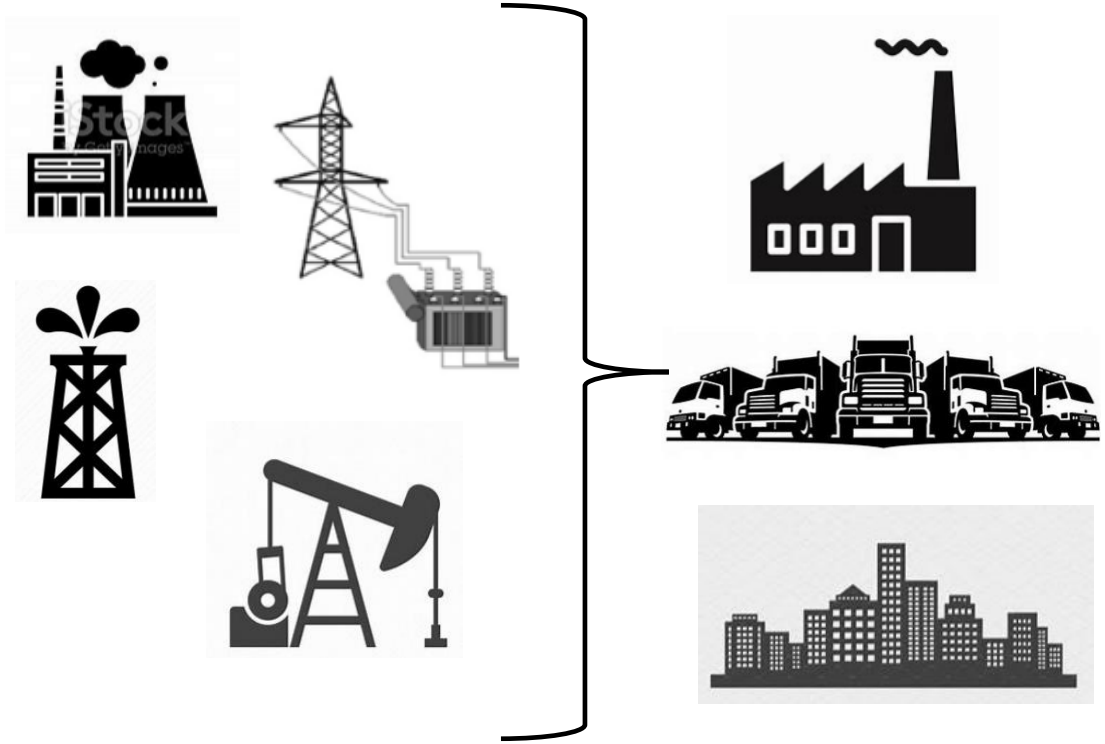
DECARBONIZATION CHALLENGE

ENERGY TRANSITION

1980



2050

FROM CARBON BASED

TO GREEN ALTERNATIVES BASED

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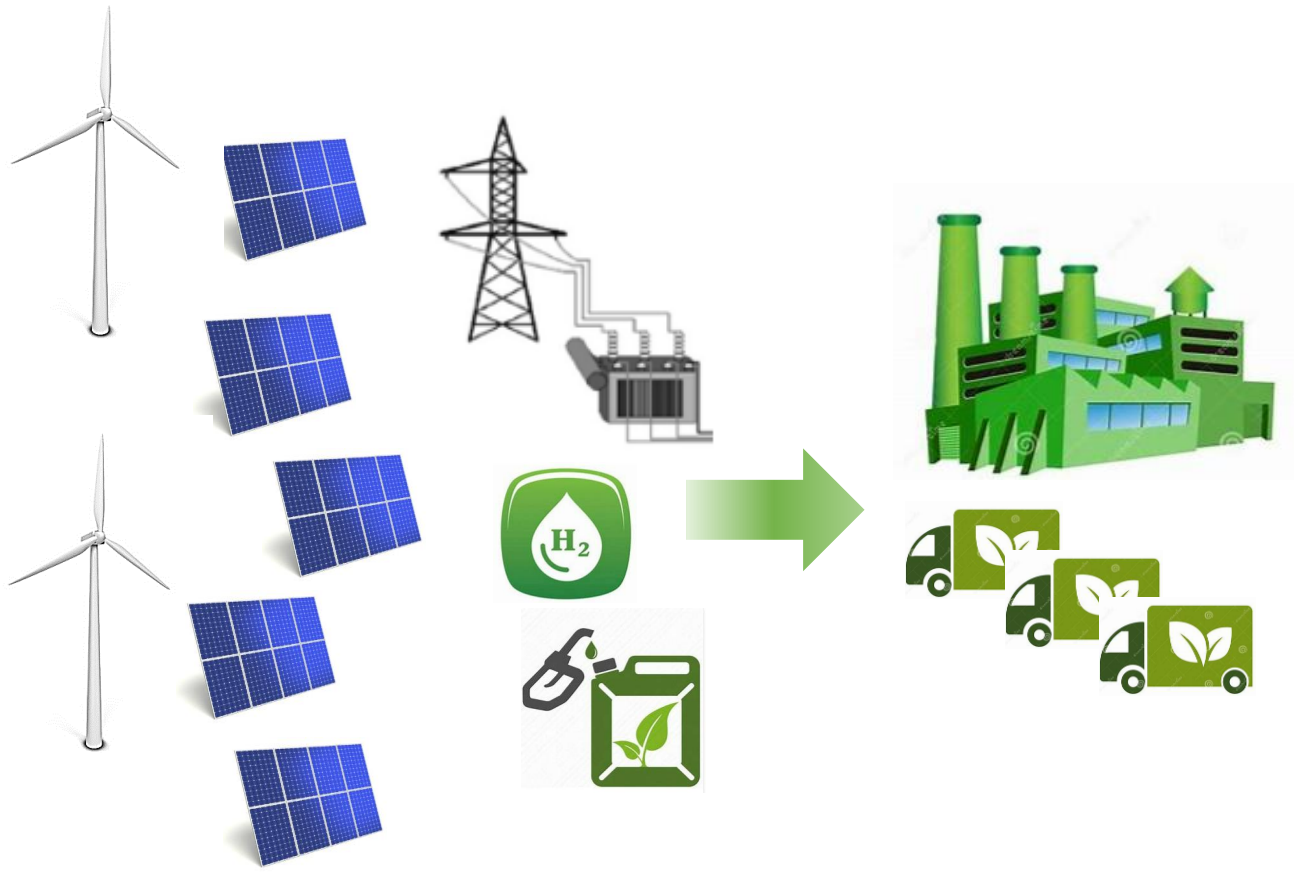
DECARBONIZATION CHALLENGE

WHAT CAN WE DO?



Decarbonization

1. Efficiency increase and consumption decrease
2. Electrification of Thermal industrial or Transport processes where possible
3. Use alternative fuels where electrification is not convenient/possible
4. Maximize distributed generation where convenient

EU targets modification proposal:

1. From 32% to 45% of RREE in electricity by 2030
2. From 2,5 % to 5,7 % of non biologic origin alternative renewable Fuels in Transport by 2030.

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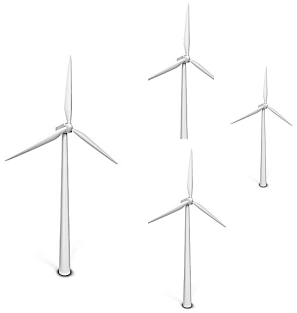
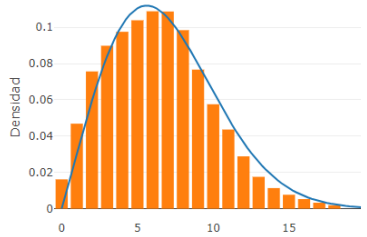
DECARBONIZATION CHALLENGE

RREE - ELECTRIFICATION CHALLENGES



Wind farms: 2.600 to 4.500 of eq hours (30 to 51 %) so we need 2 to 3 times more installed power than fossil power stations.

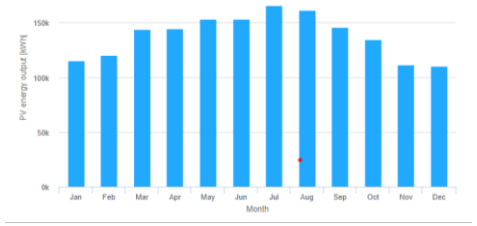
1 Mw occupies around 5.000 sqm.



Typical Wind speed distribution m/sec

PV farms: 1.200 to 2.500 of eq hours (14 to 28 %) so we need 3,5 to 7 times more installed power than fossil power stations.

1 Mw occupies around 10 to 15.000 sqm.



Typical PV monthly generation kwh

Electrical grid would need a reinforcement of 4 times current installed power.

Not all industrial processes are easy to electrify

Not all means of transportation are easy to electrify

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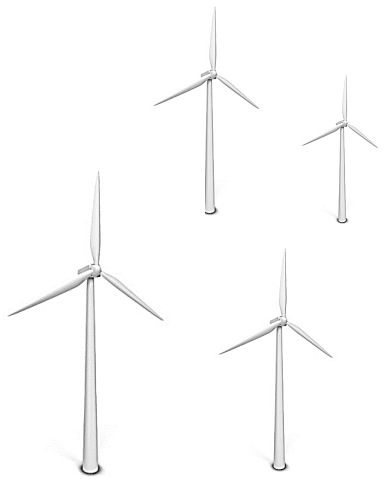
DECARBONIZATION CHALLENGE

RREE - ELECTRIFICATION CHALLENGES



SO WE NEED

WAYS TO STORE RENEWABLE ENERGY

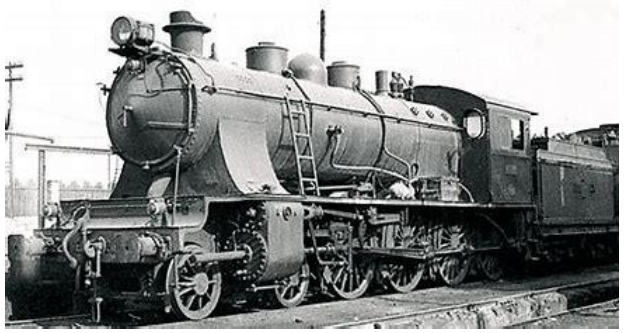
AND

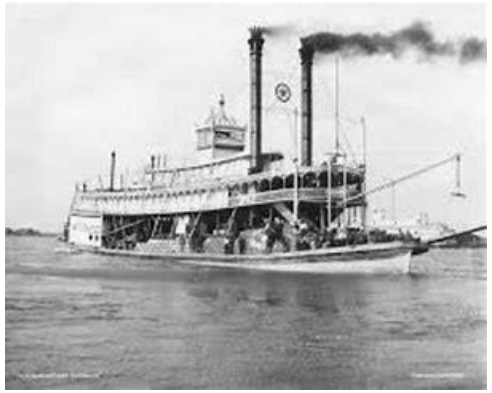
ALTERNATIVE FUELS - ZERO/NEUTRAL IN EMMISIONS

"....water will be the fuel of the future....." (1874)

"...Water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. ..."

(The Mysterious Island. Jules Verne 1875)





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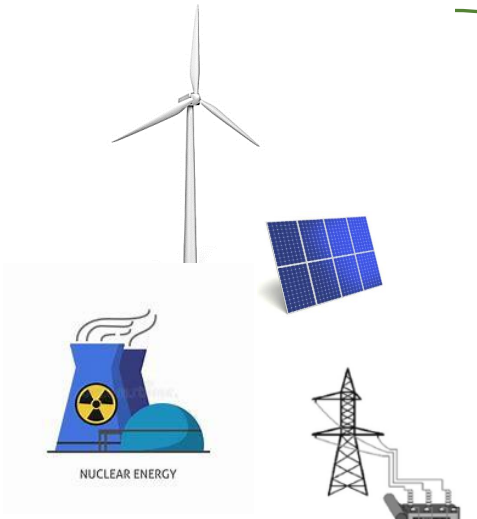
GREEN HYDROGEN PRESENT AND FUTURE

HYDROGEN AS ENERGY VECTOR



Electrolisys

Fuel Cell

Combustion Engine

Combustion Boiler

Hydrogen as energy vector can be:

- **Stored: (gas, liquid, as part of other molecules…)**
- **Distributed: pipe, compressed, ship tankers….**

HIGH LEVEL ENERGY-MASS BALANCE

(≈15 L)

(≈ 58 kwh)

PEM / ALKALINE ELECTROLISYS

1 kg H_2

(≈ 33,3 kwh)

7,9 kg O_2

State of the art today
(Efficiency ≈ 57%)

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GREEN HYDROGEN PRESENT AND FUTURE

HYDROGEN GENERATION FROM ELECTROLISYS

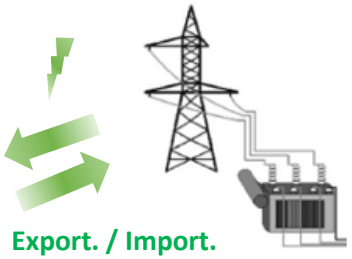
HYBRIDATION (RREE) + HYDROGEN

RREE – Hybrid system

H_2 Generation

Water Treatment Plant

Water
15 litre (max)
per kg of H_2



Export. / Import.
RREE - Grid

Excess of EERR Locally distributed

Export. Of O2

Export. of H2
By road

Export. Of H2
Blending or Hydroducts

Projects 4.0

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GREEN HYDROGEN PRESENT AND FUTURE

HYDROGEN STORAGE AND DISTRIBUTION

H2 Molecule

Compressed Gas

16, 60, 200, 350, 700, 1000 bar….

Liquid Hydrogen

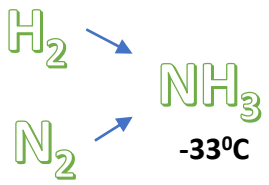
-253⁰C
1 bar

Liquid Organic Hydrogen Carriers
LOHC technology

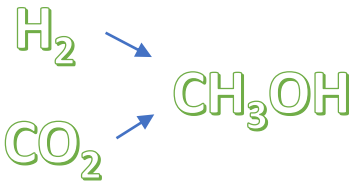
Ambient Pressure & Temperature

Other Molecules as vehicle

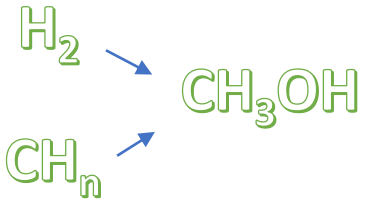
Green Ammonia



Green Methanol



Biokerosene



HIGH LEVEL COSTS BALANCE

(≈15 L)

(≈ 58 kwh)

PEM / ALKALINE ELECTROLISYS CAPEX

1 kg H_2

(≈ 33,3 kwh)

7,9 kg O_2

State of the art today

(Efficiency ≈ 57%)

GREEN HYDROGEN COSTS - FACTORS

LCOE

Plant Utilization Factor

CAPEX / OPEX

- Size
- Yield
- Self life

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GREEN HYDROGEN PRESENT AND FUTURE

HYDROGEN GENERATION COSTS - ELECTROLISYS

Remark: Just generation costs

Cost of renewable hydrogen with varying LCOE and load factors
USD/kg H_2

< USD 2/kg | USD 2-3/kg | USD 3-4/kg | > USD 4/kg | Viable medium-term (<2030)

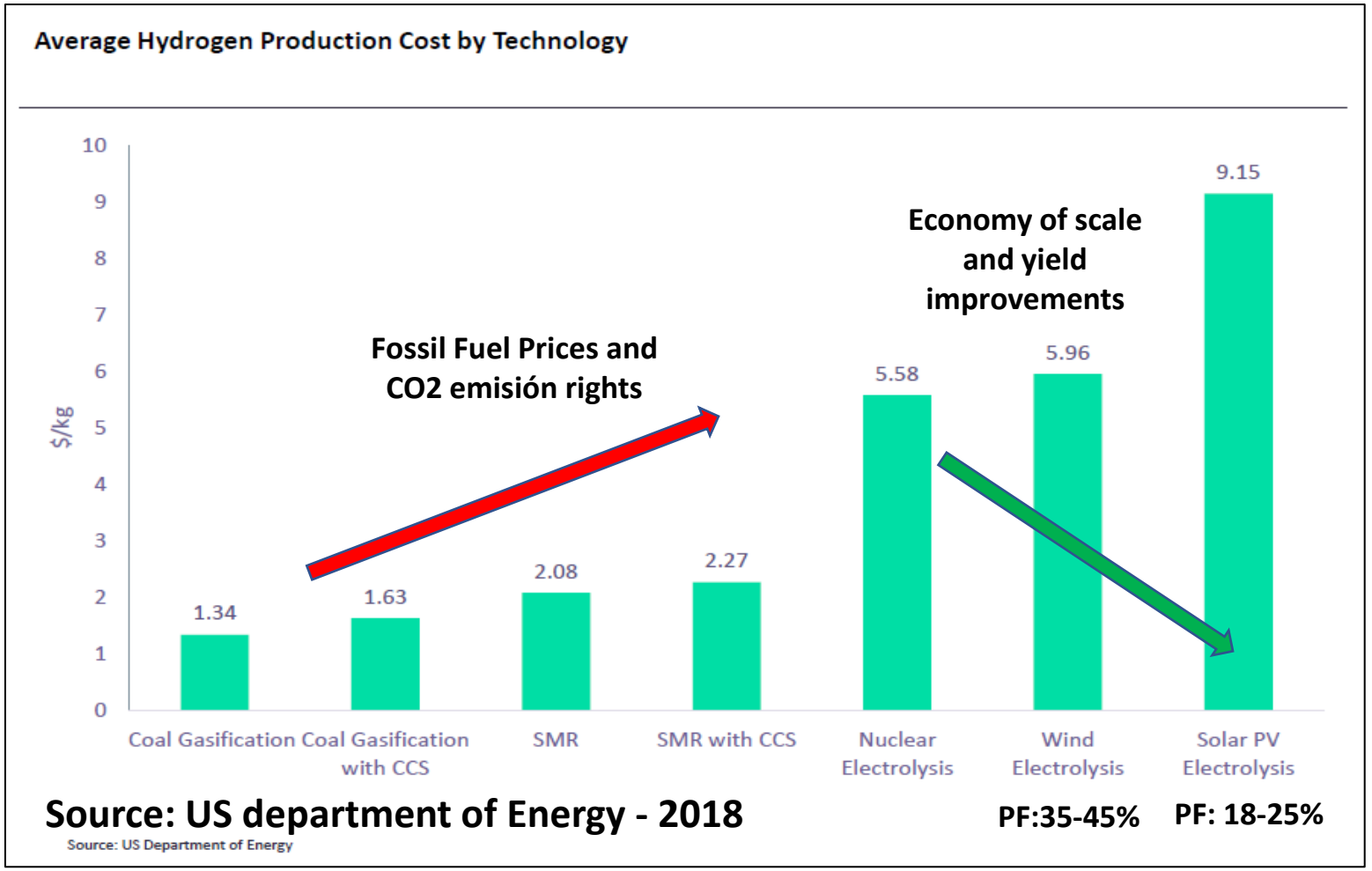
We are around here today

LCOE	Capex electrolyser	USD 750/kW				USD 500/kW					USD 250/kW				
UDD 0/MWh		5.7	2.8	1.9	1.4	1.1	4.2	2.1	1.4	1.1	0.9	2.8	1.4	0.9	0.7	0.6
USD 10/MWh		6.1	3.3	2.4	1.9	1.6	4.7	2.6	1.9	1.5	1.3	3.2	1.9	1.4	1.2	1.0
USD 20/MWh		6.6	3.8	2.8	2.4	2.1	5.2	3.0	2.3	2.0	1.8	3.7	2.3	1.9	1.6	1.5
USD 30/MWh		7.1	4.2	3.3	2.8	2.5	5.6	3.5	2.8	2.5	2.2	4.2	2.8	2.3	2.1	2.0
USD 40/MWh		7.5	4.7	3.8	3.3	3.0	6.1	4.0	3.3	2.9	2.7	4.6	3.2	2.8	2.6	2.4
USD 50/MWh		8.0	5.2	4.2	3.7	3.5	6.5	4.4	3.7	3.4	3.2	5.1	3.7	3.2	3.0	2.9
USD 100/MWh		10.3	7.5	6.5	6.1	5.8	8.9	6.7	6.0	5.7	5.5	7.4	6.0	5.6	5.3	5.2
Load factor		10%	20%	30%	40%	50%	10%	20%	30%	40%	50%	10%	20%	30%	40%	50%

We are around here today

Source: McKinsey

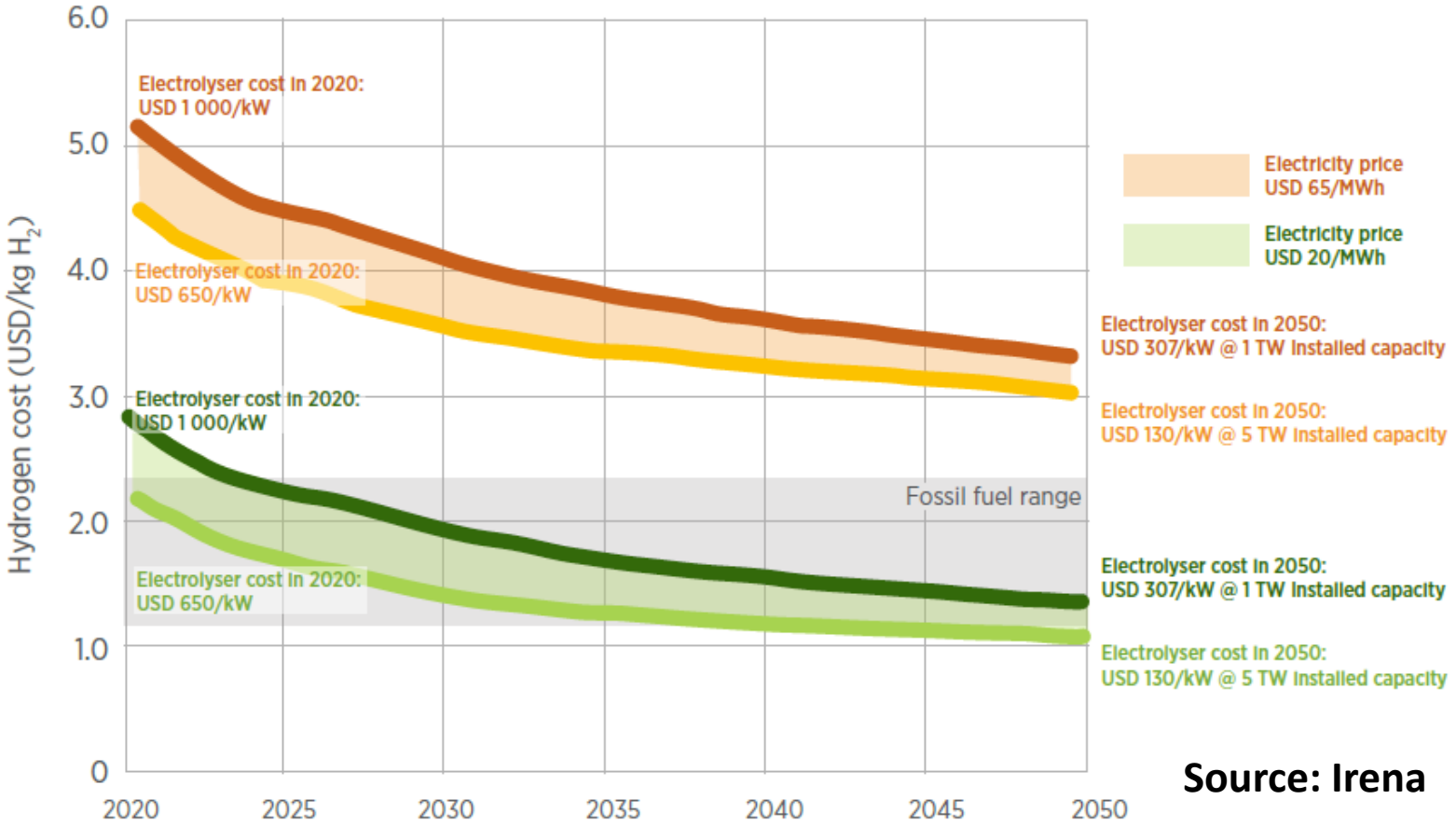
So……How much did it cost in 2018?



Source: US department of Energy - 2018

PF:35-45% **PF: 18-25%**

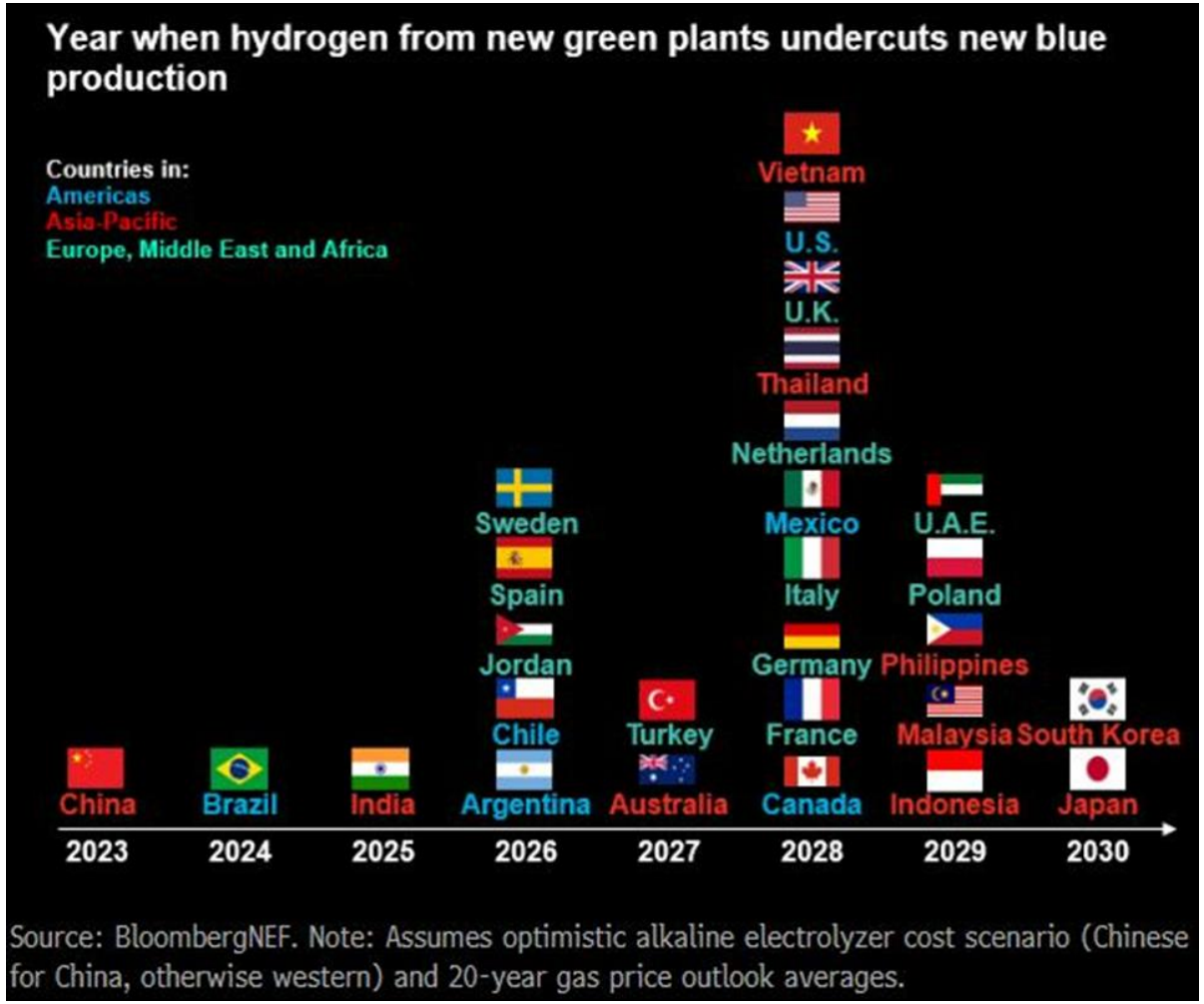
But.....How much will it cost in.....?

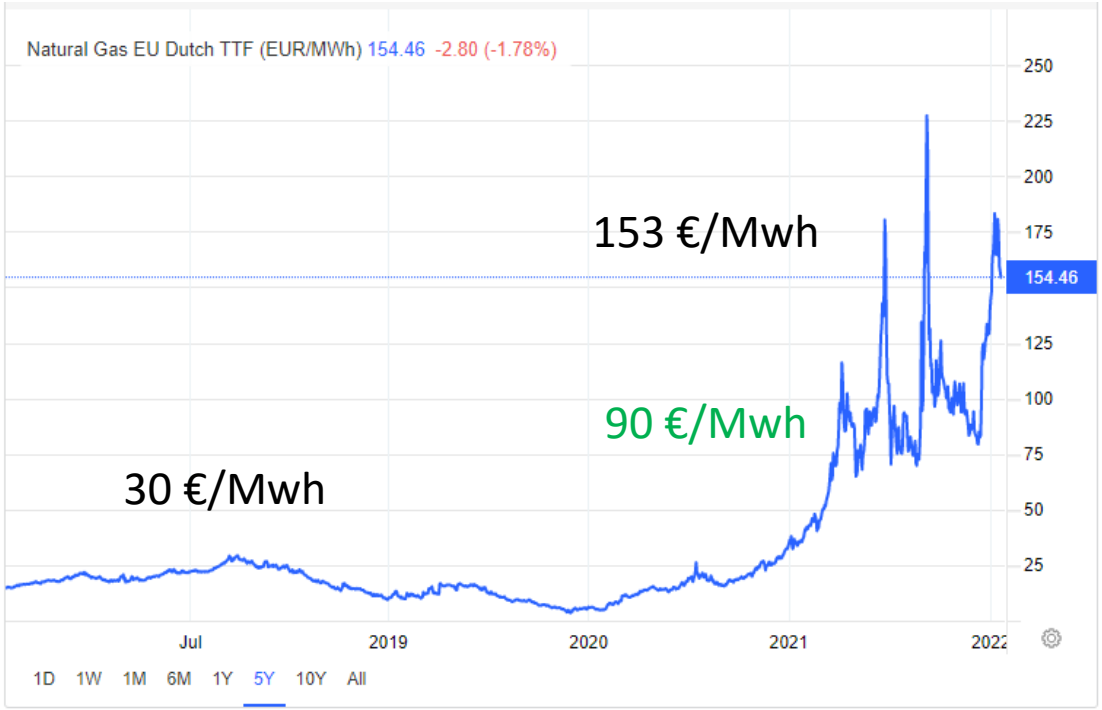


Source: Irena

	2030	2040	2050
Pesimistic	4,0 $/kg	3,5 $/kg	3,0 $/kg
Optimistic	2,0 $/kg	1,5 $/kg	1,0 $/kg
Pesimistic	120 $/Mwh	105 $/Mwh	90 $/Mwh
Optimistic	60 $/Mwh	45 $/Mwh	30 $/Mwh

When would it be competitive.....?





	2030	2040	2050
Pesimistic	120 $/Mwh	105 $/Mwh	90 $/Mwh
Optimistic	60 $/Mwh	45 $/Mwh	30 $/Mwh

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GREEN HYDROGEN PRESENT AND FUTURE

HYDROGEN GENERATION COSTS - ELECTROLISYS

Precio de Diesel (€/l)	1,00	1,25	1,50	1,75	2,00	2,50
Equivalent Price of Green Hydrogen for Fuel Cells (€/kg)	5,01	6,26	7,51	8,77	10,02	12,52

June-28-2022
12,85 €/kg of H2

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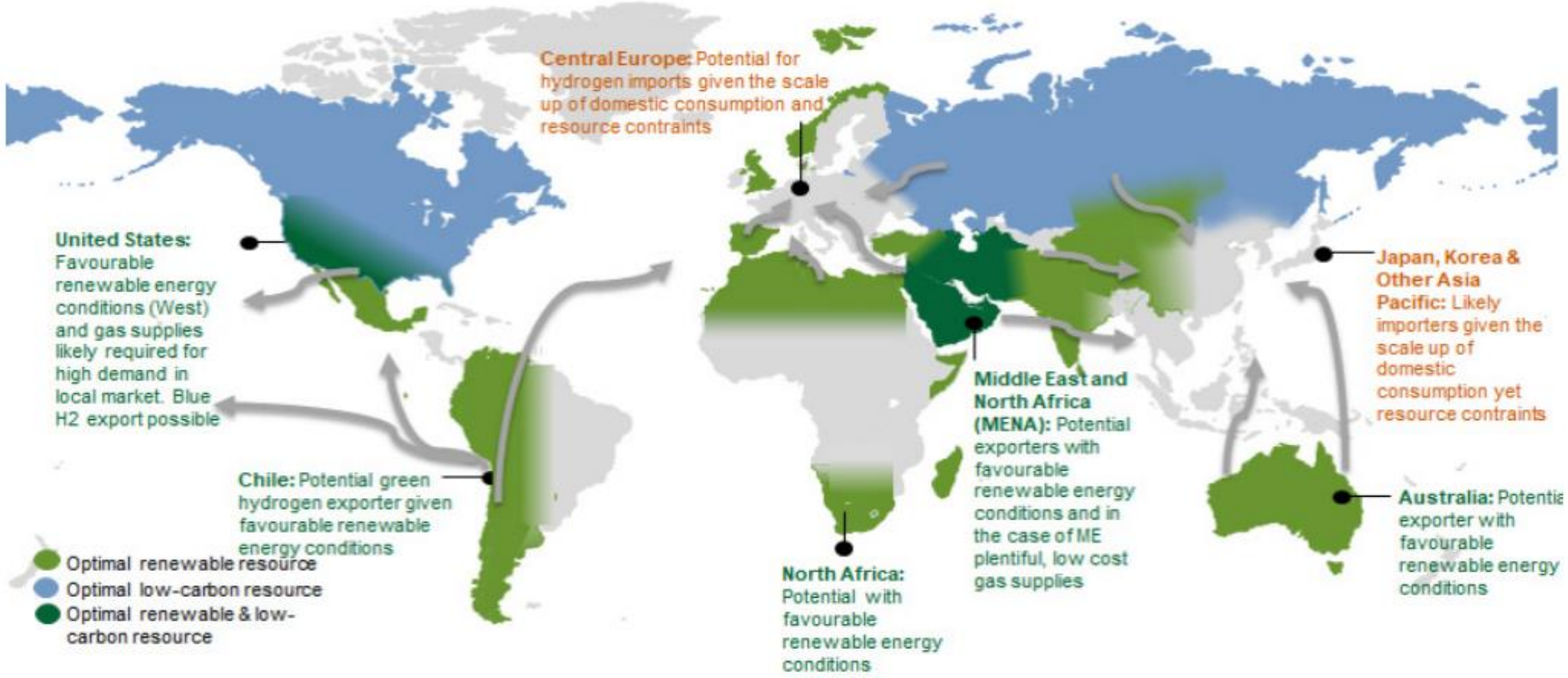
GREEN HYDROGEN PRESENT AND FUTURE

GLOBAL MARKET OF HYDROGEN

Exhibit 17: We see potential for c.30% of the global hydrogen market to be involved in international trade



Source: Compiled by Goldman Sachs Global Investment Research

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GREEN HYDROGEN PRESENT AND FUTURE

EU HYDROGEN ROADMAP

PHASE-1 (2020-2024):

- Up to 6 Gw of electrolysers & 1.000.000 tons of Hydrogen.
- Mainly targeting industries already consuming grey hydrogen.
- First deployment of HRS (Hydrogen Refuelling Stations).

PHASE-2 (2025-2030):

- Up to 40 Gw of electrolysers & 10.000.000 tons of Hydrogen.
- More generalization of applications in industry, heavy duty transport including marine applications.
- Applications for energy storage were convenient.

PHASE-3 (2030-2050):

- Big scale deployment and market generalization.

But new geo-strategic scenario is redefining the Schedule….

JULES VERNE PROJECT

PORT OF VIGO

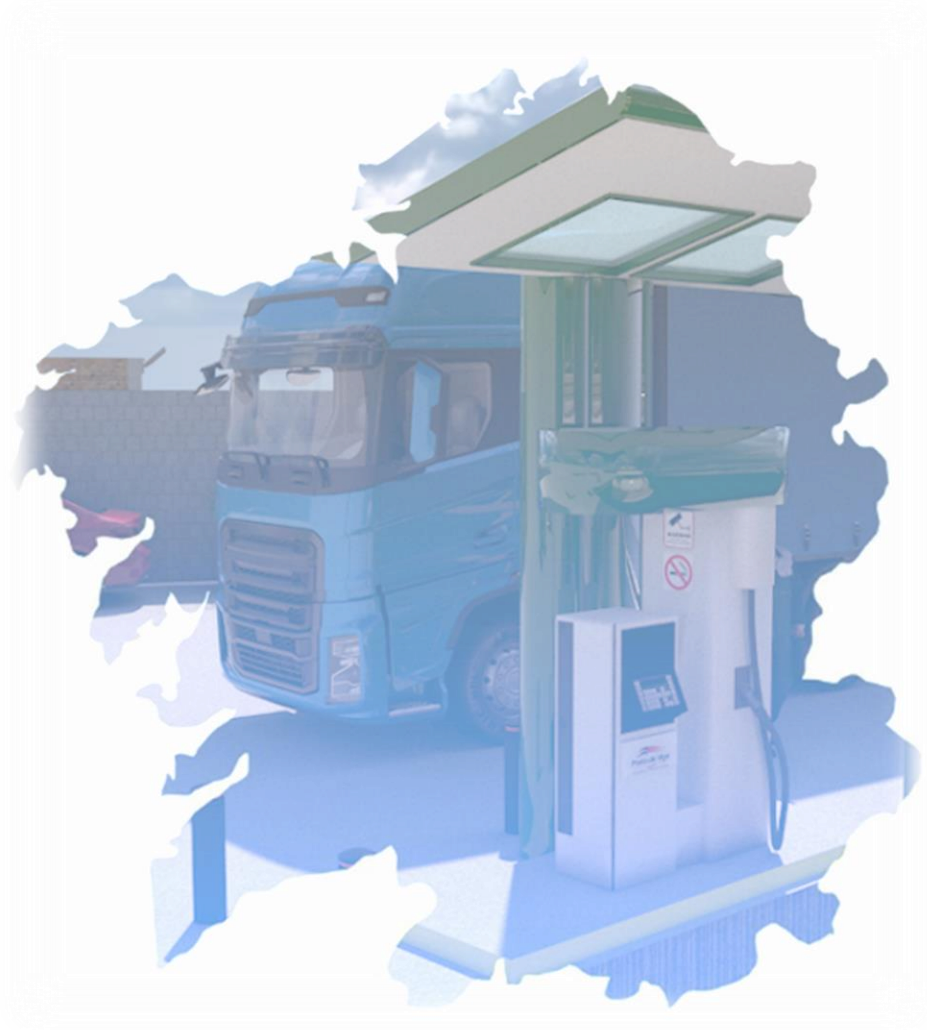
Hidrógeno Julio Verne
PUERTO DE VIGO

Puerto de Vigo
Autoridad Portuaria de Vigo

Hidrógeno Julio Verne
PUERTO DE VIGO

SCOPE & TARGETS

EXECUTIVE SUMMARY



PROJECT SCOPE:

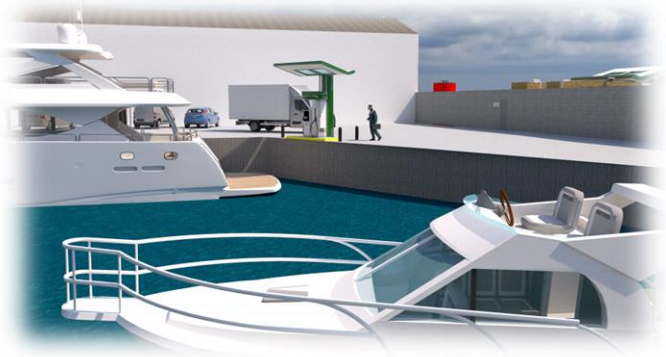
Local Generation and dispensing of Green Hydrogen for **port logistic operations, industrial** consumptions, **heavy transport / marine mobility** applications and "zero emissions" **Cold Ironing** application in the port area of Vigo.

Main Figures:

- Location: Port of Vigo (Bouzas).
- Electrolyzer: Alkaline 1,4 Mw.
- H2 Generation (350 bar): 570 kg/day. 213 tm/year.
- Max refuelling capacity: > 40 refuelling/day (Heavy trucks).
- CAPEX: 6 Mio€
- Start up: January 2024.

Project Main Singularities:

- Public Access to our refuelling station.
- Land/Marine Transport applications.
- Industrial Consumptions (Grey Hydrogen replacement).
- Cold Ironing “Zero Emissions”.



Hidrógeno Julio Verne
PUERTO DE VIGO

MAIN PLAYERS – TECHNOLOGY & KNOWLEDGE IMPACT

INVESTORS/DEVELOPERS

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Investor/Developer & Project Coordinator
RREE Company

SOLTEC ingenieros

Investor/Developer
Engineering Company

QUANTUM GROUP

Investor/Developer
RREE Company

ANFACO CECOPESCA

Investor/Developer
National Association of Food Canning Manufacturers

LEADER/SPONSOR

Puerto de Vigo
Autoridad Portuaria de Vigo

COLABORATION ENTITIES & COMPANIES

CTAG

CTAG
Automotive Technology Center

energylab

ENERGYLAB
Energy Technology Center

Universidade Vigo

University of Vigo

exportrends

Import/Export - Consulting Company

Neuwalme
HIDRÁULICA, NEUMÁTICA & CONTROL

H2 - Manufacturing / Installations

ACLUNAGA
ASOCIACIÓN CLUSTER DEL NAVAL GALLEGO

Ship Building Association

GRUPO BOTAMAVI
Since 1926

Port Marine Operations

UNVI

Bus Manufacturer

AISTER
BOATS • MARITIME • MARINAS

Ship Builder

Hidrógeno Julio Verne
PUERTO DE VIGO

CONSUMERS / OFF TAKERS OF HYDROGEN&OXIGEN

PORT LOGISTICS/ AUTOMOTIVE / MARINE

H2 Marine Sector

350 / 700 bar



Ferries, port operations, shipyards

H2 Automotive Sector

350 bar



Bus, Urban waste, Heavy Transport

Hydrogen distribution to other close locations

700 bar


Taxi /last mile transport

H2 Port Operations

350 bar



Forklifts, Reachstackers, Heavy Transport

700 bar


Small-Medium operation vehicles

O2 for Industrial Applications

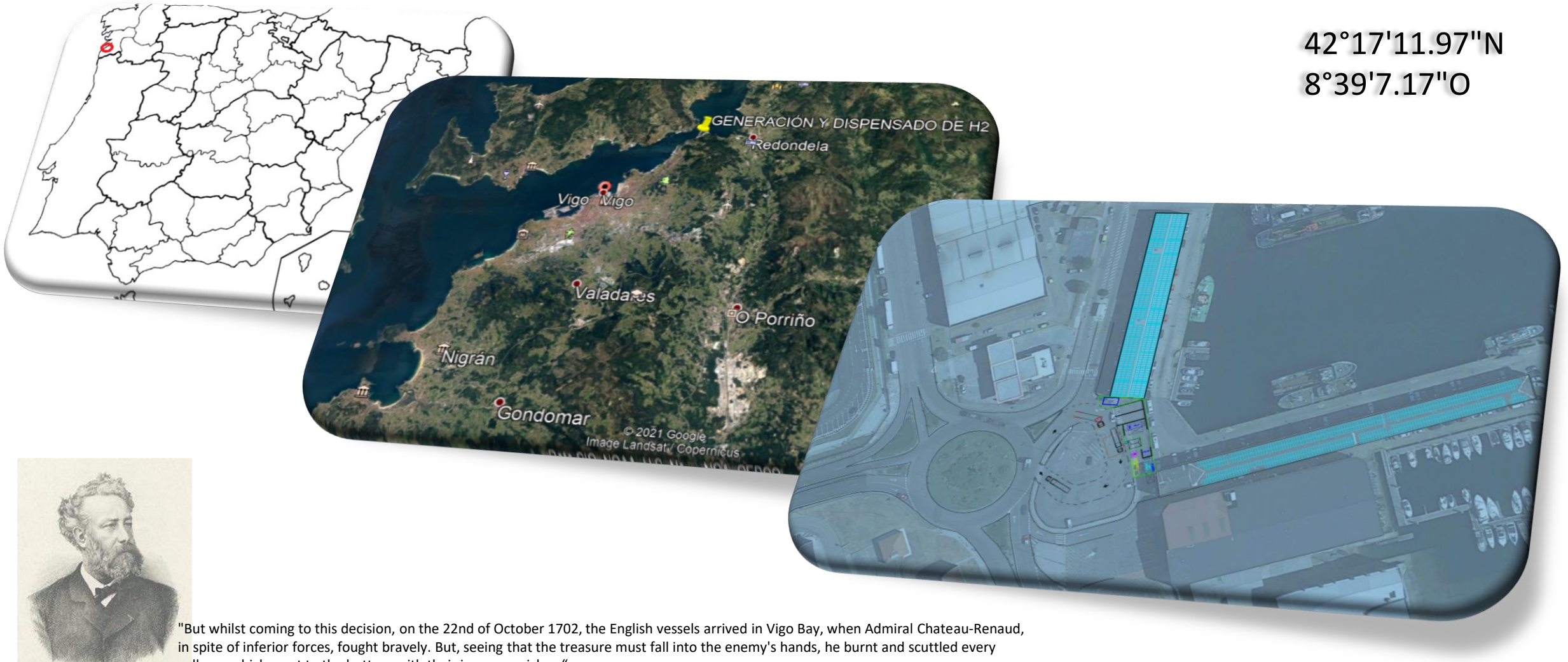
Workshops, shipyards, industrial processes, welding....

Hidrógeno Julio Verne
PUERTO DE VIGO

LOCATION: BOUZAS

PORT OF VIGO / VIGO ESTUARY

42°17'11.97"N
8°39'7.17"O

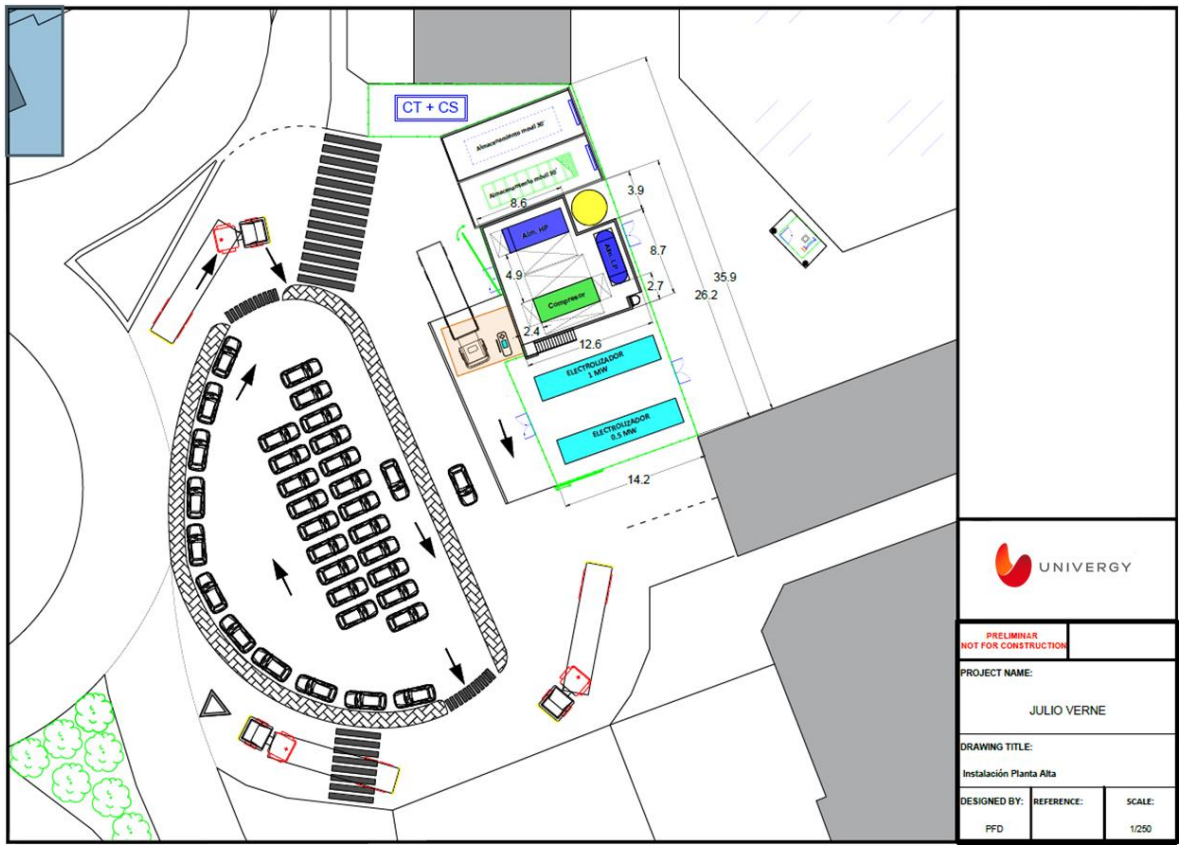


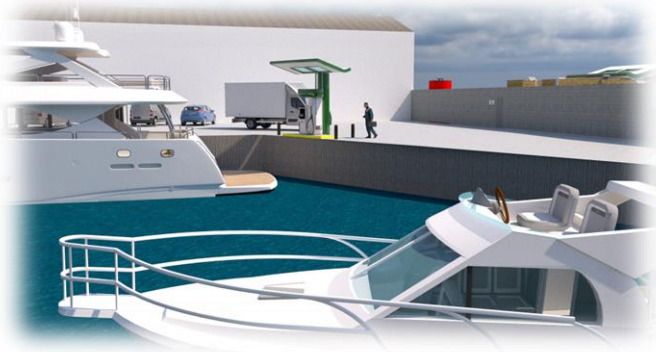
"But whilst coming to this decision, on the 22nd of October 1702, the English vessels arrived in Vigo Bay, when Admiral Chateau-Renaud, in spite of inferior forces, fought bravely. But, seeing that the treasure must fall into the enemy's hands, he burnt and scuttled every galleon, which went to the bottom with their immense riches."……..
"Well, M. Aronnax," replied Captain Nemo, "we are in that Vigo Bay; and it rests with yourself whether you will penetrate its mysteries."
(20,000 Leagues Under the Sea. Jules Verne. 1870)

Hidrógeno Julio Verne
PUERTO DE VIGO

LOCATION: BOUZAS

TENTATIVE LAYOUT & INFOGRAPHY

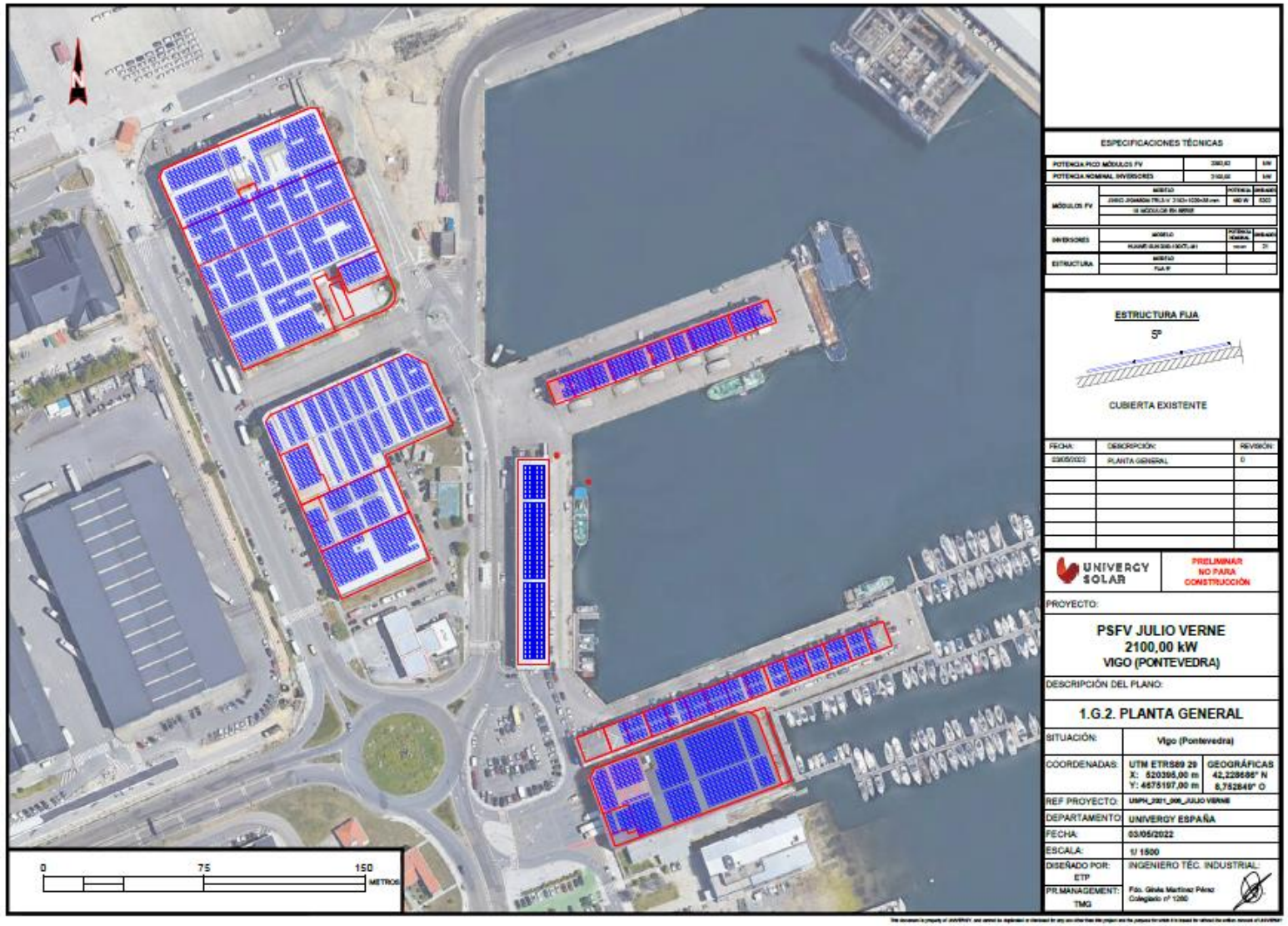




Hidrógeno Julio Verne
PUERTO DE VIGO

LOCATION: BOUZAS

LAY OUT PV-ROOF



60 MW PROJECT

CASTILLA Y LEON

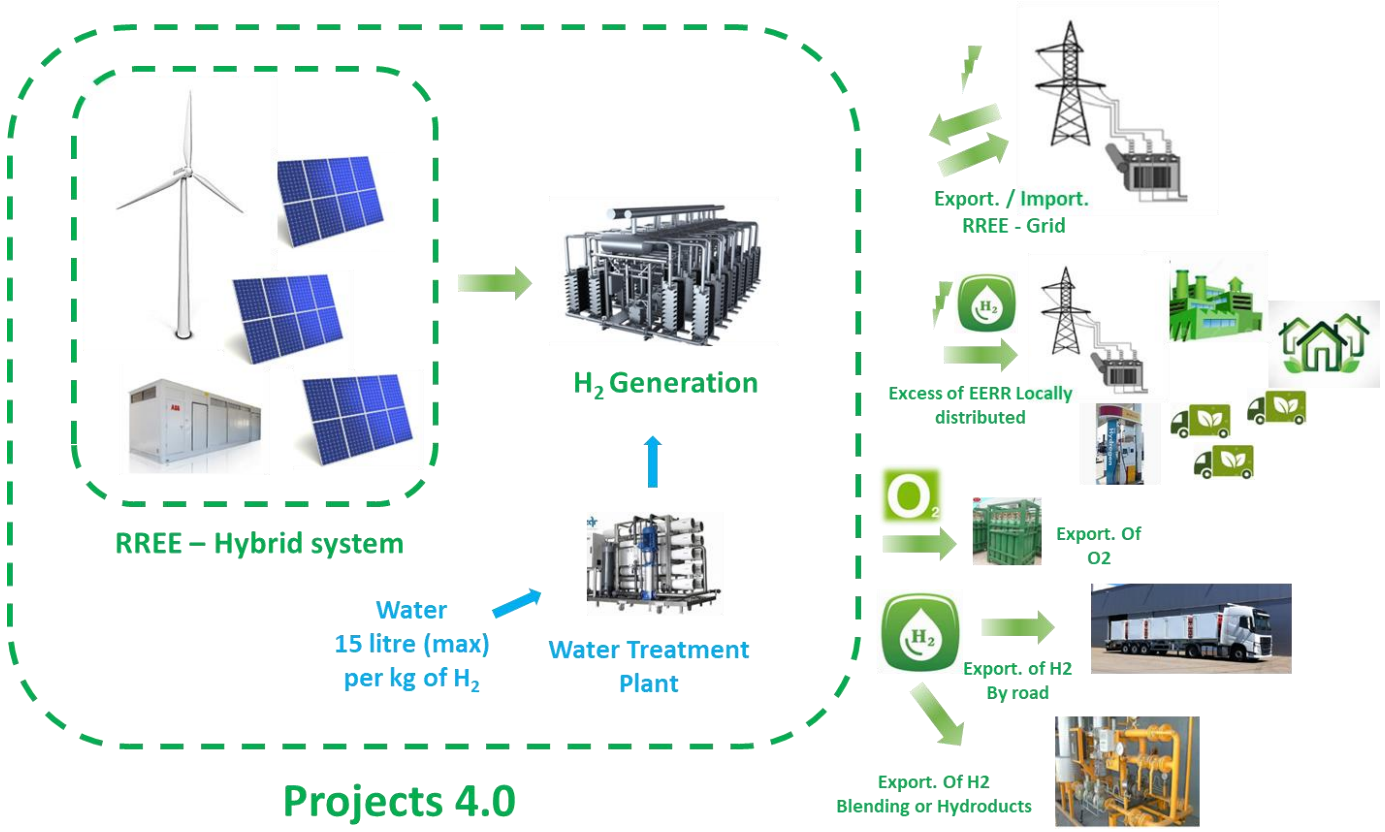
UNIVERGY

PROJECT SCOPE:

Big scale hydrogen generation. Gas piping at scale (blending or Hydro-ducts).

Main Figures:

- Location: Castilla y León (Spain).
- Electrolyzer: PEM 60 Mw.
- RREE: FV 80 Mw + Wind 60 Mw.
- Land area: 4.000.000 sqm
- H2 Generation: 11 Tm/day. 4.000 Tm/year.
- CAPEX: ≈ 160 Mio€
- Start up: 2027.
- LCOH: < 3 €/kg



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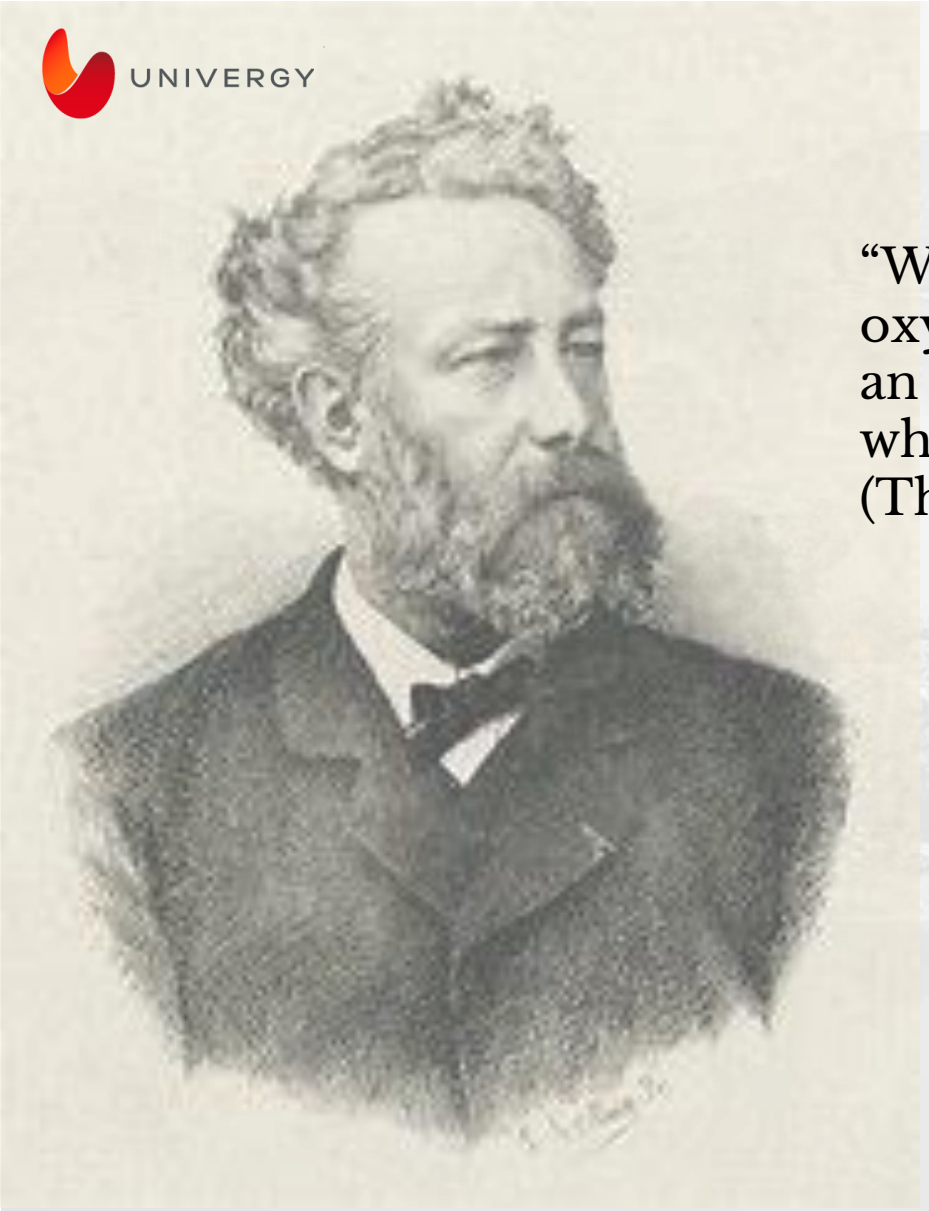

JULES VERNE

“Water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable”
(The Mysterious Island. Jules Verne 1875)

“WATER IS THE COAL OF THE PRESENT.....” 2022

THANK YOU!