



End User Application: Port of Palma FC - Site Layout and preliminary engineering design

Deliverable 2.9

February 2022

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Preface

The aim of **GREEN HYSLAND** is to **deploy a Hydrogen ecosystem on the island of Mallorca**. The initiative is receiving **10 Million Euros of funding** from the European Commission through the **Clean Hydrogen Partnership**. It is a 5-year-project that started on the 1st January 2021, and will end on 31st December 2025. The consortium is formed by **30 partners from 11 countries**, 9 from the European Union, as well as Chile and Morocco. The project will deliver the **first hydrogen valley of the Mediterranean**, developing a fully functioning hydrogen (H₂) ecosystem covering all the value chain, from the production to the distribution and consumption of, at least, 330 tonnes per year of green H₂, traced through a Guarantee of Origin System. This hydrogen will be used in six different applications, as follows:

- The **H₂ pipeline and the injection point** of part of the H₂ produced at the Lloseta plant into the island's natural gas network operated by Redexis.
- The **100 kWe fuel cell** that will supply electricity to the maritime station of the **Balearic Port**.
- The **50 kWe CHP** system to be located in the **Iberostar Bahía de Palma hotel (4*)**, which will cover part of the hotel's energy demand.
- The **25 kWe CHP** system to be located at the **Municipal Sports Centre in Lloseta**, which will cover part of the site's energy demand.
- The integration of **5 hydrogen buses to the EMT** city bus fleet of Palma de Mallorca.
- The integration of **H₂ vans** in the Alfill Logistics vehicle fleet as well as the search for rental car companies to incorporate H₂ vehicles in their **rental car fleets**.

The infrastructures which will be developed within the project are:

- The **green H₂ production plant** located on CEMEX land in Lloseta.
- The deployment of a **Hydrogen Refuelling Station (HRS)** at the EMT facilities.
- The development of tube trailers which will transport the H₂ produced in Lloseta's plant to the different applications.

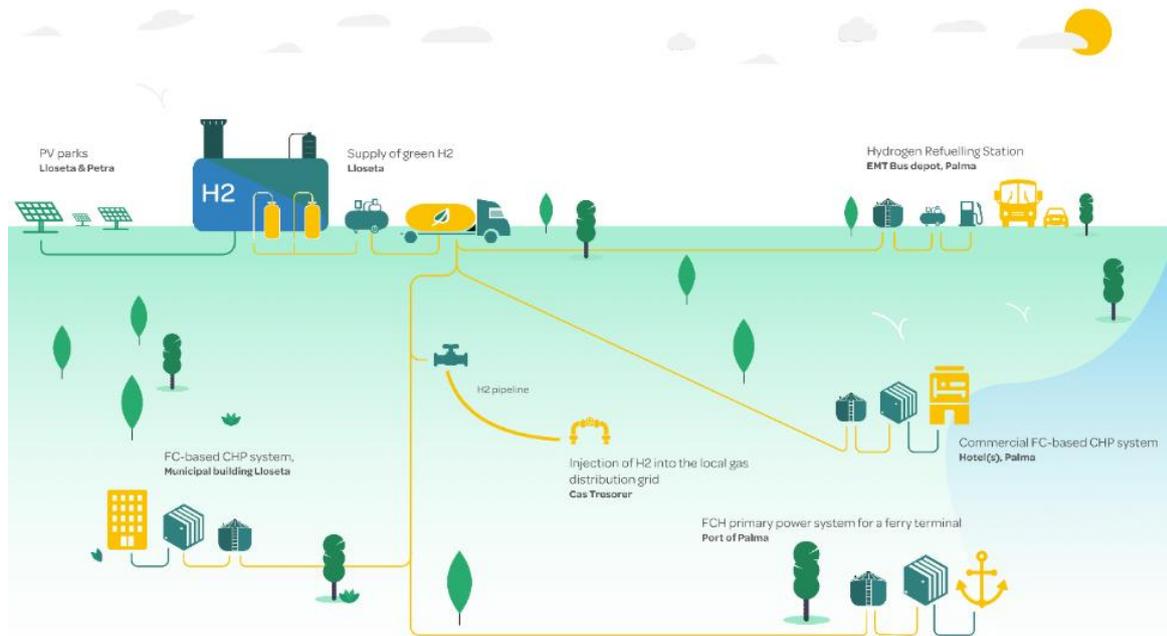
This initiative aims to reduce the CO₂ emissions of Mallorca up to 20,700 tonnes per year by the end of the project.

The project will also deliver a **roadmap towards 2050** that compiles a long-term vision for the **development of a widespread H₂ economy in Mallorca and the Balearic Region**, in line with the **environmental objectives set for 2050**. This long-term roadmap will be an evolution of the current regional roadmap for the deployment of renewable energies and the energy transition, and will involve local and regional stakeholders through public consultations.

In addition, GREEN HYSLAND contemplates the **development of replication experiences** in five other EU islands: Madeira (PT), Tenerife (ES), Aran (IE), Greek Islands and Ameland (NL) as well as Chile and Morocco. Within the project, the impact of deployment of H₂ technologies at regional level (Mallorca and Balearic islands) at technical, economic, energy, environmental, regulatory and socioeconomic levels will be analyzed. Additionally, detailed techno-economic studies for scaling-up renewable H₂

production, interconnecting infrastructure and local H₂ end-uses, both within the island of Mallorca and beyond, will be developed to facilitate and de-risk future sector investment.

The infrastructures for the hydrogen production and distribution, together with the end-users' pilot sites and the logistics required for the green hydrogen distribution will be developed as follows:



No	Participant Name	Short Name	Country Code	Logo
1	ENAGÁS S.A.	ENAGAS	ES	
2	ACCIONA ENERGIA S.A.	ACCIONA ENER	ES	
3	REDEXIS GAS S.A.	REDEXIS GAS SA	ES	
4	Empresa Municipal de Transportes Urbans de Palma de Mallorca S.A.	EMT-PALMA	ES	
5	CALVERA MAQUINARIA E INSTALACIONES S.L.	CALVERA	ES	
6	AJUNTAMENT DE LLOSETA	Lloseta Council	ES	
7	AUTORIDAD PORTUARIA DE BALEARES	PORTS BALEARS	ES	
8	CONSULTORIA TECNICA NAVAL VALENCIANA S.L.	COTENAVAL	ES	

9	BALEARIA EUROLINEAS MARITIMAS S.A.	Balearia	ES	
10	INSTITUTO BALEAR DE LA ENERGIA	IBE	ES	
11	UNIVERSITAT DE LES ILLES BALEARS	UIB	ES	
12	FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON	FHa	ES	
13	CENTRO NACIONAL DE EXPERIMENTACION DE TECNOLOGIAS DE HIDROGENO Y PILAS DE COMBUSTIBLE CONSORCIO	CNH2	ES	
14	ASOCIACION ESPANOLA DEL HIDROGENO	AeH2	ES	
15	COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	CEA	FR	
16	ENERCY BV	ENER	NL	
17	HYENERGY CONSULTANCY LTD	HYE	NL	
18	STICHTING NEW ENERGY COALITION	NEW ENER.COALIT	NL	
19	HYCOLOGNE GMBH	HyCologne	DE	
20	FEDERATION EUROPEENNE DES AGENCES ET DES REGIONS POUR L'ENERGIE ET L'ENVIRONNEMENT	FEDARENE	BE	
21	NATIONAL UNIVERSITY OF IRELAND GALWAY	NUI GALWAY	IE	
22	THE EUROPEAN MARINE ENERGY CENTRE LIMITED	EMEC	UK	
23	GASNAM - ASOCIACION IBERICA DE GASNATURAL Y RENOVABLE PARA LA MOVILIDAD	GASNAM	ES	

24	UNIVERSIDAD DE LA LAGUNA	ULL	ES	
25	ENERGY CO-OPERATIVES IRELAND LIMITED	En.Coop.Ireland	IE	
26	AGENCIA REGIONAL DA ENERGIA E AMBIENTE DA REGIAO AUTONOMA DA MADEIRA	AREAM	PT	
27	GEMEENTE AMELAND	Gem.Ameland	NL	
28	DIKTYO AEIFORIKON NISON TOY AIGAIYOU AE	DAFNI	EL	
29	ASOCIACION CHILENA DE HIDROGENO	H2 CHILE	CL	
30	Association Marocaine pour l'Hydrogène et le Développement Durable	AHMYD	MA	

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1. Executive Summary

The project Green Hysland will create a ‘green hydrogen ecosystem’ in the island of Mallorca. It will generate, distribute and use at least 300 tonnes of renewable hydrogen locally per year, produced from solar energy. Green hydrogen will have multiple applications on the island, including the fuel supply to a fleet of fuel cell buses and fuel cell vans, the generation of heat and power for commercial and public buildings and the creation of a hydrogen refuelling station. The project also includes green hydrogen injection into the island's gas pipeline network, through a Guarantees of Origin System, to contribute to the decarbonisation of the gas supply.

The aim of this document is to define the conceptual design of the installation of a hydrogen fuel cell for the Balearic Port maritime station located in Palma. This 100kW fuel cell supplies the maritime station with the support of PV panels on the cover on the building. The principal objective is that the maritime station will run without energy from the grid. There are some months when the surplus of the fuel cell will supply other buildings near this.

This document contains:

- Site general information
- Process calculations
- System sizing
- General lay out equipment distribution
- CAPEX
- Single-line diagram

2. Objectives

GREEN HYSLAND is built around three main strategic objectives, namely:

1. Establishing an integrated H₂ ecosystem in the island of Mallorca, deploying H₂ across the entire value chain to demonstrate sector coupling.
2. Delivering a roadmap towards 2050 that compiles a long-term vision for the development of a widespread H₂ economy in Mallorca and the Balearic Region, in line with the environmental objectives set for 2050.
3. Showcase the capacity of H₂ to decarbonize EU islands and beyond, maximizing the integration of renewable energy.

The objective of this deliverable is to define the conceptual design of the installation of the hydrogen fuel cell for the Balearic port, which will be powered with green hydrogen from the plant located on the grounds of CEMEX in Lloseta. The purpose of this installation is to reduce the CO₂ emissions and working in line with 2030 European agenda in the Green Hysland framework.

This project integrates the new power generation installation (compounded by the hydrogen storage, the unloading station and the hydrogen fuel cell) with the existing power grid in order to provide green energy for the maritime stations.

This project shall fulfil the agreement number 101007201 relative to the Green Hysland project in which it is established that the H₂ consumed by the maritime station in the Port of Palma comes from the hydrogen plant developed in the project by Enagás. Moreover, Calvera would be the one that provides the tube trailers as well as the storage and the regulation panel associated with the fuel cell consumption in Port of Palma. This agreement means:

- Electricity supply for critical infrastructure at the port of Palma (100kWe)
- To consume 40 Tn H₂ per year.

3. Description of work

The document describes the work carried out to deliver the site layout and the engineering studies on the area where the fuel cell will be installed.

The work consists on the adaptation of their facilities to be suitable for the installation of a 100kW fuel cell and all the associated equipment, such as the hydrogen discharge panel and storage. The location is next to the maritime station facilities that will be supplied by the fuel cell. All the safety requirements have been considered, and are duly presented on the following sections.

The maritime station is selected according to the studies developed, and it will be adapted for the electrical connection to the fuel cell. In case of energy surplus for the maritime station selected, the energy will be discharged to the port's energy network, to supply other nearby maritime stations.

3.1 Fuel Cell installation at the Port of Palma

In this section, the location where the hydrogen fuel cell will be installed in the surrounding of the maritime station to which it will supply energy will be preselected.

3.1.1 Site selection

Several locations have been analysed, specifically in 3 maritime stations in the Pelaires area and Poniente docks, maritime stations No. 2, No. 3, and No. 4.

Maritime Station No. 4, EM4, has a total area of 3,927.72m², it is planned to make a 50% expansion. In this extension, energy efficiency improvements will be carried out with the incorporation of photovoltaic panels on the roof. That is why it has been decided to incorporate the hydrogen cell in this station so that the terminal can operate without having to depend on grid connexion, becoming an independent station of the electrical network.

Once the expansion works have been carried out, incorporating the photovoltaic panels, the fuel cell will have enough energy to cover the remaining demand of the station and will provide green energy generated by H₂ to cover part of the demand of the adjacent maritime stations, No. 2 and No. 3. The necessary actions will be carried out to deliver this energy to these stations.

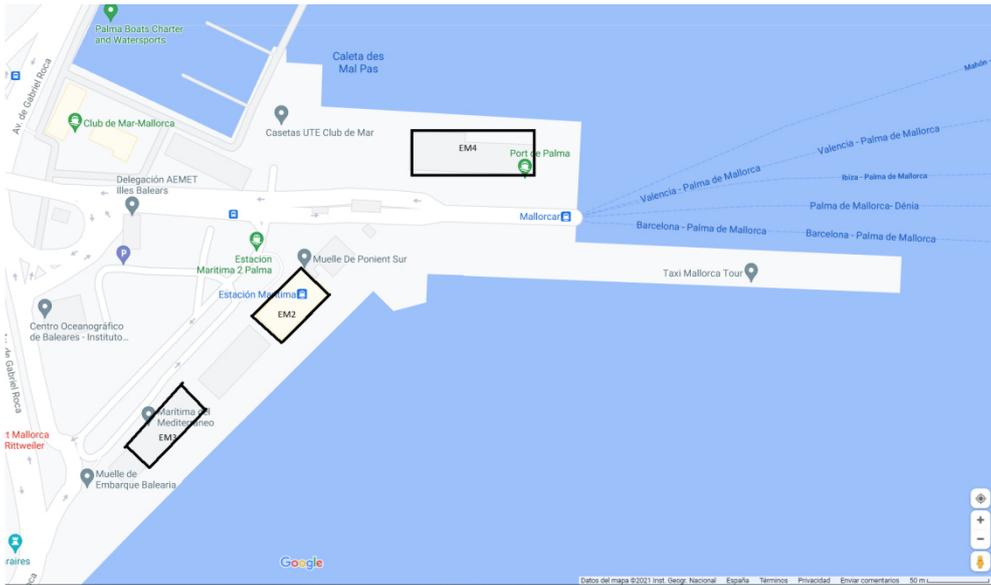


FIGURE 1. POSITION OPTIONS



FIGURE 2. FV PANELS

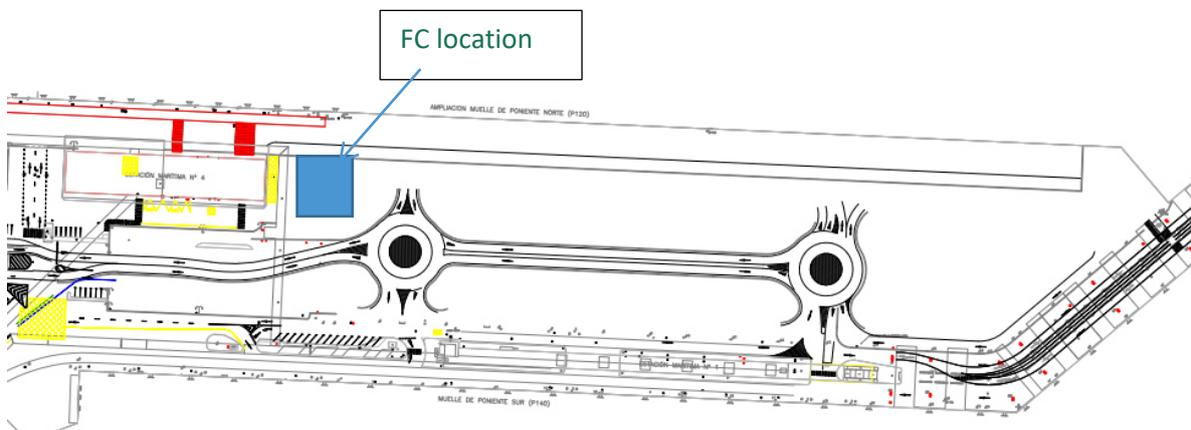
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER		
TOTAL DEMAND	22,927	18,591	19,863	19,170	26,698	34,241	43,906	43,009	31,742	24,921	17,999	21,910	324,977	kWh
100kW FV	10,224	10,948	13,895	14,599	16,982	15,107	16,402	15,176	13,109	11,311	9,343	9,130	156,226	kWh
REST	12,703	7,643	5,968	4,571	9,717	19,134	27,504	27,833	18,632	13,611	8,656	12,780	168,752	kWh

TABLE 1. DEMAND

Site visit has been carried out to show the location with personnel from the Balearic Port Authority, several photos and plans are included below.

It should be noted that to date some works have been carried out on the Poniente esplanade and it has been enlarged, as it is shown in the following image, the photographs and final plans of the performance are not yet available.

It has been decided that the fuel cell will be located to the right of the maritime station, since there is a space large enough to locate the associated hydrogen storage maintaining safe distances to the maritime station. Taking into account the daily hydrogen supply, an independent route has been designed for the tube trailer, this being the most ideal location and with more space for it. This route does not interfere with the rest of the operations of the maritime station.


FIGURE 3. MARITIME STATION 4

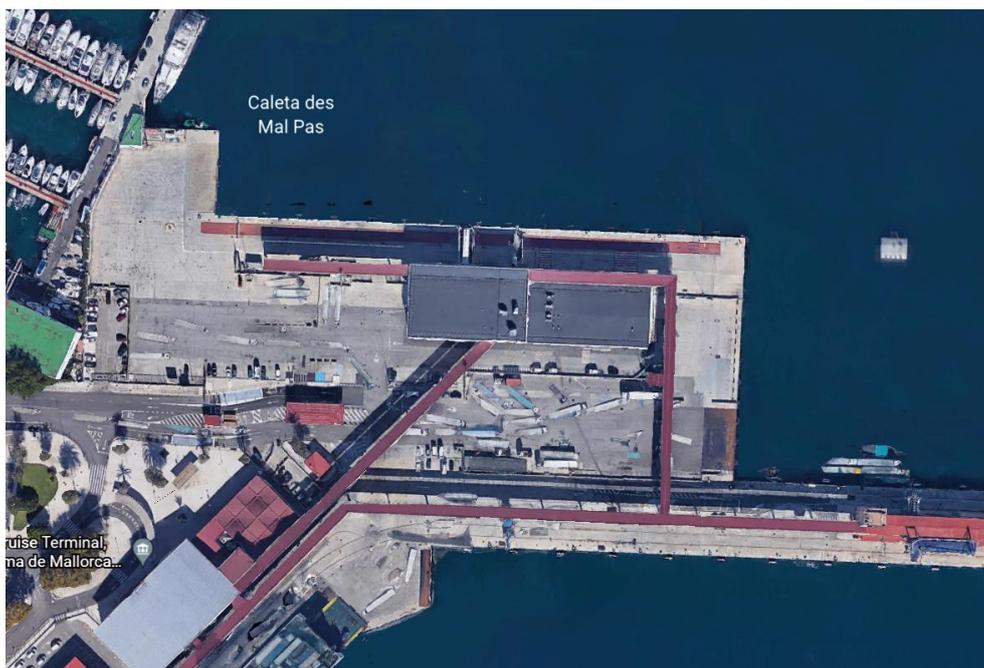


FIGURE 4. MARITIME STATION 4 (GOOGLE EARTH)

The fuel cell is expected to run over 17.93 hours per day considering 6.8kg H₂/h consumption. It is considered 10% day maintenance /shut down.

3.1.2 Fuel Cell Site Design

As it was agreed in the GREEN HYSAND consortium, it will be installed and operated a 100 kWe hydrogen cell fuel at the Port of Palma. The following equipment / areas will be required in the location indicated in the previous section:

- A tube trailer entrance to the site, a one-way system past the dispenser, then a site exit.
 - The tube trailers are 30 ft standard size.
 - The minimum inner radius considered is 5.9 m (minimum radius required for 40 ft trailers)
- A tube trailer discharge area (REI-180 protection walls are considering based on the code APQ5)
- High pressure storage area. This area will be outdoors in the surroundings of the H₂ discharge area and separated by a REI- 180 protection walls. The high pressure storage hardware will be provided by CALVERA (partner of the consortium) and it is compounded by:
 - 6 blocks of bottles (6 bottles per block)
 - Design pressure of the bottles: P= 300 bar
 - Volume of the bottles: 153 L
 - Effective mass of the bottles: 93.29 kg. (hydrogen storage capacity of the entire storage, bottle + H₂)

For further details, refer to Annex 1.

- A 100kWe fuel cell
- Electrical installation to supply power to the Port building (Refer to Annex - 03 to further details)
- H₂ discharge panel provided by CALVERA
- Interconnecting piping among the discharge panel, the high pressure storage and the H₂ fuel cell.

After having made the calculations throughout the year, there is a consumption of 30 tons of hydrogen, instead of 40 tons (as is taken into account in the Grant Agreement). For this reason, it was decided to expand the storage in 3 additional blocks of 6 bottles each.

This fuel cell will supply more than 588 MWh per year of green energy saving more than 260 Tn CO₂, it's working in line with Govern objectives.

This means an increase in space on the esplanade and an increase in price.

Extra blocks are underlined in the annexes.

Refer to the “Annex 4 – General lay out drawing” to check the arrangement of the equipment listed above.

Also, refer to the “Annex 2 - Process flow diagram H₂ fuel cell system EM4 Balearic Port” to check the process flow and main values.

Refer to Annex 4 – General lay out drawing where the required civilworks details are shown. It has been not required any modification, alternative study or civil re design due to the topographic information received.

The topographic study was done during the expansion of the area civilworks (ended in June 2021) where the fuel cell is located. This area is at west side of maritime station 4 of Balearic Port.

The maximum elevation of the area is +3,065 over the Palma Port reference. There is cross slope to evacuate the rainwater (1.6% south direction, 1.75% north direction).

3.1.3 Site power and communication requirements

The H₂ fuel cell will be connected to the normal bush bar of the maritime station 4. To further details, refer to Annex 3.

The fuel cell will be control locally, using a PLC. It will be connected to maritime station 4 using Ethernet cable to communication box (located at ground level of the building).

The next steps will be to study how this control is, taking into account that everything must be centralized with the hydrogen production plant.

3.1.4 Energy Application 1: auxiliary heat & power at the Port of Palma

The study carried out during the engineering phase includes the evaluation of the possibility of using the heat generated by the fuel cell and its integration in the maritime station. The values associated to the 100 kWe fuel cell considered are:

- Temperature: 65-90°C approx.
- Thermal power:
 - “Beginning of Life”: 12,667 kWt
 - “End of Life”: 150 kWt

In the maritime station No. 4, the air conditioning installations are based on a centralized air heating/cooling system through a rooftop on the deck and the temperature of the zones is controlled by regulating the air flow that is supplied to each one of them.

Considering the possibility of using the heat (in winter), a heating system would have to be installed on the existing rooftop, in addition to the necessary pipes, valves and connections, which would increase the budget by about 25,000€.

In case of using the heat for cooling (in summer) it would imply the installation of an adsorption equipment to use the heat to generate cold during the summer periods, whose cost would be added to the previous one (although in this scenario, the replacement of the existing rooftop could be considered). The budget for the equipment is between €50,000 and €90,000 for thermal power between 100kWt and 150kWt.

In the next engineering phase and with more accurate data related to the fuel cell, it will be evaluated if it is finally possible to use the heat of the fuel cell and if it is economically worthwhile.

3.1.5 Tender Pack

The following annex will be used in the future for the tender stage.

- Annex 1 - Mechanical sizing calculation
- Annex 2 - Process flow diagram H₂ fuel cell system EM4 Balearic Port
- Annex 3 - Single line
- Annex 4 - General lay out - H₂ fuel cell system EM4 Balearic Port

It is indicated a preliminary CAPEX in section 3.1.6.

The costs of the hydrogen storage are assumed by Calvera. The additional storage costs are not yet covered.

3.1.6 Civil/electrical works quotations

A preliminary CAPEX has been estimated for the tender stage for the main expenditure items for a tender in a future stage.

The cost of extra blocks is still calculating.

According to the Grant Agreement, a budget of €456,500 is estimated for the purchase of the hydrogen fuel cell, which is mostly subsidized. At the time of bidding it is expected that there may be some drop in the estimated cost. Even so, the costs that exceed the amount of the subsidy will be managed with private funds.

CAPEX

1.	Civil		
1.1		Earth- moving	3,348.44 €
1.2		Concrete	70,141.10 €
1.3		Total	73,489.55 €
1.4		Unaccounted items (10 %)	7,348.95 €
1.5		Total increased	80,838.50 €
2.	Equipment		
2.1		Fuel cell 100 kWe	620,000.00 €
3.	BOP		
3.1			124,000.00 €
		Total	824,838.50 €

4. Conclusions

This document describes the conceptual design of a 100kWe fuel cell that works with green hydrogen to supply electricity to Balearic Port. This fuel cell will be located in the surroundings of the Maritime Station 4 (which currently is being expanding). The grid of maritime stations of the Port are connected in a ring, so considering the initial statement, this fuel cell will supply more than 588 MWh per year of green energy saving more than 260 Tn CO₂.

It shall be considered that the Balearic Port of Palma is a much crowded place, full of tourist, local people, workers... To locate the FC, where H₂ will be storage and downloading, will carry out some risks. Although the H₂ area will be located close to a traveller platform, the design of the plant is based on the applicable norms and codes (UNE-EN and APQ) considering the safety distance indicated in APQ 5 (refer to Annex 4) and considering also the retention walls where required.

For the next phase, it is planned that the possible events that generate serious accidents will be identified, as well as their causes and frequencies. PB will carry out a quantitative risk analysis in the area of the port's maritime station around the hydrogen FC. These studies are planned to be incorporated into the general safety study for the Green Hysland project.

5. Annexes

Annex 1: Mechanical sizing calculation.

Annex 2: Process flow diagram H₂ fuel cell system EM4 Balearic Port

Annex 3: Single line

Annex 4: General lay out and hazardous areas - H₂ fuel cell system EM4 Balearic Port

1. AIM
The purpose of this annex is to calculate and to define the mechanical/process integration of the H2 fuel cell installation at the EM4 of Balearic port.

2. INPUTS

This installation is compounded by:

Equipment	Purpose	Supplier	Remarks
H2 fuel cell	Energy generation	TBD later	
H2 rack bottles	H2 storage	CALVERA	
H2 tube trailer	H2 supply	CALVERA	The Hydrogen is produced by ENAGAS
Control panel	To control H2 flow	CALVERA	

The H2 consumed in the fuel cell was agreed by CALVERA, ENAGAS and the Balearic port:

		Remarks
H2 mass per year	40 Tn	
H2 fuel cell working days	328	10% days maintenance / shut down. Internal reference
Mass per day	121,95 kg	
Fuel cell		
Power	100 kW	Fuel cell supplier reference
Consumption	6,8 kg/h	
Working time per day	17,93 h	
Daily energy	1793,40 kWh	
Yearly energy	588,24 MWh	
CO2 saved	264,71 Tn	

The CALVERA storage hardware it is compounded by:

Nº blocks	6 units
Bottles per block	6 units
Block size	0,82 x 1,16 x 2,53 m3
Volume per bottle	153 l
Volume per block	0,918 m3
Total volume	5,508 m3
Design pressure	300 bara
Minimum pressure	30 bara

The tube trailers will be as follows:

Maximum operating pressure	300 bara
Volume per bottle	153 l
Nº bottles	143 uds
Total volume	21879 l
Nº sections	6 units

Based on the capacity in Nm3 the transported mass per tube trailer is:
Capacity at 15°C 5465 Nm3
Density at 15°C and 1 bara 0,084094 kg/m3
Mass 459,57 kg

Also, checking the total volume, the mass is:
Density at 300 bara at 15°C 21,152 kg/m3
Mass 462,78 kg

So it will be considered:

Mass	460 kg
Operating pressure	300 bara
Temperature	20 °C

3. CALCULATIONS

3.1. EFFECTIVE STORAGE

As it was agreed, the fuel cell will be fed from a storage which will be filled daily. This storage is feeded from a tube trailer connected to it and equalizing the pressures. In order to calculate the effective mass of H2 per day available the following inputs has been considered.

P truck	300 bara
P storage (empty)	30 bara

The filling process described by CALVERA is:

- The first two sections are connected to the storage.
- The pressure is equalized between both volumes.
- The first two sections are close and the second two sections are connected to the storage.
- The pressure is equalized between both volumes.
- The second two sections are close and the third two sections are connected to the storage.
- The pressure is equalized between both volumes and the third two sections are closed.

	Before the equalizing								After equalizing							
	truck				storage				Truck				Storage			
	P (bara)	V (m3)	Dens (kg/m3)	Masa (kg)	P (bara)	V (m3)	Dens (kg/m3)	Masa (kg)	P (bara)	V (m3)	Dens (kg/m3)	Masa (kg)	P (bara)	V (m3)	Dens (kg/m3)	Masa (kg)
First filling	300,00	7,293	20,84	151,99	30	5,51	2,44	13,43	173,00	7,29	12,92	94,24	173,00	5,51	12,92	71,17
									P (bara)	P1 bara	Dens 1 (kg/m3)	P2 bara	Dens 2 (kg/m3)			
									Iteration	173,00	170,00	12,72	180	13,39		
Second filling	300,00	7,293	20,84	151,99	173	5,51	12,92	71,17	243,01	7,29	17,43	127,14	243,01	5,51	17,43	96,02
									P (bara)	P1 bara	Dens 1 (kg/m3)	P2 bara	Dens 2 (kg/m3)			
									Iteration	243,01	240,00	17,25	250	17,86		
Third filling	300,00	7,293	20,84	151,99	243	5,51	17,43	96,02	274,99	7,29	19,37	141,29	274,99	5,51	19,37	106,71
									P (bara)	P1 bara	Dens 1 (kg/m3)	P2 bara	Dens 2 (kg/m3)			
									Iteration	274,99	260,00	18,47	270	19,07		

If the truck is full of H2, the transfer mass to storage is:

Eftec mass 93,29 kg

As it can be checked in the section 1, the required hydrogen which shall be consumed per day shall be 121.95 kg to fulfill the 40 Tn per year so the current storage is not large enough to fulfill this initial criteria.

Considering this scenario, the energy generated will be:

Energy/day	1371,85 kWh
Energy year	449,97 MWh
CO2 saved	202,49 Tn

And the hydrogen consumed per year will be:

Mass H2 / year 30,60 Tn

In order to fulfill the 40 Tn criteria, the number of blocks shall be increased:

Initial proposal nº blocks	6 units
Extra blocks required	3 units

	Before the equalizing								After equalizing							
	truck				storage				Truck				Storage			
	P (bara)	V (m3)	Dens (kg/m3)	Masa (kg)	P (bara)	V (m3)	Dens (kg/m3)	Masa (kg)	P (bara)	V (m3)	Dens (kg/m3)	Masa (kg)	P (bara)	V (m3)	Dens (kg/m3)	Masa (kg)
First filling	300,00	7,293	20,84	151,99	30	8,26	2,44	20,14	145,82	7,29	11,07	80,70	145,82	8,26	11,07	91,42
									P (bara)	P1 bara	Dens 1 (kg/m3)	P2 bara	Dens 2 (kg/m3)			
									Iteration	145,82	140,00	10,66	150	11,36		
Second filling	300,00	7,293	20,84	151,99	146	8,26	11,07	91,42	214,61	7,29	15,65	114,12	214,61	8,26	15,65	129,29
									P (bara)	P1 bara	Dens 1 (kg/m3)	P2 bara	Dens 2 (kg/m3)			
									Iteration	214,61	210,00	15,35	220	15,99		
Third filling	300,00	7,293	20,84	151,99	215	8,26	15,65	129,29	253,59	7,29	18,08	131,88	253,59	8,26	18,08	149,40
									P (bara)	P1 bara	Dens 1 (kg/m3)	P2 bara	Dens 2 (kg/m3)			
									Iteration	253,59	250,00	17,86	260	18,47		

If the truck is full of H2, the transfer mass to storage is:

Eftec mass 129,26 kg

In order to fulfill the 40 Tns criteria 9 blocks will be required.

The H2 thermodynamic properties are extracted from NIST (National Institute of standards and Technology, U.S. Department of Commerce)

The H2 thermodynamic properties are extracted from NIST (National Institute of standards and Technology, U.S. Department of Commerce)

3.2. HYDROGEN FUEL CELL HEAT AND MASS BALANCE

3.2.1. Energy balance

Based on a H2 fuel cell supplier reference, the fuel cell performance data will be:

Net power	100 kW
H2 Mass flow	6,8 kg/h
Fuel cell efficiency (approx)	45%

The efficiency of the fuel cell is checked based on the specific heat:

H2 energy	120 MJ/kg
H2 power	226,67 kW
Efficiency	44,12%

So the heat losses will be:

Heat loss	126,67 kW
Heat loss	56%

3.2.2. Mass balance

To calculate the mass flows of the system, the fuel cell reaction shall be checked. (H2+ O2 --> H2O)

Inputs from H2 fuel cell vendor

Air mass flow	6800 NLPM
---------------	-----------

Based on the air composition:

	mol(%)	PM (umas)	mass (%)
N2	78%	28	75%
O2	21%	32	23%
Ar	1%	40	1%

Air inlet	529,97 kg/h
-----------	-------------

H2 mass flow	6,8 kg/h
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H2 FUEL CELL - BALEARIC PORT

DATE

-

ANNEX 1 - MECHANICAL SIZING CALCULATIONS

REVISION

-

H2 consumption 100%

	H2	+	O2	+	N2	+	Ar	--->	H2O	+	H2	+	O2	+	N2	+	Ar
stoichiometric coef	1		0,5		0		0		1		0		0		0		0
PM(umas)	2		32		28		40		18		2		32		28		40
stoichiometric mass (g)	2		16		0		0		18		0		0		0		0
stoichiometric flow (kg/h)	6,8		54,4		0		0		61,2		0		0		0		0
inlet mass flow (kg/h)	6,8		122,98		399,67		7,32		61,2		0		68,58		399,67		7,32
Outlet mass flow (kg/h)									61,2		0		68,58		399,67		7,32
Outlet mass %									11,40%		0,00%		12,78%		74,46%		1,36%
Outlet mass flow (kmol/h)									3,40		0,00		2,14		14,27		0,18
Outlet vol %									17,00%		0,00%		10,71%		71,37%		0,91%

The outlet of the fuel cell is humid air. In order to avoid condensation at the outlet (which could produce corrosion) it is checked the composition of the outlet air:

T outlet	80	°C
P outlet	1	bara
Water saturation pressure	0,47	bara
P part H2O	0,17	bara
P part H2	0,00	bara
P part O2	0,11	bara
P part N2	0,71	bara
P part Ar	0,01	bara

As it can be checked, the water saturation pressure is larger than the partial pressure of the water of the humid air, so there will not be any condensation issue.

1 2 3 4 5 6 7 8

A

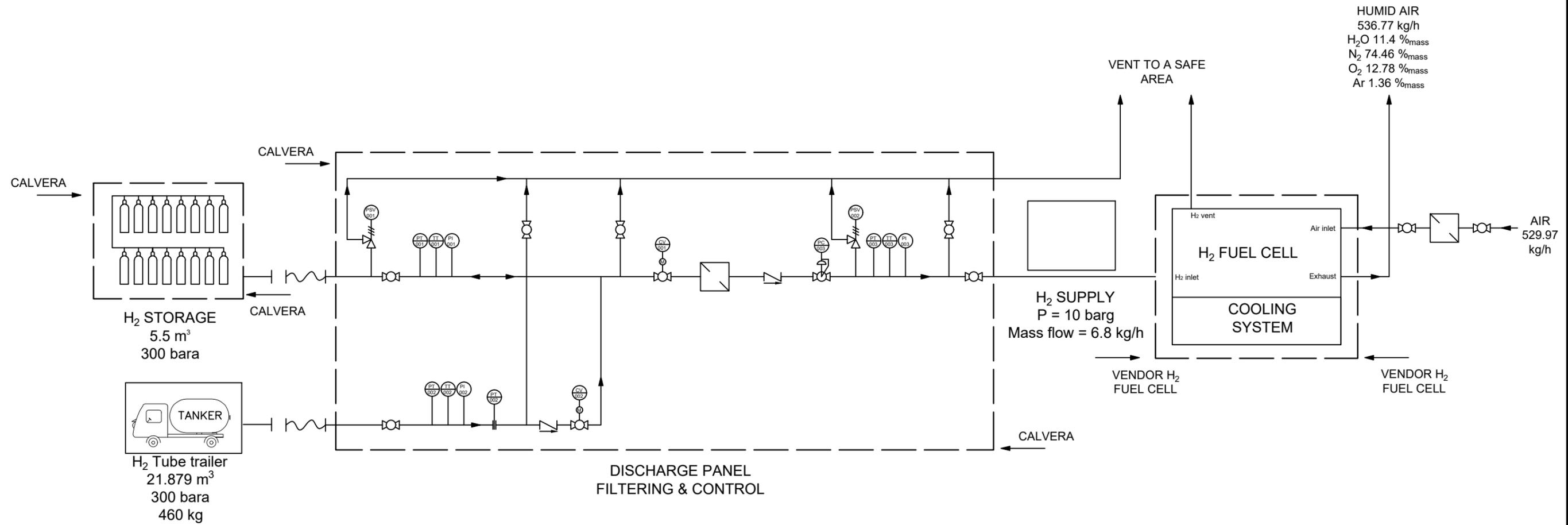
B

C

D

E

F



H2 fuel cell system EM4 Balearic Port

OWNER:

DRAWING NAME:

Process flow diagram

SIZE	SCALE	REV.	DATE	DESCRIPTION	DESIGNED	CHECKED	APPROVED	DESIGNER:
A3	-	0	28-01-22	FOR INFORMATION	D.B.B.	R.N.I.	J.S.U.	IDOM

DRAWING NUMBER:

SHEET: 01

DOCUMENT OWNER

NEXT: -

IDOM

1 2 3 4 5 6 7 8

P= 567.914 W
 Cs= 0,7
 Pc= 397.540 W
 I = 819,74
 L= 160 m
 S= 3x(3x240mm²)+1x240mm²
 $\Delta u = 6,57V(1,64\%)$

GRID ANALYSER

PM700

EMERGENCY GENERATOR

GRID-EMERGENCY GENERATOR SWITCHING

P= 131,6 kW
 I = 189,96A
 L= 59 m
 S= 4x120mm²
 $\Delta u = 1,97V(0,49\%)$

INSTALLED POWER: 567.914 W
 CALCULATED POWER: 397.540 W
 MAX ADMISIBLE POWER: 554.240 W

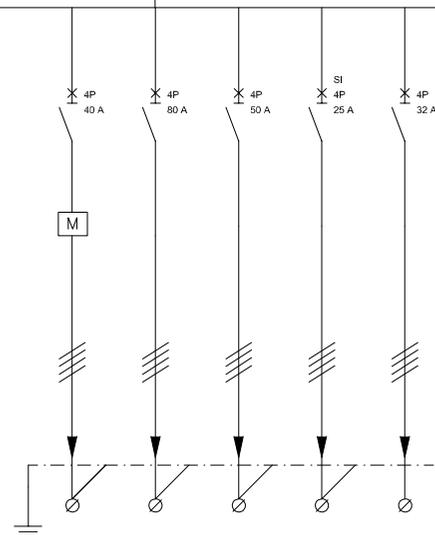
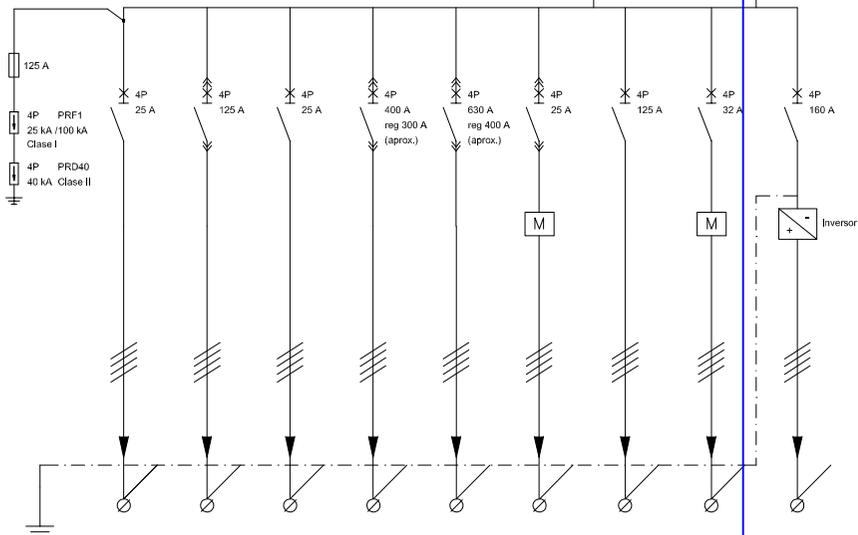
NORMAL BUSBAR 400 V 1000 A 50 kA

H2 FUEL CELL CONNECTION

SWITCHED BUSBAR

400 V 800 A 36 kA

LEGEND	
	SWITCH DISCONNECTOR nPOLES/AMPERES
	MAGNETO THERMIC AUTOMATIC CIRCUIT BREAKER
	WITHDRAWABLE AUTOMATIC CIRCUIT BREAKER
	AUTOMATIC CIRCUIT BREAKER WITH RESIDUAL DEVICE
	AUTOMATIC CIRCUIT BREAKER WITH RESIDUAL BLOCK DEVICE
	MOTOR PROTECTION CONTACT
	CONTACTOR
	EARTH
	INCOMING / OUTGOING FEEDING OR DIRECT CONNECTION WITH BUSBARS
	POWER TERMINAL



REFERENCE	SC OF	SC PB	SC P1	SC INST P1	COMP REACT	SC LC	SC PASARELA	SC CAF	H2 FC
TAG	SUBCUADRO OFICINAS	SUBCUADRO PLANTA BAJA	SUBCUADRO PLANTA PRIMERA	SUBCUADRO C.INSTALACION P1	COMP.REACTIVA VARSET 240 kVAr	SUBCUADRO LOCAL COMERCIAL	SUBCUADRO PASARELA	SUBCUADRO BAR CAFETERIA	H2 FUEL CELL
POWER (CALC) (W)	5.435	74.069	8.860	122.340	-	7.020	80.000	15.000	100.000
CURRENT (CALC) (A)	12,33	106,91	12,79	176,59	-	10,30	115,47	21,65	144,34
LENGHT (M)	46	8	42	51	8	21	8	43	TO BE DEFINED LATER
SECTION (mm ²)	6	50	6	150	2 x 120	6	50	10	4 x 150 x T mm ²
CABLE TYPE	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV
-	2,92	0,79	3,76	3,48	-	1,65	0,57	2,88	TO BE DEFINED LATER
-	0,73	0,20	0,94	0,87	-	0,41	0,14	0,72	TO BE DEFINED LATER
PIPE DIAMETER (mm)	25	50	25	63	160	25	63	32	160

REFERENCE	SC FACT	SC CAF	SC PB CONM	SC P1 CONM	SC ASC
TAG	SUBCUADRO FACTURACION	SUBCUADRO P.BAJA CONMUTADO	SUBCUADRO P.PRIMERA CONMUTADO	SUBCUADRO ASCENSOR	SUBCUADRO C.INSTALACION PB
POWER (CALC) (W)	30.670	41.665	35.576	5900	17.279
CURRENT (CALC) (A)	44,27	60,14	51,35	8,52	24,94
LENGHT (M)	54	8	42	52	38
SECTION (mm ²)	16	25	25	6	10
CABLE TYPE	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV	RZ1-K 0,6/1 kV
-	3,01	0,75	2,96	2,26	3,57
-	0,75	0,19	0,74	0,57	0,89
PIPE DIAMETER (mm)	40	50	50	25	32

H2 fuel cell system EM4 Balearic Port

OWNER:

DRAWING NAME:

Interconnecting single Line diagram



SIZE A3
 SCALE -

REV.	DATE	DESCRIPTION	DESIGNED	CHECKED	APPROVED
0	17-12-21	FOR INFORMATION	D.B.B.	R.N.I.	J.S.U.

DESIGNER:

IDOM

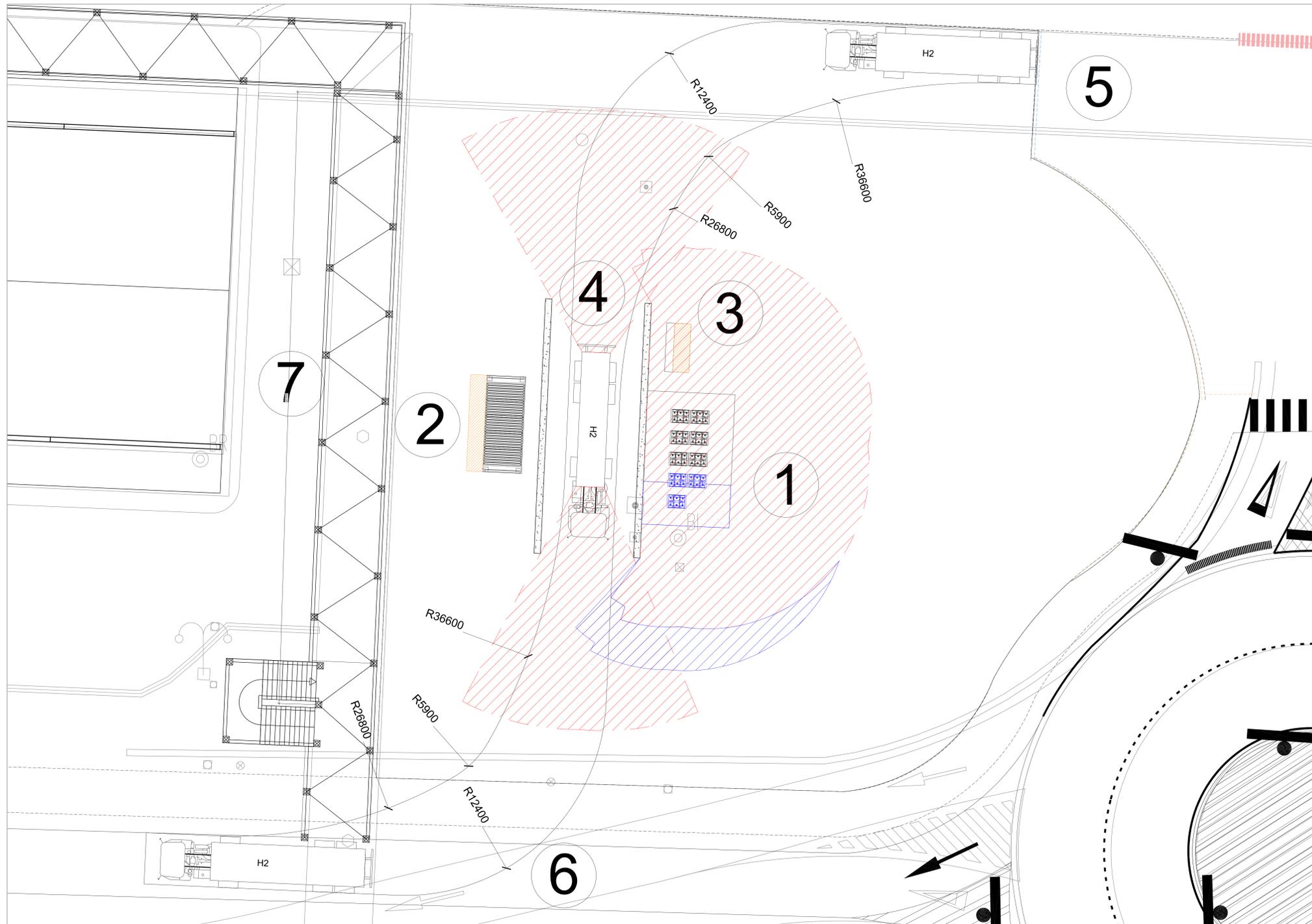
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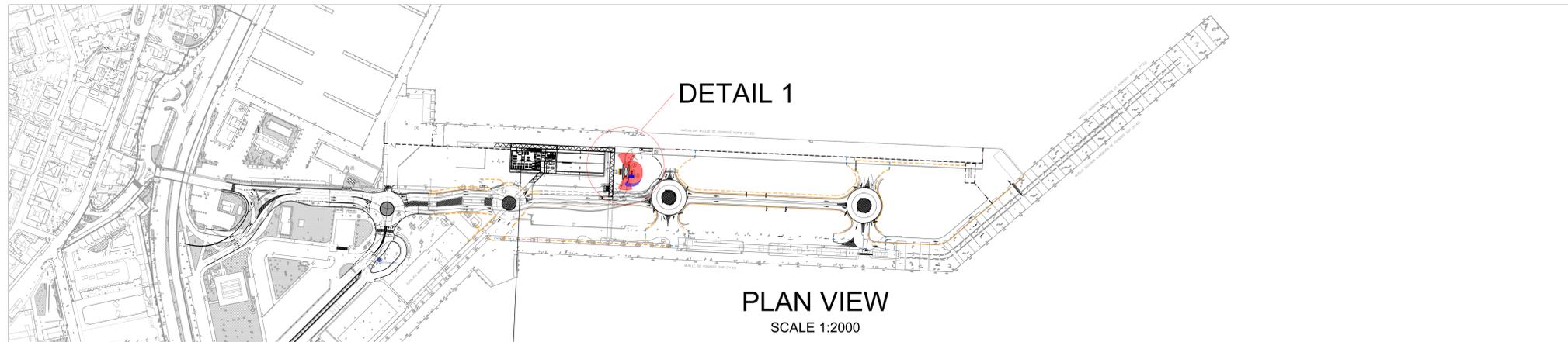
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NEXT: -

IDOM



DETAIL 1
SCALE 1:100



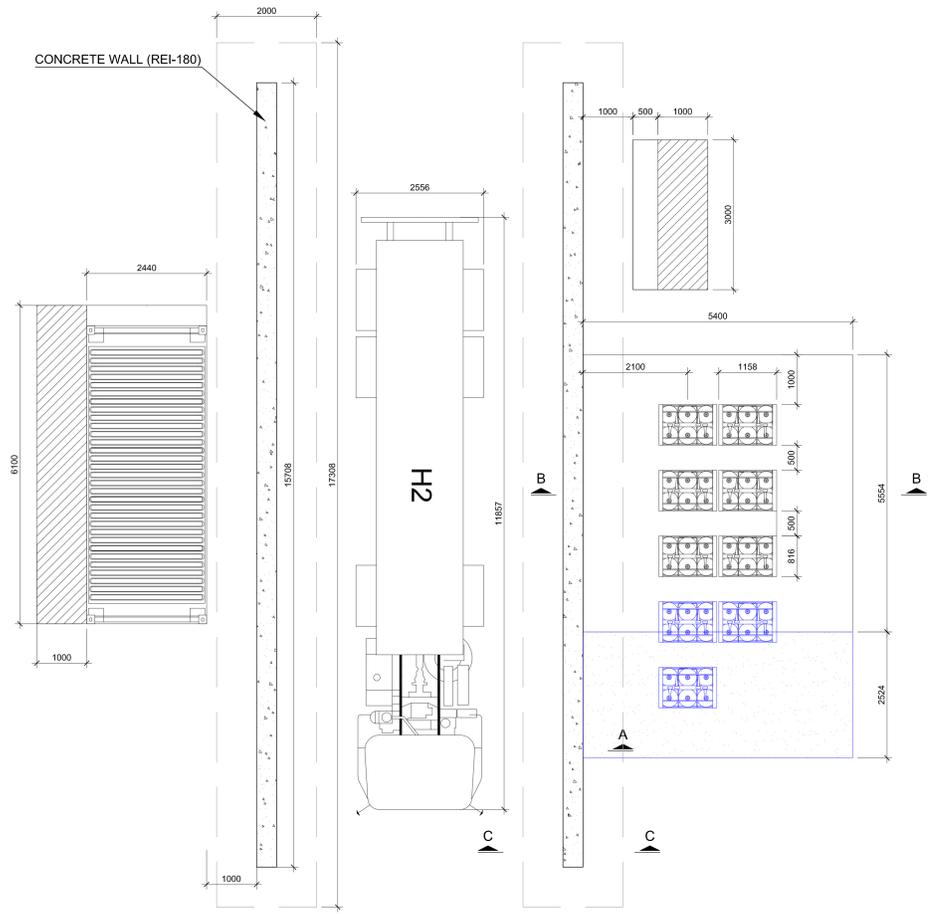
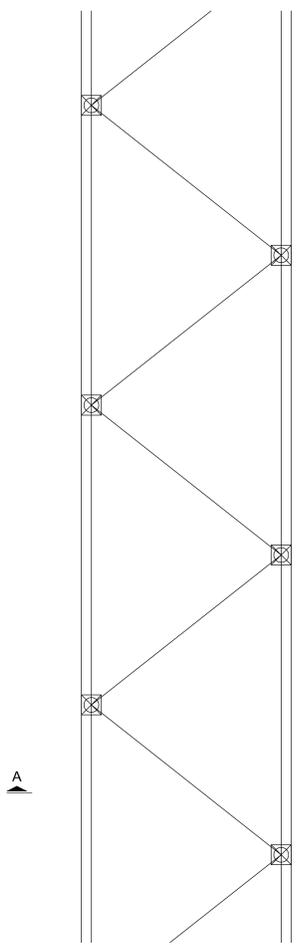
PLAN VIEW
SCALE 1:2000

Note: In case the storage is increased, the Harardous Area will be the sum of the red area and the blue area.

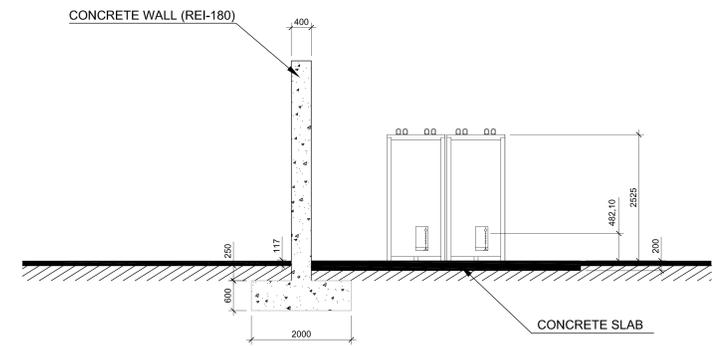
LEGEND	
	Extra slab required if the storage is increased
	Extra hazardous area required if the storage is increased
	Hazardous Area
	Maintenance Area

ITEM	DESCRIPTION
1	H2 storage
2	H2 fuel cell
3	Discharge panel (filtering and control)
4	H2 discharge bay
5	Entrance
6	Exit
7	Travelers runway

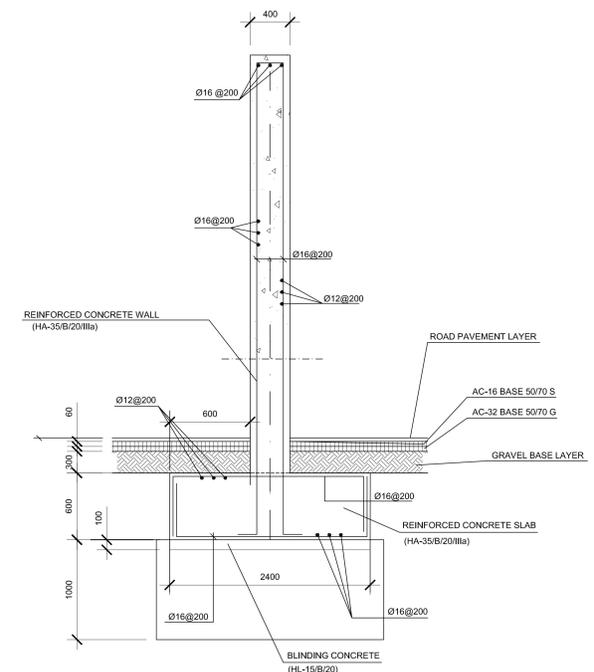
OWNER'S / OWNER'S ENGINEER'S STAMP	EPC CONTRACTOR'S STAMP																								
SIGNATURE	SIGNATURE																								
OWNER:																									
OWNER'S ENGINEER:																									
EPC CONTRACTOR:																									
DESIGNER:																									
IDOM																									
PROJECT: H2 fuel cell system EM4 Balearic Port-																									
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REV.	DATE	DESCRIPTION	DESIGNED	CHECKED	APPROVED																				
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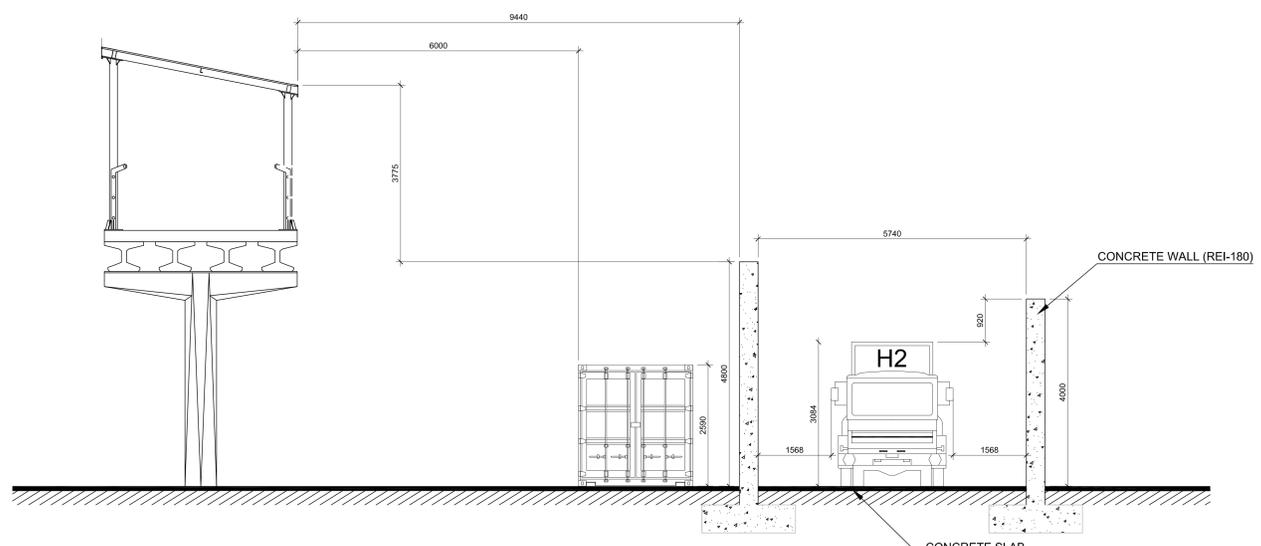
PLANT VIEW
ESCALA 1:50



SECTION B-B
ESCALA 1:50



SECTION C-C
ESCALA 1:25



SECTION A-A
ESCALA 1:50

LEGEND

Extra slab required if the storage is increased

OWNER'S / OWNER'S ENGINEER STAMP		EPC CONTRACTOR'S STAMP																			
SIGNATURE		SIGNATURE																			
OWNER:																					
OWNER'S ENGINEER:																					
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DESIGNER:																					
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		NEXT: -																			
DRAWING NAME:		General lay out and hazardous areas																			
DOCUMENT OWNER: IDOM																					



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