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WP4 – "Demonstration and Monitoring"
D4.1 – "Best practices and measures for the installation of the FC gensets in demonstrator venues for future replication"

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Executive Summary

This deliverable was prepared within the framework of Work Package 4 – Demonstration and Monitoring and it is the first report of such WP, containing relevant information to guide the demonstration campaign from an operative and permitting point of view.

It contains the outcomes of an overall assessment of existing regulatory framework and technical normative which the EVERYWH2ERE gensets should be compliant to in order to properly and safely operate.

This work has been realized under the responsibility of RINA-C with the supervision of ENVI as WP4 leader and the main inputs and contribution of FHA/ACC/D1 as responsible of the demonstration campaigns respectively in Spain, in construction sites and music festival linked with the events scheduling; contribution of LINDE mainly for the logistics management and of technological manufacturers for what it concerns the proposition of technological needs/details.

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1. Introduction

This public report is part of H2020-FCH-JU project “EVERYWH2ERE - Making Hydrogen affordable to sustainably operate Everywhere in European cities” and it was prepared within the framework of Work Package 4.

EVERYWH2ERE aims to demonstrate the reliability of using FC technologies in temporary power gensets replacing current state-of-the-art solutions mostly based on diesel engines, thus opening a niche but relevant market for FC technologies. During the whole project 8 PEMFC (4x25 kw and 4x100 kW) equipped containered “plug and play” gensets will be realized and tested through a pan-European demonstration campaign in a demonstration to market approach. The prototypes will be tested in construction sites, music festivals and urban public events all around Europe, demonstrating their flexibility and their.enlarged lifetime. Demonstration results will be widely promoted and they will be helpful for the promotion of replicability studies (for the use of gensets in further end-user contexts) and for the definition of a commercial roadmap and suitable business model for the complete marketability of the gensets within 2025.

This document, as first deliverable of WP4, represent a set of best practices and guidelines (also inspired by D6.1 and WP1 outcomes) that would be beneficial to demosite campaign responsibles to facilitate the permitting, installation and operation of EVERYWH2ERE gensets according to technical normative and best practices also collected from project stakeholders via bilateral meetings (i.e. CGT Energia in February and November 2019, GoodLive and Wacken Festival Organizer in January 2020).

Generically speaking it is worthy to highlight that RINA-C has redacted a “mini-HAZOP” (as prodromal document to D5.4 Health & Safety analysis of the 25 and 100 kW gensets) that will be included in “EVERYWH2ERE DEMOKIT” (to be described in D4.3) to facilitate the permitting aspects for demosite supervisor and managers (both in construction sites and temporary events).

Such document, which presents a brief risk assessment and relevant regulatory framework to be taken into account, is included as ANNEX 1 to this document.

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2. Guidelines for FC Based Gensets operation in Construction Sites

In this chapter, guidelines related to the operation of EVERYWH2ERE Gensets in construction sites are presented. They have been redacted by RINA-C according to its worldwide expertise as project manager and construction site supervisor.
Such guidelines contains mostly aspects related to installation and management of hazardous gases and pressurized equipment in construction sites. Health and Safety aspects are also reported in ANNEX 1.
As RINA-C and ACC has a strong sensibility to sustainable construction, a paragraph related to the functional advantage of manageing FC based gensets in construction sites has been added, also considering that ACC is aiming to achieve the BREEAM certification for the Alicante demosite.
Such analysis has been inspired by D5.1 contents.

2.1 General guidelines for installation and management of temporary power gensets in construction sites

The construction site is an extremely complex environment, composed of multiple unitary operations included in the "construction operation system". In light of that, each construction site has the conditions to be a "unicum" and the reasons can be conditioned by several factors as following summarized:

- The context in which the organization operates (the construction site in a small city is different from a construction site for the same activity in a large city);
- The type of activities that need to be done (building a road is different than build a railway)
- Involved Organizations and the contract structure (a contract Design/Build with a General Contractor is different than implementing the same project splitting the contract into small and medium sub-projects);
- The types of equipment and the construction techniques used (building a tunnel with classical excavation methodology is different than building it with TBM).

All these factors must be assessed in their complexity by the organizations involved in the projects within a Health & Safety Risk Assessment according to the European level by Directive 92/57 / EEC "implementation of minimum Safety and Health requirements at temporary or mobile construction sites ".

2.2 General guidelines for installation and management of pressurized equipment in construction sites

If a piece of pressure equipment fails and bursts violently apart, the results can be devastating to people in its vicinity.

Parts of the equipment could also be propelled over great distances, causing injury and damage to people and buildings hundreds of meters away.

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Assess the risks

You need to assess the levels of risk when working with pressure equipment. The level of risk from the failure of pressure systems and equipment depends on a number of factors including:

- the pressure in the system
- the type of liquid or gas and its properties
- the suitability of the equipment and pipework that contains it
- the age and condition of the equipment
- the complexity and control of its operation
- the prevailing conditions (eg a process carried out at high temperature)
- the knowledge and experience of the people who maintain, test and operate the pressure equipment and systems

For all the Health and Safety and Risk assessment aspects, please always refer to ANNEX 1.

Basic precautions

To reduce the risks you need to know (and act on) some basic precautions:

- Ensure the system can be operated safely, for example without having to climb or struggle through gaps in pipework or structures (site arrangement);
- Be careful when repairing or modifying a pressure system. Following a major repair and/or modification, you may need to have the whole system re-examined before allowing the system to come back into use;
- Ensure there is a set of operating instructions for all of the equipment in the system and for the control of the system as a whole, including in emergencies;
- There should be a maintenance programme for the system as a whole. It should take into account the system and equipment age, its uses and the environment in which it is being used;

Written scheme of examination

A written scheme of examination is required for most pressure systems:

- This should be drawn up (or certified as suitable) by a competent person – someone who has the necessary skills, knowledge, and experience to carry out the work safely
- It must cover all protective devices, every pressure vessel and those parts of pipelines and pipework which, if they fail, could be dangerous
- The written scheme must specify the nature and frequency of examinations, and include any special measures that may be needed to prepare a system for a safe examination
- Remember, a statutory examination carried out in line with a written scheme is designed to ensure your pressure system is suitable for your intended use. It is not a substitute for regular and routine maintenance

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2.3 General guidelines for installation and management of hazardous and flammable gases in construction sites

Fires can and do kill, injure and cause serious human suffering and financial loss. The potential dangers are particularly severe on many construction sites, where high-risk activities such as hot work are frequently combined with circumstances where fires can spread quickly and escape may be difficult.

Construction fire safety needs to be managed from the earliest stages of design and procurement and needs to address the risks both to site workers and to site neighbors. This may mean rejecting proposals for construction methods and materials in a specific location, based on the potential for serious consequences from any fire during the construction stage, or planning additional, sometimes expensive or difficult, mitigation methods if a specific design or method is not to be changed. It is essential that fire safety measures are considered throughout all stages of the procurement and design process and implemented effectively during the construction phase.

The Construction Health and Safety Regulations also place duties on duty holders in relation to fire safety.
In outline, the European Legislation requires that those with control over construction work must demonstrate that they have:
- recognized the risks in their workplaces;
- considered who will be affected;
- assessed the extent of the risks;
- come to an informed decision on the necessary action to reduce them; and
-ensured that the actions decided are implemented.

In general, the regulations require a suitable and sufficient fire risk assessment to be carried out by a responsible person. Frequently, the local regulations require that the fire risk assessment will be submitted to the local fire department.
In general, preventive engagement with the local fire department is suggested to understand if a specific permit needs to be requested to start the works and through what administrative process.

Basic precautions

In addition to the basic precaution for the pressure vessels, to reduce the risks, you need to know (and implement) some basic precautions:

- Ensure the system can be operated safely, for example, make sure that the H_2 cylinders (i.e. the hydrogen bundle provided by the EVERYWH2ERE Genset as well as more generic hydrogen bootles) are stored in a segregated area with an adequate and visible safety labeling (site organization);
- Ensure that no fire sources are in the risk areas;

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- Ensure that fire extinguish equipment are in place according to the fire risk assessment. According to the local legislation, a maintenance programme for the fire extinguishing equipment/system should be planned, implemented and recorded.

Written scheme of examination

In addition to the examination items to the pressure vessels, the following examination items are required to check:

- all protective devices, fire extinguishes equipment and systems (where applicable),
- A statutory examination carried out in line with a written scheme is designed to ensure the system conditions are suitable for the intended use.

2.4 How low carbon generators can be evaluated in building sustainability protocols

Within this section the deliverable explores the relationship between low carbon generators sustainability advantages during the construction stage and the most advanced and internationally recognized sustainability protocol for the built environment.

The analysis includes a short overview of LEED and BREEAM certification protocols, the identification of the way the protocols consider the potential benefit of adopting low carbon generators and presents the comparison in terms of CO_2 emissions between a traditional diesel generator and H_2 fuel cells power systems.

Setting targets for the construction stage is currently quite complex and with significant uncertainty, a lot of effort is still put in the data collection in order to set reliable baselines.

As an example of such studies, the “Emission-reduction potential of fossil-and emission-free building and construction sites” report by the Climate Agency, City of Oslo (10078671-R-01-A - 2018-04-27) provides the overview of the total energy demand and emissions of three types of construction sites in total and per construction contract millions of krones (1 krone = 0.100 euro).

Table 1 Overview of the total energy demand and emissions of three types of construction sites in total and per construction contract millions of krones (from “Emission-reduction potential of fossil- and emission-free building and construction sites” – Climate Agency, City Of Oslo10078671-R-01-A - 2018-04-27)

Total energy demand and emissions of three types of construction sites			
Project		Energy demand (kWh)	CO2e (kg)
Water & Sewage project	In total	149.000	131.000
	Per M€	53.000	47.000
Small transport project	In total	26.000	23.000
	Per M€	25.000	23.000
Large transport project	In total	348.000	308.000
	Per M€	7.000	6.000

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Size and type of project can change significantly the CO_2e emissions per M€, in addition, in the same report the uncertainty of CO_2e emissions from building and construction activities in Oslo Municipality account for a range between 44.300 and 122.000 tonnes of CO_2e per year.

2.4.1 BREEAM protocol

BREEAM (Building Research Establishment's Environmental Assessment Method) is an internationally recognised measure and mark of a building's sustainable qualities. Since its launch in 1990, BREEAM has certified over a quarter of a million buildings and is now active in more than 50 countries around the world.

BREEAM works to raise awareness amongst owners, occupants, designers and operators of the benefits of taking a life cycle approach to sustainability. It also helps them to successfully and cost effectively adopts solutions.

Using independent, licensed assessors such as those included in the RINA staff, BREEAM examines scientifically based criteria covering a range of issues in sections that evaluate

- management processes;
- health and wellbeing;
- energy;
- transport;
- water use,
- materials;
- waste;
- land use and ecology;
- pollution.

BREEAM challenges the perception still held by many that good quality, sustainable constructions are significantly more costly to design and build than those that simply adhere to mandatory (regulatory) requirements.

A growing body of research evidence demonstrates that sustainable options often add little or no capital cost to a development project. Where they do incur additional costs, these can frequently be paid back through lower running expenses and ultimately lead to savings over the life of the building.

Research studies have also highlighted the enhanced value and quality of sustainable constructions. Achieving the standards required by BREEAM requires careful planning, design, specification and detailing, and a good working relationship between the client and project team.

2.4.2 LEED protocol

Developed by the U.S. Green Building Council, LEED (Leadership in Energy & Environmental design) is a framework for identifying, implementing, and measuring green building and neighbourhood design, construction, operations, and maintenance. LEED is a voluntary, market driven, consensus-based tool that serves as a guideline and assessment mechanism. LEED rating systems address commercial, institutional, and residential buildings and neighbourhood developments. LEED seeks to optimize the use of natural resources, promote regenerative and restorative strategies, maximize the positive and minimize the negative environmental and human health consequences of the construction industry, and provide high-quality indoor environments for building occupants.

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LEED is designed to address environmental challenges while responding to the needs of a competitive market. LEED gives building owners and operators the tools they need to immediately improve both building performance and the bottom line while providing healthful indoor spaces for a building's occupants. LEED-certified buildings are designed to deliver the following benefits:

- lower operating costs and increased asset value;
- reduced waste sent to landfills;
- energy and water conservation;
- more healthful and productive environment for occupants;
- reduction of greenhouse gas emission.

The LEED rating systems aim to promote a transformation of the construction industry through strategies designed to achieve seven goals:

- to reverse contribution to global climate change;
- to enhance individual human health and well-being;
- to protect and restore water resources;
- to protect, enhance, and restore biodiversity and ecosystem services;
- to promote sustainable and regenerative material resources cycles;
- to build a greener economy;
- to enhance social equity, environmental justice, community health, and quality of life.

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- to protect, enhance, and restore biodiversity and ecosystem services;
- to promote sustainable and regenerative material resources cycles;
- to build a greener economy;
- to enhance social equity, environmental justice, community health, and quality of life.

The LEED for Building Design and Construction (LEED BD+C) rating system adaptations address the design and construction activities related to new constructions and major renovations.

Achieving LEED certification requires satisfying prerequisites and earning a minimum number of credits in the following categories:

- Integrative Process (IP)
- Location and Transportation (LT)
- Sustainable Sites (SS)
- Water Efficiency (WE)
- Energy and Atmosphere (EA)
- Materials and Resources (MR)
- Indoor Environmental Quality (EQ)

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- Innovation (IN)
- Regional Priority (PR)

2.4.3 Construction sites impacts in LEED protocols

The LEED protocols considers an overall impact of the construction activities in the Sustainable Sites (SS) category, but no direct evaluation of the emissions related to the construction activities is included in the protocol.

2.4.4 Construction sites impacts in BREEAM international New Construction 2016

The BREEAM protocol BREEAM international New Construction 2016 takes into account the constructions in the category "Management", oriented to the adoption of sustainable management practices in connection with design, construction, commissioning, handover and aftercare activities by means of the issue "Man 03 Responsible construction practices" (Man 03).

The Man 03 recognizes and encourages construction sites, which are managed in an environmentally and socially considerate, responsible and accountable manner.

Specifically, the carbon emissions are taken into account for two main aspects:

The onsite energy consumption: it is required to monitor and record data of the site energy consumption in kWh (and where relevant, litres of fuel used) as a result of the use of construction plant, equipment (mobile and fixed) and site accommodation. The total carbon dioxide emissions (total kg CO_2/project value) from the construction process are to be reported via the dedicated BREEAM assessment scoring and Reporting tool;

Transport of construction materials and waste: it is required to record transport of materials from the factory gate to the building site, including any transport, intermediate storage and distribution, the transport of construction waste from the construction gate to waste disposal processing or the recovery center gate. The total transport-related carbon dioxide emissions (kgCO_2 eq) data collated for materials and waste, are to be reported via the BREEAM Assessment Scoring and Reporting tool.

As illustrated in the introduction of the section, setting reliable targets for the construction activities related to a specific project is difficult and the main effort is dedicated to the monitoring in order to set future baselines. Following this principle, the BREEAM protocol requires to report the data related both to the onsite energy consumption and the transport of construction materials and waste via the BREEAM Assessment Scoring and Reporting tool for the purposes of potential future BREEAM performance benchmarking.

2.4.5 Traditional diesel generator

Based on the data included in D5.1 the average amount of diesel required by a diesel generator to produce 1kWh is 0,24 kg.

Considering the case of a single genset operating in a construction site for 8 hours a day at full power for 6 days a week for 52 weeks a year, the total electricity production for a 25kW generator and a 100kW is as in Table 2.

Table 2 Annual elecrticity production of a 25kW and 100kW diesel genset

Annual elecrticity production		
	25kW	100kW

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Total production (kWh)	62.400	249.600

According to “UK Government GHG Conversion Factors for Company Reporting” version 1,2 – 2019 the CO_2e emission of a tonne of diesel is 3.088,23kg. Therefore, the annual CO_2 emissions for a 25kW generator and a 100kW is as in Table 3

Table 3 CO2 annual emission of a 25kW and 100kW diesel genset

CO2 emissions		
	25kW	100kW
Total CO2 emissions (kg CO2e/year)	48.0006	192.025

The data in Table 2 does not consider the emission due to the diesel refueling logistic due to the very extended network of diesel fuel stations.

2.4.6 FC Based Gensets

In order to evaluate the CO_2 emissions of the FC Based in accordance with the BREEAM protocol two main contributions are considered:

- direct CO_2 emissions due to H_2 consumption;
- CO_2 emission due to the logistics between the construction site and the Hydrogen Refueling Station (HRS).

Direct CO_2 emissions due to H_2 consumption

The H_2 consumption both for the 025 system and 100 system are calculated considering the operating hours at full power for the tanks provided for each system (3 tanks for the 025 system and 9 tanks for the 100 system).

Table 4 FCPS (Fuel Cell Power System) main specifications ralted to H2 consumption[1]

FCPS (Fuel Cell Power System)		
	025 system	100 system
Power genset, kW	25	100
H_2 consumed (g/s) at max power	0.64	2.2
H_2 consumed (kg/h)	2.304	7.92
Tanks/racks	3	9
Vol. BB (m3)	0.66	1.98
Vol. @350bar (m^3)	231	693
Storage H_2 (kg) @20°C	14.4	43.2
Single tank weight (kg)	188	188
Total tanks weight (kg)	564	1692

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[1] Values related to D1.7

Operating hours at full power (h)	8.22	7.18

According the data in Table 4 the H_2 consumption for each system is as following:

- 025 system: 0.092 kg/kWh
- 100 system: 0.0792 kg/kWh

Since it is expected that the hydrogen production would have a big impact on the CO_2e emissions, in the D5.1 – “Preliminary screening of the environmental impacts of the FC genset” three different cases for hydrogen production have been considered:

- hydrogen produced from natural gas by steam methane reforming (SMR);
- hydrogen produced with electrolysis with a proton exchange membrane (E-PEM) using average European market electricity;
- hydrogen produced similarly to FC2 but with renewable energy (E-PEM-R).

Table 5 CO_2 emissions per MWh elecrticity produced H_2 (SMR, E-PEM and E-PEM-R) (data elabarotaed fromD.5.1 evaluation)

CO_2e emissions by FCPS		
H_2 production process	unit	kg CO_2e
SMR	MWh	517
E-PEM	MWh	1589
E-PEM-R	MWh	104

Considering the case of a single genset operating in a construction site for 8 hours a day at full power for 6 days a week for 52 weeks a year, the total electricity production is as in Table 6

Table 6 Annual elecrticity production of a 25kW and 100kW diesel genset

Annual elecrticity production		
	025 system	100system
Total production	17.333	17.333

Therefore the CO_2 emissions for the 025system and 100system are as indicated in Table 7

Table 7 CO2 emissions in a year for 025system and 100system

CO_2 emissions by FCPS		
H_2 production process	025 system (kg CO2e/year)	100 system (kg CO2e/year)
SMR	32.260,8	129.043,2
E-PEM	99.153,6	396.614,4
E-PEM-R	6.489,6	25.958,4

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CO_2 emission due to the H_2 refueling logistics

The configuration of the H_2 fuel tanks of the 025system and and the 100system are as following (see also Table 4):

- 025system: 3 tanks with a total H_2 capacity of 18.9 kg and total weight of 564 kg (empty tanks) able to cover the consuption of the 25kW genset for approx. a working day (8.22h)
- 100system: 9 tanks with a total H_2 capacity of 56.8 kg and total weight of 1692 kg (empty tanks) able to cover the consuption of the 100kW genset for approx. a working day (7.18h)

The H_2 refuelling depends on the availability of an Hydrogen Refueling Station (HRS).

Considering EU HRS availability (that has been estimated according to what present in https://h2-map.eu/) the average distance between a construction site using H_2 gensets and an HRS could be considered around 100km (optimistic scenario).

Figure 1 Hydrogen Refuelling Station Map[2] present in https://h2-map.eu/

Two scenarios have been defined for the refuelling of the genset:

- Scenario 1: for the first scenario, it is assumed that the refuelling is made by means of a van (with the capacity of carrying H_2 fuel) coming to the construction site from a HRS on a daily basis, the refuelling of the tanks is done on the construction site;

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[2] The HRSs shown on the map do not represent all the locations where the EVERYWH2ERE storage bundles could be filled, but an overview of potential hydrogen refuelling points that has been used as reference for the assessment of potential refuelling procedures.

- Scenario 2: for the second scenario it is assumed that a van collects on a weekly basis the H_2 tanks, the refuelling is done at the HRS and the tanks are taken back to the construction site.

The “UK Government GHG Conversion Factors for Company Reporting” version 1,2 – 2019 developed by the Department for Business, Energy & Industrial Strategy and the Department for Environment, Food & Rural Affairs has been considered as the reference for the calculation of CO_2 emission of the 2 scenarios above illustrated.
Freighting goods factors are used specifically for the shipment of goods through a third-party company. Factors are available for a whole vehicle's worth of goods or per tonne of goods shipped via a specific transport mode. The Table 8 indicates the CO_2 emissions value per km, mile and an equivalent measure of one tonne of transported goods over 1 km for Class 1 to Class 3 vans.

Table 8 CO_2 emissions for vans (source UK Government GHG Conversion Factors for Company Reporting)

Vans C							
			Diesel	Petrol	CNG	LPG	Battery Electric Vehicle
	Type	Unit	kg CO2e	kg CO2e	kg CO2e	kg CO2e	kg CO2e
Vans	Class I (up to 1.305 tonnes)	tonne.km	0,83071	1,21097			0,31405
		km	0,14955	0,23741			0,04598
		miles	0,24068	0,38207			0,07399
	Class II (1.305 to 1.74 tonnes)	tonne.km	0,62316	0,75887			0,36798
		km	0,19455	0,22833			0,06275
		miles	0,3131	0,36747			0,10099
	Class III (1.74 to 3.5 tonnes)	tonne.km	0,61429	0,85852			0,29565
		km	0,27777	0,3846			0,09141
		miles	0,44703	0,61896			0,14711
	Average (up to 3.5 tonnes)	tonne.km	0,62001	0,7696			0,36732
		km	0,25213	0,23645	0,61038	0,67106	0,06285
		miles	0,40576	0,38053	0,2478	0,27244	0,10115

Considering for the scenario 1 a Class 3 diesel van for a daily distance of 200 km and for the Scenario 2 a weekly load of 3384 kg trasnported by Class 2 diesel vans for the 025 system and a weekly load of 10152 kg trasnported by Class 3 diesel vans for the 100system, the CO_2 emissions due to H_2 refuelling logistics are as in Table 9.

Table 9 CO_2 emissions due to the H2 refuelling logistics for Scenario 1 and 2 for 25 kW system and 100 kW system

CO_2 emissions due to the H_2 refuelling (kg CO_2e/year)		
	025 system	100system

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Scenario 1	17.333	17.333
Scenario 2	109.656	324.286

Total emissions of CO_2 (direct emissions + refueling logistic)

Combing the CO_2 direct emissions for the different H_2 production process and the emission due to the H_2 refueling according to Scenario and Scenario 2 the results are included in Table 10 for the 025system and in Table 11 for the 100system.

Table 10 Overall CO_2 emissions for 025system

Overall CO2 emissions for 025system (Kg CO2e/year)		
H2 production process	Scenario 1	Scenario 2
SMR	49.594	141.917
E-PEM	116.487	208.807
E-PEM-R	23.823	116.147

Table 11 Overall CO_2 emissions for 100system

Overall CO2 emissions for 100system (Kg CO2e/year)		
H2 production process	Scenario 1	Scenario 2
SMR	146.376	453.329
E-PEM	413.947	720.900
E-PEM-R	43.291	350.244

2.4.7 Comparison between traditional fuel generators and FV based gensets

Comparing the results illustrated in the previous section in line with the BREEAM approach (direct emissions + emissions related to the logistic) the following conclusions can be drawn:

- the H_2 production process and the logistic can influence in very significant way the overall CO_2e emissions of an FCPS on the construction site
- the CO_2e emissions reduction due to the logistics could be reduced by both extending the HRS network and foster the adoption of low emission vehicles
- where the logistic and the H_2 process production are carefully planned the FCPS can provide a significant improvement against a traditional diesel generator (Table 12)
- even if at the moment the focus of the scientific studies and sustainability protocols is more on the monitoring of CO_2e emissions, in the near future targets will be set and overall CO_2e obtained also by the adoption of FCPS will be awarded

Table 12 Comparison between FCPS (SMR, E-PEM and E-PEM-R)and traditional diesel generators for logistic scenario 1 (on site refueling)

Comparison between FCPS and traditional diesel generators (Kg CO2e/year)			
025system	25kW diesel generator	100system	100kW diesel generator

49.594	48.000	146.376	192.025
116.487	48.000	413.947	192.025
23.823	48.000	43.291	192.025

Note: thet the green color means that the FCPS option has a lower CO2/year impact than the traditional diesel generator, the yellow color means that the FCPS option is very similar to the traditional diesel generator, the red color means that the traditional diesel generator has a lower CO2/year impact than the FCPS option

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3. Guidelines for FC Based Gensets operation in Music Festivals and Temporary Events

Generically speaking, when we talk about temporary power generation for events and music festivals, it is relevant to consider a 3-steps process:

a) Planning and identifying the most suitable power solution (size of gensets, type of gensets, etc);
b) Being authorized to operate the gensets/temporary power provision according to health and safety normative and local normatives (authorization usually released by a local committee composed by local municipal/regional environmental authotiry and fire department);
c) Being sure to install and operate the gensets/temporary power provision according to health and safety normative and local normatives

Such three phases will be described here below in the next subchapters.

3.1 Planning and identifying the most suitable power solution

Once designing and planning power supply for a temporary provision in an event, the following simple guidelines should be considered:

a) Figuring out the Power Source

When deciding what generator to use for an event, power capacity and electric output needs are the two most important aspects to be evaluated.

There are a few guidelines to be followed to see what range you should look for, starting from the following steps:

1. Checklist – Write down all the items that you plan on using with the generator.
2. Wattage – Verify the power capacity (kW/kVA) per each item.
3. Evaluate overall power capacity needed
4. Consider distribution and reactive power losses – Multiply the overall capacity calculated at point 3 per a safety factor 1.2

In this way the maximum power capacity required to the genset/power supply unit can be identified: this value will be useful to choose the power capacity of the genset/power supply unit to be used.

This is the traditional approach that rental companies[3] uses.

b) Choose the type of power supply in the events

Currently event organizer can receive power from different type of technological solutions: the two most common (with relevant guidelines to operate them) are hereby presented.

Mains Power

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[3] As EVERYWH2ERE consortium had the opportunity to verify via project stakeholders as CGT Energia

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'Mains' refers to power from 'the National grid'. It is obvious to state that for events it is always suggestedto use mains power where possible. The reason for this is that it is reliable in the most of EU countries, readily available and has a very low cost/lower environmental impacts compared to diesel generators.

Many event locations have ample power coming into a building, but a common issue is that there is not an appropriate method of attachment/Point of Delivery to the existing system. A building can have lots of power available but it may not be installed in a way that facilitates its access. In these cases it is often possible to negotiate for a dedicated power socket to be installed. Having a socket installed requires various considerations, such as distance from the power distribution board/transformation cabinet, gaining approval from landlords, agreeing on who is covering the cost and sometimes even permission for use in listed buildings.

Generators/gensets

Generators/gensets are machines which produce electricity on their own without the need for attachment to the main grid.

Generators/gensets are usually powered by a diesel engine, but even if reliable, it is always sensible to have a backup in case of failure. Uninterrupted and reliable power is essential for events and a generator breakdown, although unlikely, can mean failure of critical event equipment.

There are several ways of having a backup system. The most effective and reliable is using two generators in synchronisation. This means that both generators work together to create electricity. If one set fails the power continues without any gap in the continuity of the event. This is the ideal solution but requires the use of modern generators with a skilled operator.

The second option is using an 'AMF' or switch-over panel. These systems detect when one generator has failed, starts the other, and switches the power over. These are ideal for building sites or other locations where consistent power is not vital. For events these are in not ideal as it is essential that technical equipment is checked over by a skilled technician before being turned on again. Some equipment needs to be turned on in the correct sequence to avoid any problems.

The third option is a manual change-over. This simply means having one generator working and another sitting next to it, but not connected. With this arrangement a technician needs to manually move all attachments from one generator to the other. If done properly this is a safe and thorough system, but can result in downtime of anywhere from 1-15 minutes depending on the size of event.

It is relevant to state that all these options should be applicable to EVERYWH2ERE Gensets.

It is also worthy to highlight that first EVERYWH2ERE gensets (to be operative since June 2020) will be allowed to operate only “in-island” thus not connected to any type of other genset and/or in connection with the existing grid.

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The following 6 prototypes will be equipped with a different type of power converters and Master Control Unit allowing them to operate "in-grid" mode.

3.2 Being authorized to operate the gensets/temporary power provision according to health and safety normative and local normatives

To properly operate and to be authorized by the local committee/authorities, it is relevant that both the gensets and the fuel storage (whatever it will be, Diesel or hydrogen) are compliant to health and safety directives and to local normatives.

Further than HSE Guidelines described in ANNEX I, strongly related to EVERYWH2ERE Genset and operation, it is relevant that event/demosite manager are aware of health and safety normative for electrical generators for temporary power (§3.2.1 – 3.2.2).

Be compliant to guidelines hereby presented and presenting temporary gensets installation as duly addressing all the points presented here below can facilitate the permitting of gensets by competent local authority in charge of allowing gensets installation and operation.

Once finalized the permitting and design procedure of the temporary power supply layout, a competent power contractor/rental company is used to provide an installation sign off upon completion of the installation. This is an important process for complex systems and acquiring this documentation can be vital for an Event Manager.

The process checks that each area has been installed correctly in a formulated and thorough checklist approach. The signature states that all equipment has been installed properly and safely following here below guidelines and local technical regularoty and normative prescriptions.

3.2.1 General Safety and Usage Guidelines Normative for Generators/gensets

Some "common sense and common use" guidelines[4] to safely and effectively operate gensets/generators can be easily identified, also considering that using a generator incorrectly can lead to dangerous situations. Most of the following guidelines[5] are referred to all type of gensets (so to EVERYWH2ERE ones as well):

- Pay attention to the risks related to gensets exhaust poisoning (i.e. CO, CH_4, H_2 etc.): even if you can't smell exhaust fumes, you may still have been exposed to carbon monoxide or other type of harming exhaust gases from the gensets. It is suggested to consider installing battery-operated dangeorous gases alarms (carbon monoxide, hydrogen etc.). Be sure to read the manufacturer's instructions about potential exhausts and take proper precautions.
- Take proper precautions to risk of electric shock or electrocution.
- Follow HSE aspects to avoid any risk of fire
- Use a portable generator only when necessary, and only to power essential equipment.

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[4] Risk and Hazard Management for Festivals and Events, Peter Wynn-Moylan, 2017

[5] http://www.generator-power.co.uk/hiring-power-generators-outdoor-event/

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- Position generators outdoors and well away from any structure. Running a generator inside any enclosed or partially enclosed structure can lead to dangerous and often fatal levels of pollutant/Exhausts. Keep generators positioned outside and at least 5 metres far from open windows so exhaust does not enter your home/business or a neighboring home/business.
- Keep the generator dry. Operate your generator on a dry surface under an open, canopy-like structure and make sure your hands are dry before touching the generator. Do not use the generator in rainy or wet conditions.
- Disconnect the power coming into your home/business. Before you operate your generator, disconnect your normal source of power. Otherwise, power from your generator could be sent back into the utility company lines, creating a hazardous situation for utility workers.
- Make sure your generator is properly grounded. Grounding generators can help prevent shocks and electrocutions. Refer to EU-OSHA guidelines for grounding requirements for portable generators.
- Plug equipment directly into the generator. Use heavy-duty, outdoor-rated extension cords that are in good working condition and have a wire gauge that can handle the electric load of any connected appliances.
- Do not plug the generator into a wall outlet. Never try to power your house/business by plugging the generator into a wall outlet or the main electrical panel. Only a licensed electrician should connect a generator to a main electrical panel by installing the proper equipment according to local electrical codes. Make sure the electrician installs an approved automatic transfer switch so you can disconnect your home’s wiring from the utility system before you use the generator.
- Maintain an adequate supply of fuel. Know your generator’s rate of fuel consumption at various power output levels. Carefully consider how much fuel you can safely store (also in terms of normative for ATEX/PED in case of pressurized/hazardous gases as hydrogen is) and for how long. Store all fuels in specifically designed containers/areas in a cool, dry, well-ventilated place, away from all potential heat sources.
- Turn the generator off and let it cool before refueling. Use the type of fuel recommended in the manufacturer’s instructions.
- Inspect and maintain your generator regularly. Check aboveground storage tanks, pipes, and valves regularly for cracks and leaks, and replace damaged materials immediately. Purchase a maintenance contract and schedule at least one maintenance service per year.

3.2.2 More detailed electrical safety normative guidelines for Generators/gensets (and more generically for electrical equipment) operation in events

In this paragraph some information are presented to help organisers and others plan, use and manage electrical equipment (among them gensets/generators) at an event safely.

Event organisers, contractors and others using electrical equipment must do all that is reasonably practicable to ensure that electrical installations and equipment at an event are properly selected, installed and maintained so as not to cause death or injury.

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It is recommended to take a look to HSE for entertainers guidelines (i.e. https://www.hse.gov.uk/pubns/indg247.pdf and/or "Electrical safety at places of entertainment General Guidance Note GS50 HSE Books 2013" - www.hse.gov.uk/pubns/gs50.htm)

Planning and managing temporary electrical installations it will be important to consider and keep in mind the following:

On the site

- Layout (performance areas, traders, public areas, access routes etc)
- Power requirements
- Details of and access to any mains (utility) power supply
- Location of any existing overhead power lines or buried cables
- Environmental conditions
- Electrical environment as defined according to technical normative
- Emergency power requirements

At the event

- Timetable of power requirements to avoid overpeak and also to better define the power capacity needed by the event as described in the previous paragraphs
- In case the use of generators its planned, study its connection in islanded/grid mode
- Earthing of the generators
- Routing of temporary overhead or underground cables
- Main isolators controlling the electrical supplies to the stage lighting, sound, special effects, emergency lighting and lifting equipment
- Once evaluating event power needs for genset power capacity evaluation, don't forget to take into account:
  a) Special power supplies for some equipment, eg non-EU/country hosting equipment, hoists, portable tools etc
  b) Electrical requirements for emergency lighting and exit signs
  c) Power supplies for catering equipment, first-aid points, incident control room, CCTV cameras etc
  d) Power supplies for heating or air conditioning
- Also considering the safety normative in the event area and dispositions received by the event permitting authority/fire department, be aware to control and restrict access to electrical installations by unauthorised people
- In case of use and/or integration of renewable power sources and/or generators, be aware to consider electrical safety aspects related to associated equipment such as inverters
- Where possible, locate the main electrical intakes and/or generator enclosures where they are accessible for normal operations or emergencies, but segregated from public areas of the venue. Display danger warning signs around the intake or enclosure. (please take a look to IP aspects in the following)
- To prevent danger, construct or protect electrical equipment that could be exposed to rain or other adverse conditions with suitable and sufficient covers, enclosures or

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shelters. As far as practicable, locate all electrical equipment so that members of the public or unauthorised workers cannot touch it. (please take a look to IP aspects in the following)

Cabling

Electrical incidents and faults are often caused by a not proper maintenance and handling of cabling. Regarding cabling it is suggested to select and rate all cables to meet electrical safety standards and to withstand any unusual environmental or adverse weather conditions.

It s also suggested to route cables to minimise tripping hazards or potential mechanical damage, and in a position that allows them to be safely installed and removed. Give particular care to the position of cable connections.

It is also possible to use cable ramps or similar to protect cables running overground across route ways to help avoid them becoming tripping hazards.

Running cables alongside existing or temporary fence lines is advisable and it is important to segregate vehicle traffic and cable routes wherever possible. If this can't be achieved, you can route the cable by a cable bridge, a supporting catenary or cable ramps.

If the cable is to be routed using a cable bridge or catenary, a height of not less than 5.8m is advisable to make sure that most vehicles can pass beneath it. Advisory notices, warning of the location of the overhead cables, should be clearly displayed in both directions. Use fences to segregate roadways from overhead cables running parallel to the roadway to prevent inadvertent contact.

If it is needed to run cables underground, ideally use cable ducts or pipe, suitably sized to accommodate connectors. Do not leave cable joints underground (please follow the further guidance on burying cable according to National technical electric normative).

Water/Weather protection and IP rating

Needless to say, water and electricity don’t make good bedfellows to generators and electric equipment. For all outdoor or covered events in the EU special consideration must be given to water and the risks it poses. It should be assumed that a torrential downpour is possible at any time of year. This assumption means that all equipment specified should be suitably protected in order to safely continue to function in the event of rain. The containerized structure of the EVERYWH2ERE Gensets goes in this direction.

Equipment that is used outdoors and is otherwise unprotected from the elements should have an appropriate IP rating. IP ratings relate to how well electrical equipment can withstand dust and water. Usually a piece of electrical equipment will be stamped with an IP (Ingress Protection) rating if it has one, or the rating can be found in the documentation. The protection class after EN60529 are indicated by short symbols that consist of the two code letters IP and a code numeral for the amount of the protection. It takes the format of ‘IPXX’ where ‘XX’ is a

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two digit number. The first digit is how well protected the equipment is from solids e.g. dust on a scale of 1-6, and the second is how well it is protected from liquids on a scale of 1-9. The larger the value of each digit, the greater the protection. As an example, a product rated IP54 would be better protected against environmental factors than another similar product rated as IP42.

Table 13 IP table rating

IP..	**First digit:** **Ingress of solid objects**	**Second digit:** **Ingress of liquids**
0	No protection	No protection
1	Protected against solid objects over 50mm e.g. hands, large tools.	Protected against vertically falling drops of water or condensation.
2	Protected against solid objects over 12.5mm e.g. hands, large tools.	Protected against falling drops of water, if the case is disposed up to 15 from vertical.
3	Protected against solid objects over 2.5mm e.g. wire, small tools.	Protected against sprays of water from any direction, even if the case is disposed up to 60from vertical.
4	Protected against solid objects over 1.0mm e.g. wires.	Protected against splash water from any direction.
5	Limited protection against dust ingress. (no harmful deposit)	Protected against low pressure water jets from any direction. Limited ingress permitted.
6	Totally protected against dust ingress.	Protected against high pressure water jets from any direction. Limited ingress permitted.
7	N/A	Protected against short periods of immersion in water.
8	N/A	Protected against long, durable periods of immersion in water.
9k	N/A	Protected against close-range high pressure, high temperature spray downs.

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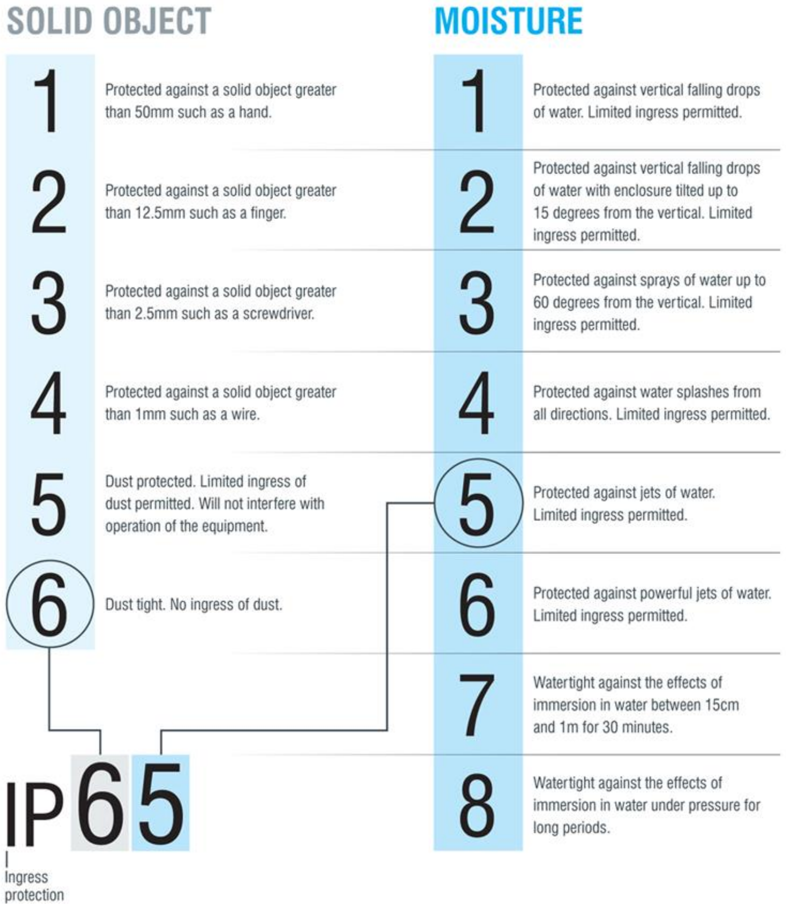
Figure 2 IP rating example



SOLID OBJECT		MOISTURE	
1	Protected against a solid object greater than 50mm such as a hand.	1	Protected against vertical falling drops of water. Limited ingress permitted.
2	Protected against a solid object greater than 12.5mm such as a finger.	2	Protected against vertical falling drops of water with enclosure tilted up to 15 degrees from the vertical. Limited ingress permitted.
3	Protected against a solid object greater than 2.5mm such as a screwdriver.	3	Protected against sprays of water up to 60 degrees from the vertical. Limited ingress permitted.
4	Protected against a solid object greater than 1mm such as a wire.	4	Protected against water splashes from all directions. Limited ingress permitted.
5	Dust protected. Limited ingress of dust permitted. Will not interfere with operation of the equipment.	5	Protected against jets of water. Limited ingress permitted.
6	Dust tight. No ingress of dust.	6	Protected against powerful jets of water. Limited ingress permitted.
		7	Watertight against the effects of immersion in water between 15cm and 1m for 30 minutes.
		8	Watertight against the effects of immersion in water under pressure for long periods.

Breakers

‘Breakers’ can refer to many types of circuit protection device. Broadly speaking, they work in the same way as a fuse insofar as that if current beyond their rated amount is drawn they will 'trip'. This causes the power to that supply to cut out immediately to avoid any electrocution or fire.

Breakers can be tripped because of over-loading, but also because of a 'short' in a system, including light bulbs blowing. Breakers tripping is not uncommon and in a well-designed power distribution system (particularly a small one like a temporary event circuit powered by a generator) should not cause major issues.

It is good practice to design event power system so that high power draw applications (such as catering and technical production) are isolated from one another, in order to avoid that temporary power extra-demand peak typical of certain type of application can cause black-out.

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RCDs

RCD stands for Residual Current Device and it is probably the single most important safety device in an electrical system. It will 'trip' in the same way as a breaker when triggered. RCDs work by detecting when current is ‘leaking’ out of a system. This situation can occur when there has been a fault and current is feeding to ground (or into a person).

RCDs come in different sensitivities (30mA, 100mA and 300mA for most applications) and this sensitivity relates to how much current has to be disappearing before they trip. In the EU any power supply that is feeding appliances in contact with people should have a 30mA RCD on it. This means that if more than 30mA is going astray the power trips.

RCDs and breakers are often combined into the same unit.

Earthing/grounding

An 'earth' is essentially an additional wiring system that runs throughout a power system that ultimately connects into the ground via long copper rod, underground grid or similar.

The idea behind an earth is that if there is a power fault the current will be directed into the ground rather than into people. In such a case an RCD or breaker should trip, indicating to the user that a problem needs investigating.

Often the cable route from appliance to ground can be very long and contains a great deal of ‘resistance’. For this reason installers will often need to conduct tests to ensure that the route to ground is good. In the case of EVERYWH2ERE Gensets earthing/grounding aspects (and how to exploit local infrastructure to facilitate this process) are duly presented in D1.7

PAT Testing

PAT stands for Portable Appliance Testing. This is an annual test procedure that should be carried out on all equipment that distributes or uses electricity for temporary events .

Whilst not a legal requirement in the EU, it is generally accepted that PAT testing is the best way of fulfilling legal obligation that all equipment used on event is safe. Normally it is possible to request from any supplier of electrical equipment that they supply proof of their electrical testing. Safe management of equipment requires annual testing, visual inspection at every use and, most of all, experienced staff and an open culture with a focus on safety.

First FRIEM Validation campaign testing could be used as PAT documents particularly for what it concerns the first demonstration campaign events

3.2.3 Permitting process for temporary events: general approach and importance to be aware of local normative

Thanks to the interaction with project stakeholders (i.e CGT Energia, GoodLive and other events organizer) the consortium had the opportunity to get aware of how authorization and permitting process for temporary gensets is quite similar in all EU countries. Timing and

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procedures are different country by country (i.e. in Italy final confirmation of the allowance to operate of a certain type of genset is usually released few days before the starting of the operation) but should take into account the following aspects, as well as to receive a “GO” regarding all the following aspects:

- Interact with local authority for all the aspects (municipal and/or regional environmental agency) related to genset environmental harmfulness
- Interact with local fire department for all the aspects related to safe storage and operation of the gensets/fuel particularly for what it concerns fuel venting/storage and fire risks
- Interact with local authority for all the aspects related to the proper design of the event in terms of people safety management: please be aware to position gensets and fuel storage in segregated areas and distant to emergency exits and safety assembly points
- Interact with local authority and fire department for what it concerns the design and authorization (also interacting with local DSO and Regulator from fiscal and power/grid compliancy point of view in presence of both mains power connection and gensets) of the event electric layout (positioning of the gensets, cable routing etc.)

In order to facilitate the permitting and authorization to operate of EVERYWH2ERE Gensets, the consortium realized a “DEMOKIT” (to be presented in D4.3) that will facilitate event organizers to ask for and receive required authorization, as well as to present the novelty of the EVERYWH2ERE Gensets and their prototypal, but secure nature.

Furthermore, even if, as described in D4.3, permitting aspects will be on behalf of event organizer (due to the fact that procedures differ country by counry and an overall unique procedure for EVERYWH2ERE genset cannot be identified also due to the fact that a specific technical normative related to hydrogen gensets/temporary power application doesn’t exist) , EVERYWH2ERE consortium commits itself to duly support event organizer during the demonstration campaign.

It is worthy to highlight that (further than compliancy of EVERYWH2ERE Gensets to all guidelines and normative previously described/described in ANNEX I) compliancy of EVERYWH2ERE Gensets to technical normative and guidelines for stationary fuel cell power equipment can be another point to facilitate permitting of operation as well.

Generically speaking all event organizer must be aware of the local (National/regional/municipality) normative and due permitting steps that allow the operation of generators/gensets and present EVERYWH2ERE Gensets following the same approach/procedure.

Considering the novelty of the technology it is recommended to present EVERYWH2ERE gensets in a complete and detailed way, in order to avoid any risk of “permitting authority unawareness/sceptism” that could prevent the demonstration campaign.

EVERYWH2ERE DEMOKIT has been prepared by the consortium at this purpose.

It is worthy to highlight that generator/gensets authorization and permitting are released time by time/location by location/event by event: it is indeed impossible to consider to receive an overall National permitting/authorization for gensets in any of EU countries, considering the uniqueness of each event and of each electric system to be installed to power the event and the fact that local authority has to authorize events time by time.

Nevertheless previous jurisdiction and permitting approval in similar contents are always favourable aspects to be promoted to facilitate the authorization to use EVERYWH2ERE Gensets.

Nevertheless the consortium suggests to event organizer interested to participate in EVERYWH2ERE Demonstration campaign to contact local permitting and safety authorities (i.e. Fire Department) to present in advance their will to use a “non-standard” temporary power supply, also presenting them EVERYW2HERE DEMOKIT contents, in order to receive a preliminary feedback about the possibility to operate EVERYWH2ERE gensets.

Here in the following the Italian Technical Normative and Regulation Framework for the operation of temporary gensets is presented as an example of the overall process. It is also worthy to highlight that the Italian context seems to be one of the most “complex” in the EU considering that the technical committee/authority in due to release the overall permitting and operation authorization is used to provide the final confirmed allowance to operate only few days before the starting of the operation.

In other countries (i.e. like Germany) some of the permitting aspects could be officially confirmed in larger advance as well as some authorization/permits received in a location in a similar context could be used to support permitting requests particularly in presence of authorization procedures allowing “self declaration” process.

- ***Legge 9 gennaio 1991, n.9***

“Norme per l’attuazione del nuovo Piano energetico nazionale: aspetti istituzionali, centrali idroelettriche ed elettrodotti, idrocarburi e geotermia, autoproduzione e disposizioni fiscali.”

- ***Decreto legislativo 26 ottobre 1995, n.. 504***

“Testo unico delle disposizioni legislative concernenti le imposte sulla produzione e sui consumi e relative sanzioni penali e amministrative.”

- ***Legge 15 marzo 1997, n. 59***

“Delega al Governo per il conferimento di funzioni e compiti agli enti locali, per la riforma della Pubblica Amministrazione e per la semplificazione amministrativa.”

- ***D. P.R. 11 febbraio 1998, n. 53***

“Regolamento recante disciplina dei procedimenti relativi alla autorizzazione alla costruzione e all’esercizio di impianti di produzione di energia elettrica che utilizzano fonti convenzionali a norma dell’articolo 20, comma 8, della Legge n°59 del 15 marzo 1997.”

- ***D.P.R. 31 marzo 1998, n. 112***

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“Conferimento di funzioni e compiti amministrativi dello Stato alle regioni ed agli enti locali, in attuazione del capo I della legge 15 marzo 1997, n.59.”

- ***Decreto Legislativo 16 marzo 1999, n. 79***

“Attuazione della direttiva 96/92/CE recante norme comuni per il mercato interno dell’energia elettrica.”

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4. Conclusion and Future Plans

Starting from the fact that technical normative for the permitting and authorization of the operation of temporary gensets is different country by country, the goal of this report is to present (together with D4.3) a set of guidelines that can facilitate the authorization and operation of EVERYWH2ERE Gensets according to EU HSE and Technical Normative and best practices guidelines.

The document has therefore the goal to make EVERYWH2ERE potential end users and demonstration campaign responsibles aware of all the guidelines and benefits of using FC Based gensets in construction sites and temporary events.

As a public deliverable, such document will be therefore beneficial to drive WP4 Demonstration campaign and it will be circulated to Demosite responsible to facilitate the presentation of EVERYWH2ERE Gensets to local permitting authority.

Such document, together with project demonstration campaign outcomes and D5.4, could be also considered as a potential starting point for a standardization roadmap that could in the future bring to the drafting of a new technical normative and standard dedicated to design and operation of “non-Diesel” temporary gensets and/or more precisely for FC based gensets.

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A1. Mini-HAZOP for EVERYWH2ERE DEMO-KIT

Mini-HAZOP for demonstration activities proposition

Author and Responsible: RINA Consulting SpA
Support and contribution from: PCS, MAHY, GENP, LINDE, ENVI

Executive Summary

This deliverable was prepared within the framework of Work Package 5: Logistic and Environmental Analysis, the task has the scope of developing appropriate safety measures and procedures for securing the safe performance of the gensets in the different demonstrators, with particular reference to temporary generation and to hydrogen storage to satisfy the safety standards.

To address the Health & Safety issues, a “risk assessment” will be applied. The proposed approach consists in performing a preliminary Risk Analysis to evaluate qualitatively the possible events sequence which could transform a potential hazard into an accident. The second step is to identify possible improvements or preventive measures for each undesirable events or hazards. In addition, the pinpointed solutions are then ranked according to the risk to allow measures to be prioritized for preventing accidents.

To address the Health & Safety issues, the following procedure has been applied:

- Preliminary Risk Analysis, aimed at identifying, for each technology involved in the Project, the main hazards only on the basis of the physical and chemical properties of the substances present in the system / process;
- Quantitative Risk Analysis, aimed at identifying the potential hazards related to a system or process and to assess the relevant risk by combining the likelihood of the accidental / unplanned event and the potential consequences of such event, and then to evaluate if the resulting risk is acceptable or not according to pre-defined Project criteria;
- Identification of possible improvements or preventive measures for each undesirable event or hazard. The pinpointed solutions are ranked according to the risk to allow measures to be prioritized for preventing accidents.

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Abbreviations and acronyms

ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
DCDC	Direct Current to Direct Current converter
FC	Fuel Cell
FCPS	Fuel Cell Power System
FCS	Fuel Cell System
FC-SuSy	Fuel Cell Sub System
FEA	Finite Element Analysis
H2	Hydrogen
HMI	Human Machine Interface
IEC	International Electrotechnical Commission
IT	Information Technology
KPI	Key Performance Indicator
MCU	Master Control Unit
MQTT	Message Queue Telemetry Transport
NIST	National Institute of Standards and Technology
LAN	Local Area Network
LFL	Lower Flammability Limit
PEHD	Poly Ethylene High Density
PWR	Power
RCS	Regulations, Codes and Standards
RTU	Remote Transmitter Unit
TCP/IP	Transmission Control Protocol / Internet Protocol
TPED	Transportable Pressure Equipment Directive
TPRD	Thermal and Pressure Relief Device

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UFL	Upper Flammability Limit
VPN	Virtual Private Network

1. General description

EVERYWH2ERE Gensets are transportable fuel cell electric generator powered by compressed hydrogen with output power rate of 25 kW and 100 kW composed from two main and separated units: H2 Storage and Fuel Cell Power System (FCPS). Within EVERYWH2ERE project a total of four 25 kW Genset (H2 storage and FCPS) and four 100 kW Genset (H2 storage and FCPS) will be built.

1.1 Operational requirements

The EVERYWH2ERE Genset are used for supplying electrical power in Off-grid application such as temporary events, festivals and construction site situated within either urban or remote areas. The wide range of application makes possible installation and operation in different context with a wide set of environment characteristics and requirements: operation in sea areas, operation in mountain areas, operation in dust polluted environment like construction site, operation in area with safety restriction like city center and crowded places, operation with low noise emission.

Black start function, namely the capability to start up without independently and without the support of energy from the grid, is requested to startup genset and provide primary power to the load.

The primary fuel is pure 350 bar compressed hydrogen delivered within containerized cylinder rack.

Transportability via truck and or ship of H2 Storage and FCPS is a key requirement as well as the ease of deployment, installation, start-up and handling. Thus, a compact and functional mechanical design is required, considering that the average user of this technology is accustomed to standard Diesel Genset, the current state of the art solution for Off-grid power application.

The operational program of the EVERYWH2ERE Project will be structured around the development of FC Genset requirements and specifications, which includes an assessment of current knowledge of the installation of EVERYWH2ERE Gensets, for details refer to “WP1 – FC Genset Specifications, D1.7 – Report on FC Gensets requirements and specifications”.

1.2 Genset layout, nomenclature and functional analysis

1.2.1 Layout

In Figure 3 the layout of the Genset is shown. Both the 25 kW and 100 kW are implemented with the same architecture exploiting sub-system/sub-part scalability and re-utilization.

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This approach leads to a more direct and robust construction process where the achievements of the development and the validation of the first 25 kW genset can be inherited from to the 100 kW and vice versa.

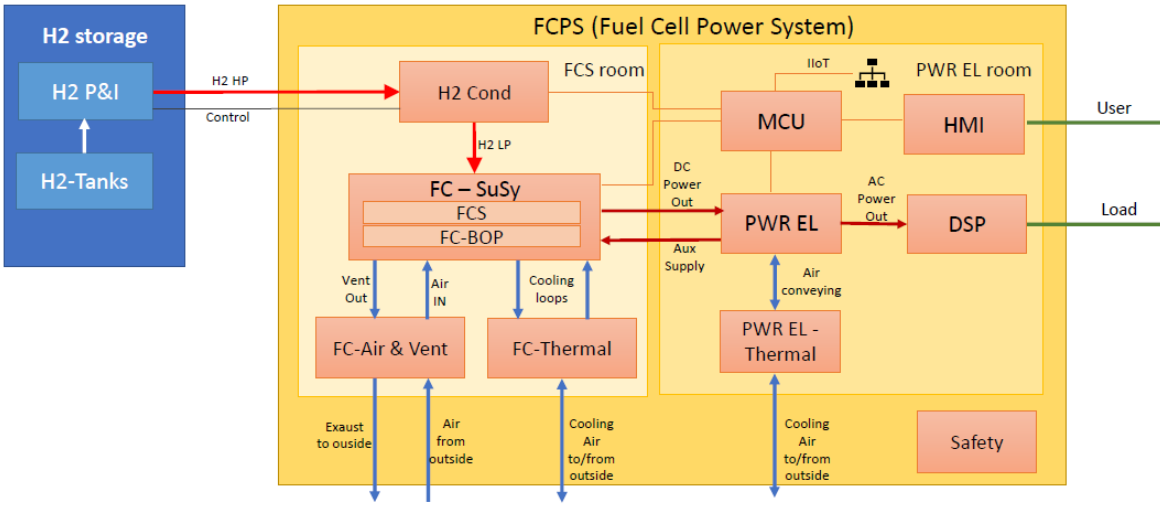

Figure 3 Genset layout valid for both 25kW and 100kW

The layout contains blocks corresponding to sub system and to sub parts. The name of each block agreed within EVERYWH2ERE technology provider partners and systematically utilized in communication and documentation. In Table 14 a quick description of the content of each block is given.

Table 14 Genset subsystem nomenclature and description

GENSET	The whole system composed by H2 Storage and FCPS
H2 Storage	Containerized hydrogen storage
H2 Tanks	350 bar compressed hydrogen tank in Type 4 Polymer liner with composite material
H2 P&I	Hydrogen Piping & Instrumentation: it connects H2 Tanks and provides first safety level with TPRD
FCPS	Fuel Cell Power System: container that host the fuel cell system, power electronics and control
FCS room	Fuel Cell System room: dedicated and separated space within the container for hosting FCS and the strictly connected components. Separation from "PWR EL room" for safety management
FC-SuSy	Fuel Cell – Sub System
FCS	Fuel Cell Stack
FC-BOP	Fuel Cell – Balance Of Plant: it includes, H2 loop, Air loop, Cooling Loop (for FCS), Control system
FC-Air & Vent	Fuel Cell – Air & Vent pre conditioning: it includes air and exhaust management complementary to FC-SuSy. It is composed by Air filters, Air conveying, water trap and piping
FC-Thermal	Fuel Cell – Thermal: it provides heat dissipation towards the outside environment for the FCS and air compressor (part of FC-BOP) by two separated and independent cooling loop
H2-Cond	Hydrogen pre conditioning circuit: manage and adapt the 350bar H2 source to 10barg
PWR EL room	Power electronics and control room: dedicated and separated space within the container for hosting power electronics and control electronics components. Separation for safety management from "FCS Room"
MCU & HMI	Master control unit & Human Machine Interface: it controls FCS, PWR-EL, H2-Cond, Safety, HMI and connects to Internet
PWR-EL	Power electronics: it includes DC/DC, Battery, Inverter, transformer, aux supply for FCS, electric protection
PWR-EL Thermal	Power electronics thermal management: it includes air conveying path/carpentry
DSP	Distribution Socket Panel with electrical protections

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PWR EL Safety	All the safety issues related to PWR EL and the devices installed into PWR EL Room, where PWR EL Room is intended to be a NON ATEX space
FCPS H2 safety	All the safety issues related to H2: Overall FCPS design, input output positioning, H2 ambient sensors, forced ventilation loop, etc

1.2.2 Nomenclature

Moreover, since EVERYWH2ERE project requires the construction of a total of eight Genset (4x25kW and 4x100kW), to further identify and distinguish between parts of different batch the prefix 025 - “Number Of Batch” or 100 - “Number Of Batch” is attached to the part name. as example:

025-3 FC-SuSy → Fuel cell subsystem of the third 25kW Genset batch

100-1 H2-Cond → Hydrogen pre conditioning circuit of the first 100kW Genset batch

1.2.3 Functional Analysis

The functional analysis of the EVERYWH2ERE Genset prodromal to demonstration and operation phases is hereby presented as following:

a) Transportation;

b) Deployment and Operation;

c) Refuelling on Site;

d) Storage.

A description of the main requirement and operational sequence is introduced here below,

Transportation:

The FCS will be transported to the demo site using competent transporters or via specific agreements with the traditional gensets supplier. In Italy the involvement of IREN (responsible of many events organized in Turin) will help the provision of H2 gensets.

Deployment and operation:

Please find here below a preliminary step-by-step guideline process for the deployment and operation procedures.

1) Placement of H2_Storage and FCPS accordingly to the installation manual prescriptions;
2) Placement of fence in the surrounding of the Genset for safety reason;
3) Connection of the H2 Storage to the FCPS: H2 flexible hose, signal cable, pneumatic hose;
4) Grounding of the masses via ground cross-shaped pole;
5) Connection of the load or local switchgear to the Genset IEC socket;

6) Start-up of the Genset via user interface (HMI and buttons);
7) Turn on the main electric switch gear;
8) Operation;
9) Turn off the main electric switch gear;
10) Shut-down of the Genset via user interface (HMI and buttons);
11) Disconnect the H2 storage from the FCPS before dismounting the Genset prior to transportation[6]

Refuelling on site:

When the autonomy requested from the end user exceed the capability of a single H2_storage, at least three different on-site refuelling procedure could be evaluated within the project:

1. Replace empty H2_storage with full H2_storage. (the FCPS and H2 Storage shall be physically disconnected);

2. Hot swap (the replacement of the device while the system using it remains in operation) the empty H2_storage with full H2_storage by the double inlet H2 connector mounted on the FCPS;

3. Perform the refilling of the empty H2_storage with H2 trailers through the refuelling connector mounted on H2_storage. Electric service continuity could be allowed.

Storage:

H2_Storage and FCPS can be stored in separated place preferably indoor. Considering the storage temperature of FC SuSy and H2_Storage bottles, if temperature of the storage location is expected to fall below 0°C or the humidity is expected to rise above 95%, connection of the FCPS to the electric grid could be required to providing heating power to prevent ice forming in the parts that manage water and to prevent condensation in the not coated electronic parts.

According to the “Instruction Manual” by Powercell, the FCS requires a fresh air supply to cover the fuel cell stack air requirements and the ventilation of the fuel cell system. The amount of ventilation required for the FCS is specified in Appendix A of “Instruction Manual”. It depends on the cathode air source, i.e. if taken either from the surrounding environment or another source. Note that this is solely the ventilation requirement of the Fuel Cell System and that external components such as gas supply system or power electronics might require additional ventilation. There may be local or national regulations concerning ventilation of H2 systems which exceed the requirements given in this manual. It is the duty of the user to comply with the most stringent ventilation requirements.

The feed hydrogen to the FCS must comply with the purity requirements and supply pressure specified in Appendix A of “Instruction Manual”. The recommended setup must at least include an upstream pressure regulator to supply hydrogen at the required pressure, a pressure relief valve as an

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[6] It is also suggested to clean hydrogen tanks with nitrogen before the transportation in order to avoid any hazardous risks and to guarantee no presence of hydrogen also for transportation purposes

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overpressure protection and a shutoff valve; a schematic of this is shown below. It is recommended that a hydrogen sensor is installed at a suitable position in the room where the FCS is located which closes a shutoff valve in case of hydrogen leakage.

It is recommended that a leakage check of the fuel system in accordance with IEC_62282-5-100 is included in the system maintenance program.

1.3 25 kW and 100 kW Genset Specifications

In this section system specifications are organized in tabular form where both 025 system and 100 system have been aggregated for direct overview. Since the Genset is composed from “two separate boxes” namely Fuel Cell Power System and H2 Storage the main specifications sheet is splitted in two separated parts in Table 4 and Table 16 as if they were standalone products. Furthermore, specifications of subsystems are separately shown in Table 17.

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Table 15 FCPS (Fuel Cell Power System) main specifications

FCPS (Fuel Cell Power System)		
Performance		
	025 system	100 system
Rated Power	25 kVA	100 kVA
Peak power (Note 1)	50 kVA	150 kVA
Voltage	230/400 Vac 50 Hz	230/400 Vac 50 Hz
THD	<3% @ full power	<3% @ full power
Load ramp (Off-Grid-Mode)	Instantaneous	Instantaneous
Operation mode	Off-grid (grid forming)	Off-grid (grid forming)
Start up-time	60 s	60 s
Autonomy	8h @25kW with 025-H2_storage	8h @100kW with 100-H2_storage
Efficiency	> 45	> 45
Note: (1) Maximum power is delivered with combination of fuel cell and batteries. According to the state of charge of the batteries maximum power can be sustained up to 5 minutes.		
Environment		
	025 system	100 system
IP-rating	IP43	IP43
Operational temperature	2 to 40°C	2 to 40°C
Storage temperature	-20 to 60°C (external power supply for sub-zero storage)	-20 to 60°C (external power supply for sub-zero storage)
Humidity	Non-condensing	Non-condensing
Altitude	2000 m	2000 m
Ambient air quality	Free from refrigerant gases, halogenated compounds, silicone vapours, formaldehyde, formic acid. Low content of sulphur components, NOx, Ammonia, non-methane hydrocarbons.	
Physical		
	025 system	100 system
FCPS dimensions	H 259 cm, L 400 cm W 250 cm	H 259 cm, L 400 cm, W 250 cm
FCPS weight	~ 2000 kg	~ 2600 kg
Connections		
	025 system	100 system
Electrical	Industrial Socket 3x16A IEC 309	Industrial Socket 16A-32A-63A IEC 309
H2	Quick connector to be defined	Quick connector to be defined
H2 quality		
	025 system	100 system
NMHC Methane	< 2 ppm < 100 ppm	

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Carbon monoxide	< 0.2 ppm	
Carbon dioxide	< 2 ppm	
Total sulphur compounds	< 4 ppb	
Formaldehyde	< 10 ppb	
Formic acid	< 0.2 ppm	
Ammonia	< 0.1 ppm	
Total halogenated compounds	< 50 ppb	
Particulates	< 1 mg/kg	
Oxygen	< 5 ppm	
Emissions		
	025 system	100 system
Sound level (Note 2 and 3)	80 dBA	80 dBA
Water production	< 0.35kg/min	< 1.15kg/min
Other FC-SuSy emissions	<16 l_N/min H2	<21 l_N/min H2
EMC compliance	IEC 61000-6-2 - IEC 61000-6-4	
Note: (2) At 80 dbA employers shall make hearing protectors (e.g. plugs or muffs) available to workers. Below this limit, the risk to hearing is assumed to be negligible). (3) Ref. EU Noise at Work Regulations		
User interface and communication		
	025 system	100 system
On site interface	HMI 10inch resistive touch / function key on panel / manual star/stop/function button	
Remote interface	3G/4G router for remote monitoring and assistance	
Transportation		
	025 system	100 system
Carrier	400cm / EU container suitable for truck and ship transportation	
Handling	With crane by lifting eyebolts - Forklift	
Maintenance		
	025 system	100 system
Tank maintenance		
FC-Susy		
Enclosure ventilation	After 1000h of operation or 2 years: Clean air inlet/outlet and exchange filters.	
Coolant	After 1000h of operation or 2 years: exchange of coolant	
FC-Air	Exchange interval of cathode air filters needs to be determined according to the ambient air pollution.	
H2 sensor calibration check	Every 6 months.	
Power converter		
LC - Filter	Replacement after 43.800 h in standard working conditions	Replacement after 43.800 h in standard working conditions

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Converter air grids	6/12 months cleaning	6/12 months cleaning
Tightening power connection	Control every 12 months in stationary conditions; Control after each transportation	Control every 12 months in stationary conditions; Control after each transportation
Standard and regulations		
	025 system	100 system
FC-SuSy	Prototype, designed to be compliant with IEC 62282-5-100:2018	
Power Converters	Prototype, designed to be compliant with IEC 62109-1-2 IEC 61000-6-2 IEC 61000-6-4 2004/108/EC 2014/35/EU	
Socket	IEC 60309	
Fuel Cell - General	IEC 62282	
	Directive 2014/68/EU – Pressure Equipment Directive	
	Directive 2014/34/EU - Explosive Atmosphere Directives	
Hydrogen System - General	2006/42/EC – Machinery Directive	
	Regulation (EU) 2016/426 – Gas Appliances Directive	
	EN 60079-14:2014 EN 60079-17:2014	
Safety Distances	ISO TR 15916 – Basic Considerations for the Safety of Hydrogen Systems	
	IGC 75/01/E/rev Determination of Safety Distances EU	
	IGC 15/06/E, Gaseous Hydrogen Stations	

Table 16 H2 Storage main specifications

H2_storage		
Performance		
	025 system	100 system
Operating pressure	350bar	350bar
Stored volume	14.4 kg H2 @ 20°C	43.2 kg H2 @ 20°C
Output pressure	10bar	10bar
Bundle size	3 tanks	9 tanks
Environment		
	025 system	100 system
IP-rating	IP43	IP43
Operational temperature	-20°C + 60°C	-20°C + 60°C
Storage temperature	-20°C + 60°C	-20°C + 60°C
Humidity	100 %	100 %
Altitude	2000 m	2000 m
Physical		
	025 system	100 system
Dimensions	H 100 cm, L 280 cm W 200 cm	H 200 cm, L 280 cm W 200 cm
Weight	~ 1000 kg	~ 2300 kg
Water volume	615 L	1845 L
Connections		
	025 system	100 system
Electrical	To Be Defined	To Be Defined
H2	To Be Defined	To Be Defined
Pneumatic	To Be Defined	To Be Defined
Tank specifications		
	025 system	100 system
Operating pressure	350 bar	
Storing capacity	4.8 kg H2 @ 20°C	
Weight	~188 kg	
Dimensions	O.D 490 mm x 2225 mm	
Water volume	205 L	
Boss thread	1 ½ inch UNF thread	
Maintenance	See § **Error! Reference source not found.**	
H2 quality		
	025 system	100 system
HiQ Hydrogen 5.0	H2O ≤ 3 ppm O2 ≤ 2 ppm CnHm ≤ 0.5 ppm N2 ≤ 5 ppm	H2O ≤ 3 ppm O2 ≤ 2 ppm CnHm ≤ 0.5 ppm N2 ≤ 5 ppm
User interface		

	025 system	100 system
Direct	Pressure gauge and manual main valve	Pressure gauge and manual main valve
Remote	Via FCPS HMI	Via FCPS HMI
Transportation		
	025 system	100 system
Carrier	Container suitable to truck and ship transportation	Container suitable for truck and ship transportation
Handling	With crane by lifting eyebolts Forklift	With crane by lifting eyebolts Forklift
Standard and regulations		
	025 system	100 system
Tank certification	NF EN 12245 / TPED regulation	
Hydrogen Fuel - General	ISO – 14687:1999 Hydrogen Fuel. Product Specification	
	ISO/TS 14687-2:2008 Hydrogen Fuel. Product specification. Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles	
	ISO – 16110 - 1 Hydrogen Generators using fuel processing technologies. Part 1: Safety	
Hydrogen Systems Installations - General	IEC 61779-1 to 5 - Electrical Apparatus for the Detection and Measurement of Flammable Gases - Part 1. Gen. Requirements. & Test Methods	
	IEC 60079-29-1 & 2 - Electrical Apparatus for Explosive Gas Atmospheres Part 1 Electrical apparatus for the detection and measurement of flammable gases-General Requirements & Test Methods - Part 2 Electrical apparatus for the detection and measurement of flammable gases-Guide for the selection, installation, use and maintenance	
	IEC 62282-3-3: 2007 - Stationary fuel cell power systems – Installation	
	IEC 60079-0 Explosive atmospheres – Part 0: Equipment – General requirements	
	EN 60079-10 - Electrical apparatus for explosive gas atmosphere - part 10 classification of hazardous area	
	HSE - HSG243 Fuel cells – Understand the hazards, control the risks	
	US DOE Regulators’ Guide to Permitting Hydrogen Technologies – Overview Module 1 – Permitting Stationary Fuel Cell Installations	
	NFPA 853: 2015 - Standard for the Installation of Stationary Fuel Cell Power Plants	

Hydrogen Storage	EN ISO 11114-1:1997 Transportable gas cylinders – Compatibility of cylinder and cylinder valve with gas contents – Part 1: Metallic materials
	EN ISO 11114-4:2017 Transportable gas cylinders – Compatibility of cylinder and cylinder valve with gas contents – Part 4: Test methods for selecting metallic materials resistant to hydrogen
General Hydrogen Safety	ISO TR 15916 – Basic Considerations for the Safety of Hydrogen Systems
	Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) – Safety Planning for Hydrogen and Fuel Cell Projects (05 July 2019)

Table 17 Subsystems main specifications

SUBSYSTEMS		
FC-SuSy (Fuel Cell – Sub System)		
	025 system	100 system
Rated power output (gross)	5-32 kW	8-120 kW
Target efficiency	> 50%	> 50%
Voltage output	105V - 225V	180V - 390V
BOP power demand (max.)	5kW@260-550VDC, 1.5kW @ 24VDC	17kW @ 340-849VDC 4kW @ 24VDC
Fuel demand	1-26 m_N^3/h @ 10bar$_g$	2-86 m_N^3/h @ 10bar$_g$
Heat production	<50kW (fuel cell stack) <5kW (BOP components)	<140kW (fuel cell stack) <11kW (BOP components)
Start-up time to full load	<220s	<220s
Dimensions	660mm (l) x 456mm (w) x 691mm (h)	750mm (l) x 600mm (w) x 750mm (h)
Weight	Ca. 150kg	Ca. 150kg
Power Electronics and batteries		
	025 system	100 system
Power Electronics		
Rated output power	25kVA	100kVA
Maximum output power	45kVA (1 min)	150kVA (1 min)
Maximum efficiency	93%	93%
Total harmonic distortion	<3% @full power	<3% @full power
Voltage output	400Vac	400Vac
Current output	36A	144A
Maximum	54A	216A
BOP power demand (max.)	1160VA@230V	1610VA@230V
Dimensions	2250x2200x825 mm	2250x2200x825
Weight	800 kg	1100 kg
Battery		
Battery Chemistry	Lithium Iron Phosphate or	Lithium Iron Phosphate or

	Nickel Metal Hydrate	nickel metal hydrate
Energy	At least 20% of the Rated power of the Genset	At least 20% of the Rated power of the Genset

For further details of 25 kw and 100 kw subsystem description, refer to “WP1 –FC Genset Specifications, D1.7 – Report on FC Gensets requirements and specifications” (Ref. [1]).

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1.4 25 kW and 100 kW Subsystem Description

1.4.1 H2 Storage

Mahytec supplies the H2 tank and propose its standard product a 500 bar type IV cylinder. This tank is a polymer liner fully wrapped and reinforced by composite materials. These tanks are assembled by Linde in bundle of 3 or 9 tanks.

No vacuum is allowed in such tank, if tank is exposed to vacuum, the liner could collapse and be destroyed.

In order to maximize service life, there is a specific protocol to follow before first use, after that the tank pressure should never drop under 15 bar. If this event happens, service life could be maintained by doing again the protocol before resuming operation.

The H2 tank technical specification is reported below.

Service conditions	
Temperature	-40°C to 65°C
Maximum working pressure (PS)	500 bar
Position of use	Vertical or Horizontal
Dimensions	
Water volume	205 L
Empty mass	188 kg
Outside diameter	490 mm
Total length (Nozzle to Nozzle)	2230 mm
List of Materials	
Liner	PE-HD
Composite	Epoxy resin / High strength carbon fiber
Boss	Aluminium alloy / Stainless steel
Certified according to	
TPED directive, EN 12245	
Hydraulic proof pressure test	750 bar
Service life	10 years / 5000 cycles

H2 Capacity

H2 capacity depends on filling temperature and refilling pressure. So, the hydrogen capacity is:

- 4.88 kg H2 at 350 bar, 15°C;

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- 4.81 kg H2 at 350 bar, 20°C;
- 4.74 kg H2 at 350 bar, 25°C;
- 4.68 kg H2 at 350 bar, 30°C.

So for a temperature variation of 15°C, the overall capacity of hydrogen decrease for 4%, if the filling pressure is maintained.

H2 tank maintenance

H2 tank must be submitted to a visual inspection (tank outside only) and leak detection on a yearly basis.

Final customer should know following points:

- Repairing composite and or boss damage is not allowed.
- All removable part must be changed, if a damage or leakage is detected.
- All composite damage should be reviewed and greenlighted by Mahytec prior to reinstated pressure.

In addition, final customer must comply to TPED / ADR mandatory requalification (visual inspection internal and external, proof pressure test) every 5 year.

H2 tank container

The H2 tank container consist of an open frame that hosts tanks TPRD safety devices, control valve, pressure reducer, quick coupling for connection to FCPS, quick coupling for refilling and pressure and temperature probes.

Refilling quick coupling are suitable for H2 inlet automotive standard and H2 inlet industrial standard. A flexible hose will be provided for the connection of the H2 storage with the FCPS. The following pictures show the layout for both the sizes:

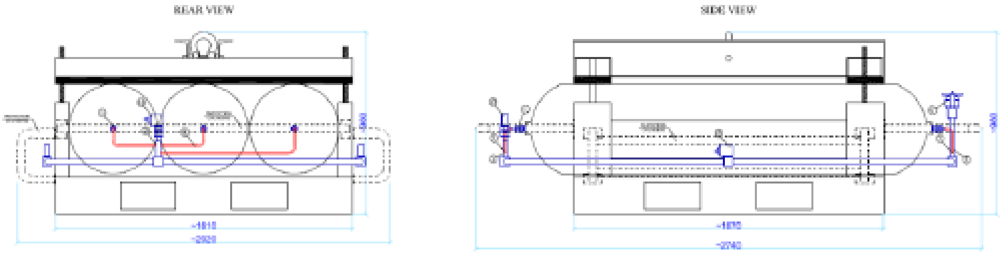

Figure 4 025 - H2 Storage (3 tanks) layout

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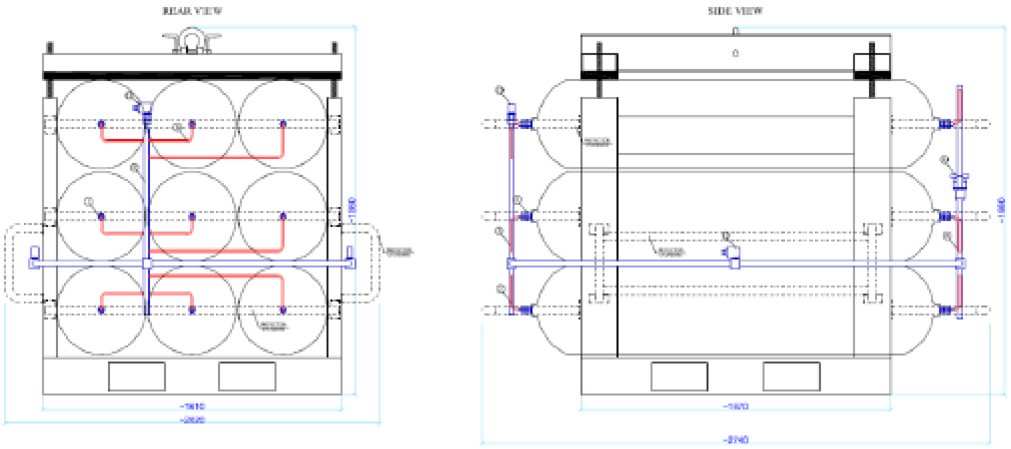

Figure 5 100 – H2 Storage (9 tanks) layout

1.4.2 FCPS

Containerization

The design of the container was based on producing a durable, easy-to-use and safe unit. Simplified, the FC-Genset is a portable metal structure that transports fuel cells, cooling systems and electrical equipment. These three entities are shared as gas, cooling and electricity. From the point of view of the metallic structure, similar frames were selected for both systems (25 kW and 100 kW). The physical size of the device corresponds to the height (259 cm) and width of the EU-container (250 cm). The length is determined by the space requirement. At present, about 120cm long space is reserved for each sub-system (gas, cooling and electricity). The hole device will be about 400cm long. Dimension is specified during the design process.

Figure 6 – FPCS container external view

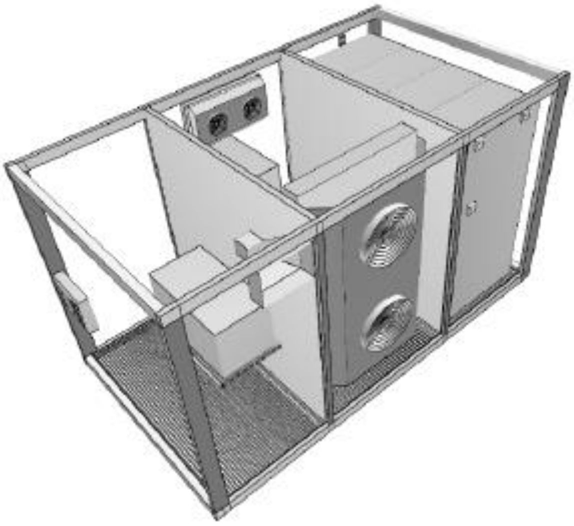

Figure 7 – FPCS container internal view

FC-SuSy

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The general layout and specifications of the 25 kW FC-SuSy are extensively explained in D2.1 (Ref. [5]). The layout of the 100 kW FC-SuSy will be quite similar with a different set of components which are more powerful and larger.
The main changes are:

- A PCS S3 fuel cell stack with 455 cells will be used instead of the PCS S2 stack with 264 cells used in the 25 kW SuSy;
- A larger air compressor is required to supply a larger air flow at a higher pressure;
- As the fuel cell stack is more powerful and releases more heat, a stronger coolant pump is required (Valeo SPump 500 CAN).

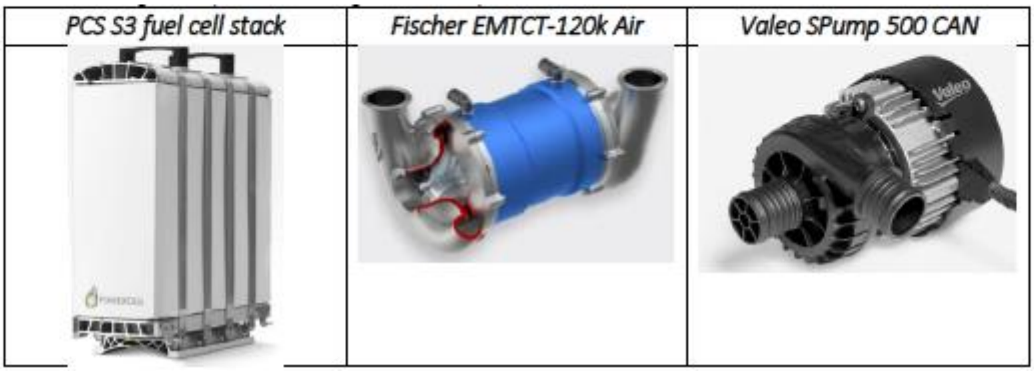

Figure 8 – FC-SuSy

A manual of the 100 kW FC-SuSy has been provided to the project consortium to inform in detail about the system's specifications.

FC-Thermal
As specified in Table 17, the FC-SuSy's release heat from two different types of sources and on different temperature levels: the fuel cell stack (ca. 70°C) and BOP components (ca. 50°C).
The most straightforward approach is therefore to use two different coolers (FC cooling and Component cooling). They need to be designed according to the max. heat demand i.e. max. current drawn from the stack at end of life conditions (10% cell voltage decay) as specified in Table 17.

According to the current container design, the coolers and fans will be exposed to rain. The fans will therefore be ordered with a IP rating of IPX4 or higher.
To ensure high fuel cell stack performance (low leakage current), cooling liquids with very low conductivity need to be used.

FC-Air & Vent
For air supply of the FC-SuSy's, there are strict requirement regarding air contaminants such as sulfur components, formaldehyde, ammonia and halogenated compounds. A detailed specification can be found in D2.1 (25kW FC-SuSy manual) which is also applicable to the 100kW FC-SuSy.
To achieve this air purity, special filters with chemisorption properties have to be used. PCS has previously purchased and tested such filters from Freudenberg Filtration Technologies and intends to use them within the EVERYWH2ERE project.

For venting of the exhaust gases from the FC-SuSy, a venting system is required with the following properties:

- Allowed pressure drop: <50mbar;
- Water collector + drain valve required;
- Vertical vent exhaust (no impact of wind);
- Exhaust with weather cap (protection from rain, leaves, etc.);
- Hoses with inclination from FC-SuSy to allow water to drain.

There is only one exhaust system per FC-SuSy required as both H2 purge and exhaust air are mixed inside the FC-Susy to reach a H2 content below flammability limit.
A schematic of such a venting system is shown below.

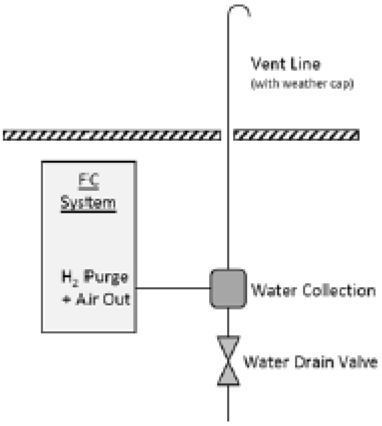

Figure 9 – Exhaust system

Power Electronics and Batteries

FRIEM supplies the main equipment identified as "PWR EL" in the block diagram of Figure 10.

Below is represented an exploded view of the main equipment that compose the "PWR EL" block.

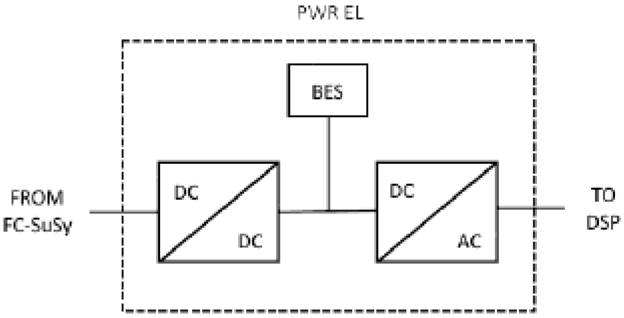

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Figure 10 – PWR EL block valid for 25kW and 100kW

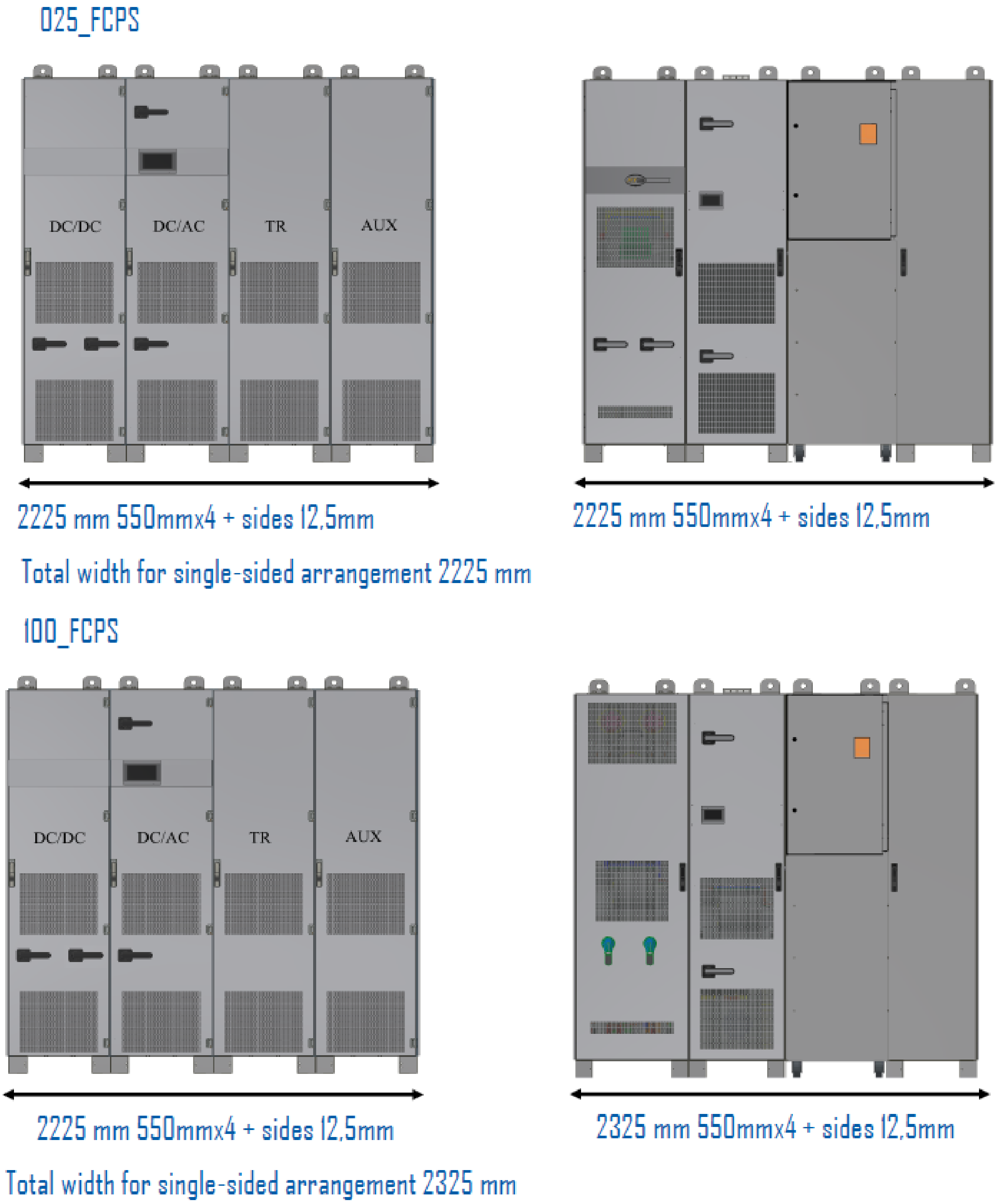

Figure 11 – Power Converter layout valid for 25kW and 100kW

Control Electronics

The control electronics includes the MCU (Master Control Unit), the HMI (Human Machine Interface) as part of a local IT network (LAN) with remote access capabilities via 3G/4G. In

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the LAN also FC-SuSy, Battery, Inverter and DCDC are connected to allow internal communication during operation and remote communication from factory to subpart via VPN. MQTT communication is also foreseen to collect operational data useful to calculate the KPI of the Genset.

Communication buses used are Modbus TCP/IP, Modbus RTU and CAN BUS.
The control routines of the whole Genset (FCPS and H2 storage) are implemented within the MCU. These routines include:

- Operation management (start-up, run, shutdown);
- H2_Storage control;
- Power Energy management within the FCPS:
    - Battery management;
    - FC-SuSy management;
- Alarm/Warning management;
- Digital/Analogic I/O management;
- Local Data Log.

Figure 12 shows the general architecture of the LAN within Genset.

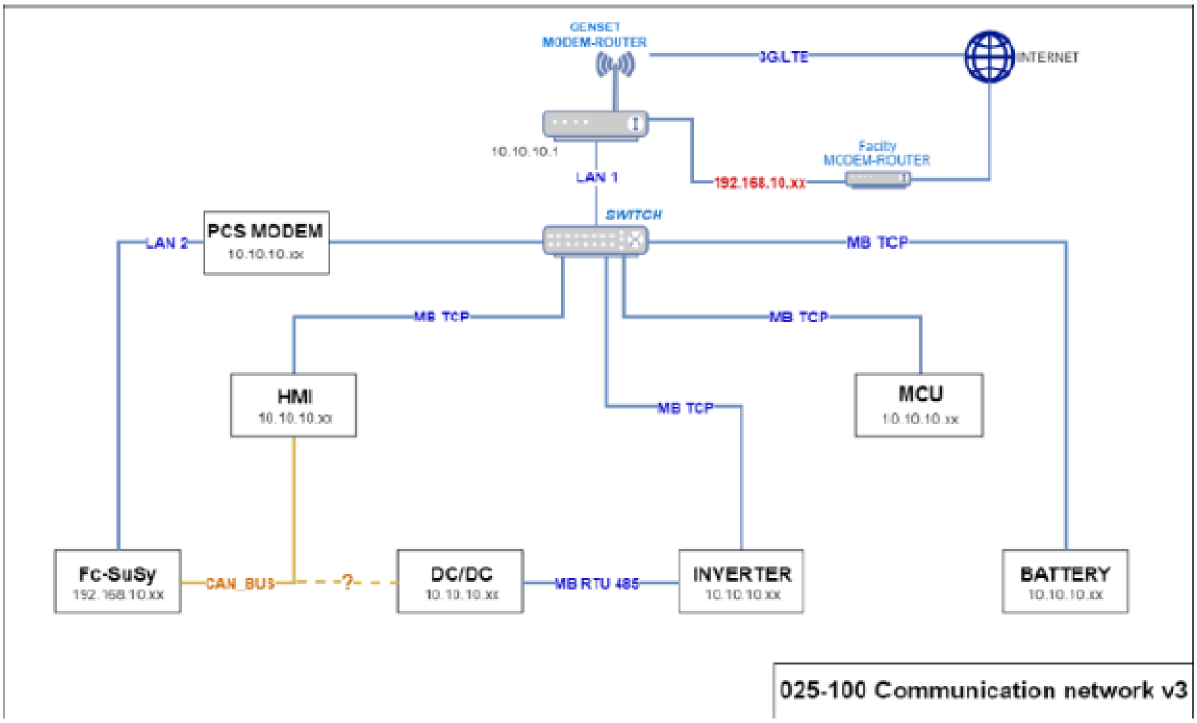

Figure 12 – Power Converter layout valid for both 25 kW and 100 kW

For further details of 25 kw and 100 kw subsystem description, refer to “WP1 –FC Genset Specifications, D1.7 – Report on FC Gensets requirements and specifications” (Ref. [1]).

2. Risk Analysis Methodology

Risk Analysis is a powerful tool to benchmark the intrinsic safety of a process or an operation against its expected performance, allowing at the same time a quantifiable appraisal of the expected issues towards the human safety and health, the environment, the property and asset, the capacity to continue business. "Risk" is a specific concept, which can be typically defined as the "Combination of the probability of an event and the consequences of the event" and it represents the qualitative and quantitative measure of the combined likelihood of an accidental or unplanned event and the potential consequences of such event.

The Risk Analysis developed in this report will be focused on “major” accidents potentially arising from the operation of the 25 kW and 100 kW Gensets that will be implemented in the EVERYWH2ERE demo sites, i.e. on those occurrences such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any installation, leading to serious danger to human health or the environment.

For this reason, the present Risk Analysis takes into consideration only those events consisting in the release into the atmosphere (loss of containment) of chemicals characterized by flammability and/or toxicity and/or toxicity to the environment. These types of substances could lead, depending on their physical/chemical properties and on the release conditions, to serious consequences for people (e.g. irreversible injuries, fatalities) and/or environment (pollution).

In the framework of EVERYWH2ERE Project, the Risk Analysis will be carried out in two steps, described in details in the next paragraphs:

- Preliminary (Qualitative) Risk Analysis (see Paragraph 3.1 for the description of the methodological approach);
- Quantitative Risk Assessment (QRA) (see Paragraph 3.2 for the description of the methodological approach).

The risk assessment of the complete EVERYWHE2ERE Gensets will be realized in two steps. First, a document “D1.7 – Report on FC Gensets requirements and specifications” (Section 2 of Ref. [1]) that describes the main safety requirements for the conception stages of the hydrogen chain is defined. Once the conception of the system is sufficiently detailed, a preliminary Risk Analysis has been carried out for the project, to identify potential causes of process deviation, their associated consequences and assess the efficiency of the existing barriers. At the end, all the safety studies will be centralized in the document “D5.4 – Health and Safety Analysis of the 25 kW and 100 kW Gensets”.

2.1 Preliminary Risk Analysis

By an overview of the EVERYWH2ERE Project, the most typical hydrogen accident is initiated by a release of hydrogen from a container or pipe which are typically operated at pressures above atmospheric pressure. Sub-atmospheric operation pressures have to be avoided to exclude air ingression. The potential consequences of a hydrogen release are detailed in the event three shown in Figure 13. Ignition and flame acceleration are safety critical as they decide

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how critical the consequences might be. The vertical upward direction in the figure implies escalation. So, the hazards associated with a “no ignition” accident (e.g. oxygen depletion) are considered less critical than those associated with a delayed ignition and fast combustion regimes, which imply far reaching explosive loads. The most likely escalating sequence observed in the majority of severe accidents, which are in fact gas explosion events, are marked with grey boxes in Figure 13.

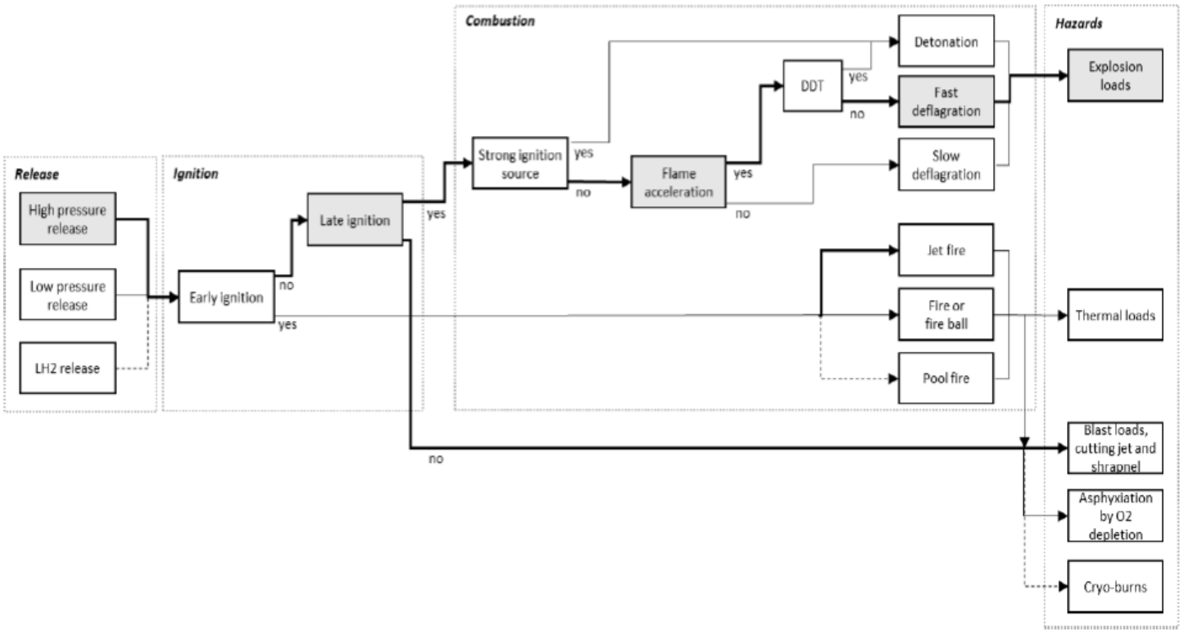

Figure 13 – Potential consequences and hazards associated with a hydrogen release

A small unignited release or a jet fire, for instance, won’t generate explosion loads, but will imply considerable physical hazards or thermal loads. The burst of a pressurized pipe or vessel will lead to serious blast loads even without a chemical reaction.

However, the derived safety principles for the EVERYWH2ERE Project state simple objectives, being widely understandable and acting as preventive barriers or at least as risk reducing measures on the various elements of the chain of events. The list of safety principles is presented below:

- Limit hydrogen inventories, especially indoors, to what is strictly allowed;
- Avoid or limit formation of flammable mixture, by applying appropriate ventilation systems, for instance;
- Combine hydrogen leak or fire detection and countermeasures;
- Avoid confinement. Place storage in the free, or use large openings which are also supporting natural ventilation;
- Provide efficient passive barriers in case of active barriers deactivation by whatever reason;
- Train and educate staff in hydrogen safety;
- Report near misses, incidents and accidents to suitable databases and include lessons learned in your safety plan.

These safety principles should be reflected in the safety plan, in any process of identifying hazards and in any risk assessment procedure. However, they do not replace neither legal requirements, comprehensive hydrogen safety engineering, nor detailed risk assessment eventually required by RCS. They allow stakeholders to take safety into account at different stages of the design, implementation and operation of a process using hydrogen in a very basic manner.

2.1.1 Objectives

In order to focus the efforts of the subsequent Quantitative Risk Assessment, a preliminary (qualitative) risk analysis will be carried out, aimed at identifying the main hazards only on the basis of the physical and chemical properties of the substances present in the system / process.

2.1.2 Scope and limitations

The preliminary risk analysis will be performed with reference to flammable and toxic substances identified within the EVERYWH2ERE Project.

2.1.3 Methodology, assumptions and criteria

The preliminary identification of the main hazards related to each technology will be carried out through the following steps:
1. Identification of the substances processed in the system under analysis;
2. Identification of the main hazards related to each substance, based on material classification according to Regulation 1272/2008/CE;
3. Definition of potential adverse effects on people or environment.

For this preliminary analysis, the main hazardous properties that will be investigated are the following:

- **Toxicity:**
    - IDLH, Immediately Dangerous to Life and Health: an atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual’s ability to escape from a dangerous atmosphere,
    - LC50, Lethal Concentration 50: concentration of a material in air that is lethal for 50% of the subjects in case of exposure for 30 minutes,
    - LOC, Level Of Concern: concentrations of an extremely hazardous substance in air above which there may be serious irreversible health effects or death as a result of a single exposure for a relatively short period of time (1/10 of NIOSH IDLH levels);
- **Flammability:**
    - LFL, Lower Flammable Limit: the concentration of a flammable gas in air below which there is insufficient amount of gas to support and propagate combustion,
    - UFL, Upper Flammable Limit: the concentration of a flammable gas in air above which there is insufficient amount of oxygen to support and propagate combustion;

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- **Toxicity for the environment.**

Depending on the hazardous properties of the materials, the following accidental scenarios could occur:

- Jet Fire: a fire type resulting from the discharge of liquid, vapour, or gas into free space from an orifice, the momentum of which induces the surrounding atmosphere to mix with the discharged material;
- Pool Fire: the combustion of material evaporating from a layer of liquid at the base of the fire;
- Flash Fire: a fire that spreads by means of a flame front rapidly through a diffuse fuel, such as a dust, gas, or the vapours of an ignitable liquid, without the production of damaging pressure;
- Explosion (confined or unconfined): a release of energy that causes a pressure discontinuity or blast wave;
- Toxic Dispersion;
- Environmental Pollution.

This preliminary analysis will allow to focus the subsequent detailed Quantitative Risk Assessment on the real major hazards related to each technology package and Demo Site.

2.2 Quantitative Risk Assessment

2.2.1 Objectives

The objective of the Quantitative Risk Assessment is to identify the potential hazards related to a system or process and to assess the relevant risk by combining the likelihood of the accidental / unplanned event and the potential consequences of such event, and then to evaluate if the resulting risk is acceptable or not according to pre-defined Project criteria.

2.2.2 Scope and limitations

The Quantitative Risk Assessment will be performed for each Demo Site contributing to the development of the EVERYWH2ERETHERMOSS Project, taking into account the specificity of the site and of the installation. (e.g. indoor or outdoor):

2.2.3 Methodology, assumptions and criteria

Generally speaking, the procedure for Quantitative Risk Assessment aligned with Industry Standards and best Practices, is as follows:
1. Definition of the scope, methodology, applicable assumptions and criteria;
2. Hazard identification;
3. Calculation of the frequency of occurrence of the identified hazards;
4. Consequence analysis of the credible hazards;
5. Risk assessment:
5.1. Risk Analysis, by combining previous Steps 3. and 4.
5.2. Risk Evaluation (acceptable or not), by benchmarking results of the analysis against criteria set in previous Step 1.

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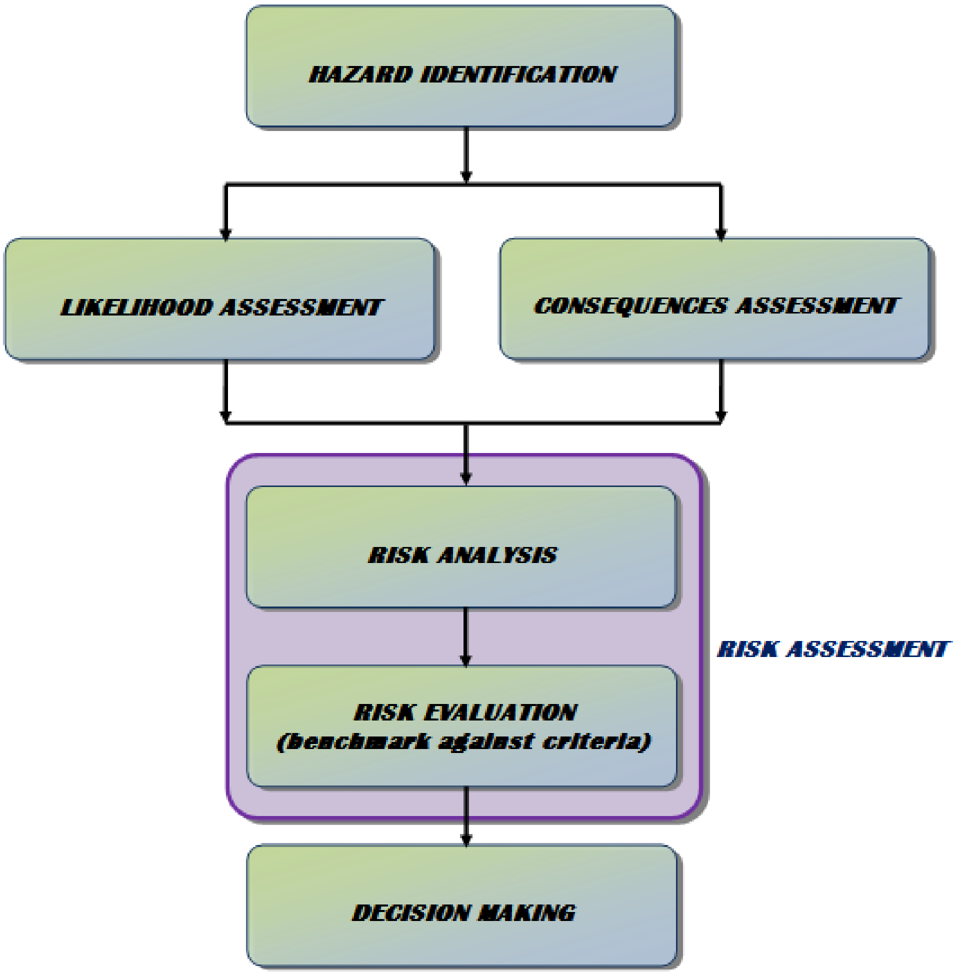
The typical flowchart for Quantitative Risk Assessment is reported in the following Figure.



The aforementioned methodology, specifically developed for process industries, has been adopted in a simplified way for the EVERYWH2ERETHERMOSS Project, taking into consideration the characteristics of the involved installations.

Particularly, a spreadsheet has been filled in with the following information (organized in different columns):

- Hazard: the main hazards, consisting in the release of hazardous substances, have been identified according to the results of the Preliminary Risk Analysis;
- Potential Scenarios: for each hazard, namely release of a dangerous substance, the possible theoretical scenarios have been indicated (fire, explosion, toxic dispersion, etc.);
- Physical effects due to accidental scenarios, e.g. heat radiation, toxic concentrations, environmental pollution, etc.
- Description of the scenario: a brief description of the event under analysis is given;
- Consequences: the potential effects on people and/or environment are summarized (injuries, fatalities, environmental pollution, etc.);

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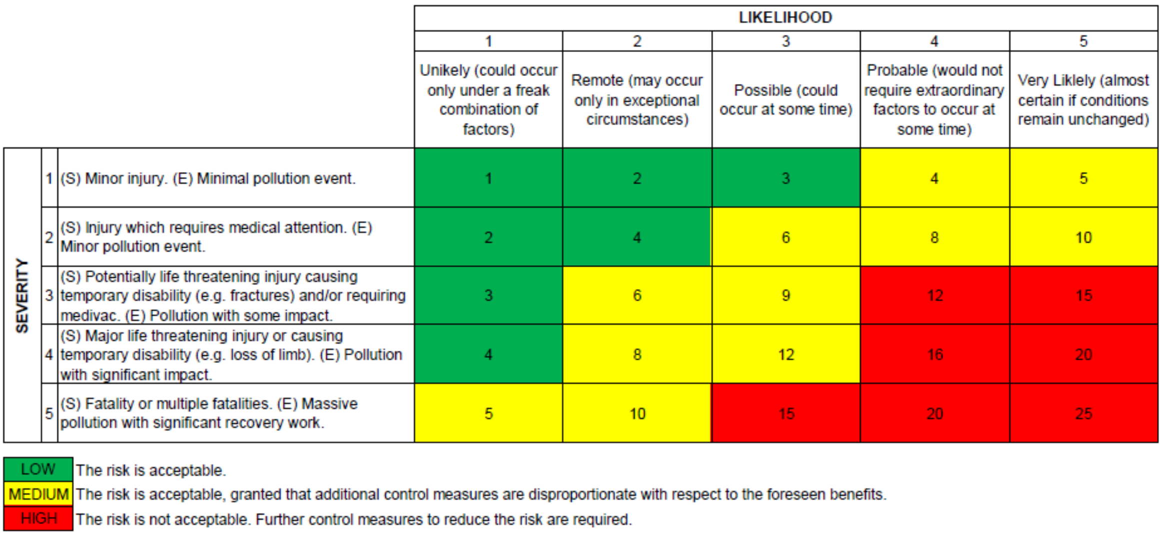
- Prevention/Mitigation Systems: all the precautions implemented at Manufacturer level (sealed connections instead of flanged connections, etc.) or Demo Site level (e.g. access procedure, emergency plans, etc.) are listed;
- Additional Remarks: any other information important for the Risk Assessment is given;
- Risk Assessment (before improvements): according to identified hazard, possible consequences and prevention/mitigation measures foreseen by the Project, a Risk Assessment is carried out, based on the following Risk Matrix (see Figure 14).



			LIKELIHOOD				
			1	2	3	4	5
			Unikely (could occur only under a freak combination of factors)	Remote (may occur only in exceptional circumstances)	Possible (could occur at some time)	Probable (would not require extraordinary factors to occur at some time)	Very Liklely (almost certain if conditions remain unchanged)
SEVERITY	1	(S) Minor injury. (E) Minimal pollution event.	1	2	3	4	5
	2	(S) Injury which requires medical attention. (E) Minor pollution event.	2	4	6	8	10
	3	(S) Potentially life threatening injury causing temporary disability (e.g. fractures) and/or requiring medivac. (E) Pollution with some impact.	3	6	9	12	15
	4	(S) Major life threatening injury or causing temporary disability (e.g. loss of limb). (E) Pollution with significant impact.	4	8	12	16	20
	5	(S) Fatality or multiple fatalities. (E) Massive pollution with significant recovery work.	5	10	15	20	25

LOW	The risk is acceptable.
MEDIUM	The risk is acceptable, granted that additional control measures are disproportionate with respect to the foreseen benefits.
HIGH	The risk is not acceptable. Further control measures to reduce the risk are required.

Figure 14 – Risk Matrix

- Proposals for improvements: based on the risk assessment (see previous point) possible additional actions are identified in order to improve safety and environmental pollution prevention;
- Risk Assessment (after improvements): Risk Assessment is repeated considering the implementation of the proposed improvements, in order to verify the benefits of the proposed actions.

3. Risk Analysis

3.1 Hazards Identified for EVERYWH2ERE Gensets

The first step of the risk assessment is to identify the hazards and the measures to be implemented to eliminate or mitigate their effects. In our case of study (hydrogen), the principal hazards will be fire and explosion ones, but other hazards, e.g. electrical, pressure and weather (for outdoor locations) related, need to be taken into account. Hazards that are likely to arise during the lifetime of the installation also need to be considered. This would include those hazards associated with installation of the equipment, start up and shutdown of the equipment, delivery of consumables (e.g. gas cylinders) and maintenance and repair. In addition, it is proposed that all that is required is that the equipment is installed according to the manufacturer's instructions, as in drawing up these instructions the manufacturer will have undertaken a risk assessment.

3.1.1 Fire and Explosion Hazards

In many situations the major hazards associated to EVERYWH2ERE Gensets are fire and explosion, particularly Hydrogen has some unusual properties. If these are not appreciated and appropriate measures not taken, then the likelihood of hydrogen escaping and a fire or explosion occurring may be greater than with many other fuels. Some of the important properties of hydrogen that may contribute towards this are:

- Very wide flammability range;
- Very low ignition energy;
- Possibility of detonation;
- Low viscosity;
- High diffusivity;
- Very much lighter than air;
- Causes the embrittlement of some metals.

Hydrogen is a gas that catches fire very easily. It burns with a flame that is almost invisible and readily forms an explosive mixture with air. The range of hydrogen/air concentrations that will explode is extremely wide, much wider than almost any other fuel. Mixtures containing from as little as 4% v/v hydrogen (in air at normal pressure and temperature conditions), which is the Lower Explosion Limit (LEL), up to as much as 75% v/v (in air at normal pressure and temperature), the Upper Explosion Limit (UEL), will readily ignite and explode. The explosive reactions may be triggered by spark, heat, or sunlight. The hydrogen autoignition temperature, the temperature of spontaneous ignition in air, is 500 °C (932 °F).

If a flammable mixture of hydrogen and air is allowed to form, the likelihood of an explosion occurring is very high. This is because the energy necessary to initiate a hydrogen/air explosion is very small. The ignition energy for a 2:1 hydrogen/oxygen mixture is only about 0.02 mJ. Even very small sparks, such as those produced by wearing certain types of clothing, are capable of igniting hydrogen/air mixtures and causing an explosion.

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A flammable fuel (hydrogen)/air mixture will not explode unless it is exposed to a sufficiently powerful ignition source. Common sources of ignition include:

- Naked flames and sparks from welding, burning or grinding;
- Electrostatic sparks from poorly earthed or non-conductive pipework;
- Electrical sparks from motors, switches, relays or mobile phones;
- Sparks from mechanical impacts;
- Hot surfaces, for example bearings.

3.1.2 Electrical Hazards

Electric shock can be a life-threatening hazard and must not be overlooked in the design, operation and maintenance of the EVERYWH2ERE Genset and its associated equipment.

Electrical hazards usually arise from two distinct areas within EVERYWH2ERE Genset installations - the normal 240 or 415 volt mains a.c. supply into the area and the d.c. electrical output of the fuel cell stack. With larger units there may be a third area - the a.c. output of an inverter connected to the EVERYWH2ERE Genset.

The voltage and current produced by each element in the stack is usually quite small; however, the total output from the stack may be of the order of 200–400 volts and large electrical currents are often available. The electrical output from quite modest fuel cells can be life threatening.

The electrical equipment associated with the EVERYWH2ERE Genset should be designed and installed to an appropriate standard, and suitable arrangements should be in place to ensure that only competent personnel are able to gain access to the equipment.

3.1.3 Leaks

Leaks have to be controlled. The main safety matter is the release of hydrogen in a place where it is not supposed to be. When a leak in an area is expected, safety systems there are put in place (detection devices). A leak in this area will not be a problem until there is an accumulation.
If hydrogen accumulates in a confined space in sufficient concentrations, like any other gas, it is asphyxiant as it deplaces oxygen from air.

3.2 25 kW and 100 kW Gensets

The 25 kW EVERYWH2ERE's solution will use tanks for a total volume of 600 L working at 350 bar and approved for TPED application. The 100 kW EVERYWH2ERE's gensets will use tanks for a total volume of 1800 L working at 350 bar and approved for TPED application. In order to save cost of development Mahytec develops a tank of 200 L for such application which can be used for both model (25 and 100 kW).
For the 25 kW the solution will use 3 tanks connected in a frame.
These section presents the design of the tank for the EVERYWH2ERE solution used in 25 kW, for details refer to "EVERYWH2ERE – D2.2 – Design and Specification of the upgrade hydrogen storage components for the 25 kW genset", Ref. [3]; the design of the tank for the EVERYWH2ERE solution used in 100 kW, for details refer to "EVERYWH2ERE – D3.2 – Design and Specification of the upgrade hydrogen storage components for the 100 kw genset", Ref. [4].

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3.2.1 Product Description

The RGV525 tank is a type 4 cylinder (fully wrapped polymer liner). Inner volume is 300 L. Working pressure is 525 bars. As a tank for hydrogen (flammable gas), it is a class 2 container as per ADR classification.
Boss design is specific, using stainless steel (316 L grade), machined.
Liner is in PEHD, end cap are welded on a standard pipe.
Composite shell is an epoxy / carbon fiber one, obtained by filament winding. Carbon fiber should be AAA YYY1 24k. Resin system use an amine based hardener to improve glass transition temperature. Actually, two resin systems are under investigation: a ZZZ system, and an TTT one.
Main application: stationary and transportation for Hydrogen use.

The design would be based on NF-EN12245+A1 and ISO 11119-3 at same time could be interesting to access a better covering of worldwide market, main objective is to obtain TPED approval.

In the report D2.2 (Ref. [3]) and D3.2 (Ref. [4]), MAHYTEC presented its own patented design for composite high pressure tanks that will be used to store hydrogen in EVERYWH2ERE Gensets. The main conclusion are the following:

- The design of the tanks for EVERYWH2ERE project have been prepared;
- The materials have been chosen and validated via FEA and preliminary lab tests;
- The FEA analysis proves the design choice.

The next step will be related to the manufacturing of the bottles to be then integrated in hydrogen storage box of the gensets. First tests proved this design while the approval in agreement with TPED regulation and certification is in progress.

3.3 Fuel Cell stack for the 25 kW and 100 kW Gensets

The fuel cell stack converts hydrogen into electrical energy in a clean and efficient way.
The Power Cell S3 stack is designed in compliance with:

- Directive 2014/35/EU—Low voltage directive;
- IEC/EN 62282-2:2012 – Fuel cell technologies – Part 2: Fuel cell modules;
- IEC/EN 60950-1 – Information technology equipment -Safety – Part 1: General requirement.

Power Cell S3 is designed for safe operation during its life cycle, but failures can occur due to abnormal running conditions. The obvious risk with a fuel cell system is leakage of hydrogen, which can either ignite directly causing fire or accumulate before ignition resulting in an explosion. Compliance with EN standard 62282-5 is recommended when designing and installing fuel cell systems.

The Fuel Cell System (FCS) has multiple layers of protection to reduce the risk and minimize the consequence of any foreseeable hazard that the system will present. However, external factors to the FCS, such as improper use or a faulty installation, can present hazards that the FCS cannot control.

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For details refer to "WP2 – System Integration and 25 kW Prototype Realization, D2.1 – Design and specifications of the upgraded fuel cell stack for the 25 kW Genset" (Ref. [5]) and to "WP3 – System Integration and 100 kW Prototype Realization, D3.1 – Design and specifications of the upgraded fuel cell stack for the 100 kW Genset" (Ref. [6]).

3.3.1 General Safety

The following list indicates the general safety points related to the FCS. Keep in mind that the Fuel Cell System is a power generation system and should be treated with the same caution as any other electrical generator system. The end user should only allow the access to training personnel and the area shall be secured to prevent any unauthorized access to the system.

- The area surrounding the FCS must be kept clear and free of combustible materials, gasoline, and other flammable vapors, gases and liquids. In addition, no ignition sources should be present around the fuel cell system;
- The operation site for the FCS must not be routinely occupied by personal, or directly attached to a building or area that is routinely occupied. In addition, the FCS must be located at minimum two meters away from non-fire protected walls or ceilings. Other installations are possible, but the user accepts all additional risks associated with the non-standard installation site;
- Do not block or obstruct the air openings on the FCS, air openings communicating with the area in which the FCS is installed, or the required spacing around the FCS;
- The air exhaust from the FCS is oxygen depleted due to part of it being consumed in the electrochemical reaction in the FCS. Unless the air exhaust is properly ventilated, conditions around the FCS may become asphyxiating;
- The user can install a vent system themselves that complies with the following statements (adapted from EN 62282-3-100);
- The FCS shall never be operated without its protective covers securely attached in their correct places;
- Do not use the FCS if any part has been under water. A flood-damaged fuel cell is potentially dangerous. Attempts to use the FCS can result in fire or explosion. A qualified service agency should be contacted to inspect the FCS and to replace all gas controls, control system parts, electrical parts that have been wet;
- When changing any of the serviceable parts of the FCS, follow all instructions given in the manual. Failure to do so may result in personal injury or death and may irreversibly damage the FCS;
- The environmental conditions in which the FCS is installed must be pollution degree 2 or better (i.e. office environment) such that there is only non-conductive pollution in the environment;
- If any liquids spill from the FCS, allow sufficient time for them to cool down before cleaning them up as internal temperatures can reach 90°C and can present a burn hazard;
- The FCS shall always be operated in combination with a suitable DC/DC converter and electrical load/battery. It shall not be used as stand-alone;
- Read the safety data sheet of the coolant to ensure that appropriate personal protection is used.

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3.3.2 Electrical Safety

The Fuel Cell System can produce high voltages and should not be used without its protective covers which prevent direct contact with the internal electrical components. There may be local or national regulations regarding the connections between the FCS and the DCDC converter / battery bank(s) which require the wiring to be carried out by qualified personnel. The operator needs to make sure that the connected DCDC converter fulfils the requirements given in Appendix A of WP2 – "System Integration and 25 kW Prototype Realization", D2.1 – Design and specifications of the upgraded fuel cell stack for the 25 kW Genset (Ref. [5]).
Ref. [5] and that the batteries can operate within the required power and voltage limits.
Ensure the FCS does not have electrical potential (i.e. < 5 V) between the stack power terminals before any work is carried out. High voltages can be present inside the system or at its output terminals even after the fuel supply is shut off. Also make sure that other high voltage components are not connected to any high voltage supply and that all disconnected high voltage connectors do not have electrical potential (i.e. < 5 V).

The following list indicates the electrical safety points related to the FCS:

- High voltages can be present inside the FCS or at its output terminals. This voltage can be sustained even after the hydrogen fuel supply is stopped. Make sure the FCS has no electrical potential between the power terminals before any work is carried out;
- High voltages can be present on the compressor output terminals on the FCS. This voltage can be sustained even after high voltage supply is disconnected. Make sure all high voltage components has no electrical potential between the power terminals before any work is carried out;
- Do not perform any service activities on the FCS while it is connected to the DCDC converter / batteries. Always disconnect the DCDC converter / batteries before starting to service the system;
- If there is a potential for a static charge to be built up in the hydrogen supply piping, the piping should be grounded to prevent this from occurring.;
- Do not spray water on or into the Fuel Cell System. There are exposed electronic circuits inside the FCS that will be damaged if there is liquid water on them when they are powered;
- The fuel cell stack can sustain a high voltage for several hours after the fuel supply has been stopped. Do not attempt to access the fuel cell stack of the FCS as it can remain energized.

In addition, the FCS should be disposed of at an authorized disposal centre. Apart from the coolant which is discussed below, there are no components that require specific treatment for disposal; however, there may be local or national regulations on the disposal of the fuel cell stack itself.
The FCS coolant is ethylene-glycol based and is treated as anti-freeze which typically must be disposed of at an authorized hazardous material recycling centre.

3.4 H2 Storage

By an overview of the "Health and Safety Analysis of the 25 kW and 100 kW Gensets", the most typical accident scenarios that might happen to the H2 Storage is listed in Table 18.

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779606. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Accordingly, proper safeguards are proposed against the accidental scenarios which are also included in Table 18. The scenarios stated below are all directly or indirectly related to hydrogen event evolutions, e.g. hydrogen release, hydrogen accumulation/ distribution or hydrogen ignition and so on, which indicate further study must be applied to assess the influence of hydrogen leakage.

The hazards and safeguards for the H2 Tank are reported in the below table:

Table 18 Identification of Hazards for H2 Tank

HAZARD	SAFEGUARD
Over-Pressure	Immediately discharge the tank. If the pressure exceed 590 bar
Vaccuuming	Let the tank get back to atmospheric pressure and stop using the tank
Over-heat (>65°C)	Cool of the tank immediately and stop using the tank
Freeze (<-40°C)	Heat the tank immediately and stop using the tank
Fire exposure	Discharge tank ASAP with all necessary precautions and stop using the tank
Sharp pressure drop (safety device open)	Stop using the tank and make a visual of the internal surface of the liner. Check all safety devices
Impact/Drop	Depends on the severity, discharge the tank and stop using the tank
Excessive tightening torque on the components	Control the presence of leak on the bosses, dissemble the intermediary part and check the threads. In case of trouble stop using the tank

For further details refer to User instructions RGV525B – MAHYTEC (Ref. [2]).

3.4.1 Location of Hydrogen Storage and Fuel Cell Power System (FCPS)

The installation of Hydrogen Storage and Fuel Cell Power System (FPCS) shall be located so that it is readily accessible to delivery vehicles, to authorised personnel and to emergency services. However, it shall be protected against physical damage and access by unauthorised personnel. Fencing shall be provided unless there is adequate control to prevent access by unauthorised persons.
On controlled sites with sufficient supervision fencing is optional.
Where fencing is provided the minimum clearance between the fence and the installation shall be 0.6 m to allow free access to and escape from the enclosure.
Timber or other readily combustible materials should not be used for fencing. The height of the fencing should be at least 1.8 m.

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Minimum separation distance between Hydrogen Storage and Fuel Cell Power Systems (FPCS) is 5 m according to Table 1 – Minimum Recommended Horizontal Distances of BCGA Code of Practice CP 33 – The Bulk Storage of Gaseous Hydrogen. The safety distances given in Table 1 will apply regardless of the position of the fence.

Approval may be required for the installation from the local planning authority, the fire authorities and the Health & Safety Executive. These requirements should be resolved with the owners of the premises where the installation is planned.

In addition, notices shall be positioned so that they are visible from all sides of approach to the installation. They should read:

HYDROGEN – FLAMMABLE GAS
NO SMOKING – NO NAKED FLAMES

These notices shall include "pictorial" symbols in accordance with the Health and Safety (Safety Signs & Signals) Regulations. Compliance with these Regulations is mandatory. These signs shall be supplemented by a flammable material warning triangle. Examples are shown in Figure 15.

Figure 15 Signs of flammable material - Examples

3.5 Summary of main identified hazards

The main hazards identified within the EVERYWH2ERE Project are related to the presence and potential release of hazardous materials, as reported in the following table:

- H_2;
- Glysantin FC G20-00/50;
- H_2O/glycol mixture.

A more detailed analysis is reported in the following table in according with the description provided in Chapter 2.2.3.

Hazard	Scenario	Risk Assessment (RA)			Proposal for Improvements	RA		
		Likelihood (L)	Severity (S)	Risk (R)		L	S	R
Release of Hydrogen	Fire/Explosion	3	2	6	1) To foresee the installation of H2 detectors, connected with visual/audible alarms 2) To integrate the emergency/evacuation plan of the site, including also the description of actions to be done in order to stop the event	2	2	4
Release of Glysantin FC G20-00/50	Toxic dispersion	2	5	10	See above 1) and 2)	1	5	5
Release of water/glycol mixture	Toxic dispersion	2	5	10	See above 1) and 2)	1	5	5

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4. Safety Strategy of the FC Gensets

Safety of system and installation is always a key consideration. A good knowledge of FC gensets, hydrogen behavior and a conception in accordance with European codes, standards and best practices allows to maintain a high safety performance.

The overall safety strategy of the FC Gensets (hydrogen chain) is detailed below.

4.1.1 Leak suppression and control

Hydrogen is a highly flammable gas that can release a vast amount of energy in a very short amount of time. The main hazards of hydrogen are related to hydrogen leaks building up in contained areas which can be effectively mitigated through simple precautionary actions. First and foremost, ensure that all pipes transporting hydrogen are leak tight and cannot be damaged in any foreseeable event. Furthermore, ensure that the area around and above these pipes is properly ventilated and that there are no sources of ignition. Be aware that there may be local or national regulations on the storage and use of hydrogen gas. It is recommended to install the FCS according to IEC standard 60079-10.

The following list indicates the general safety points related to the hydrogen:

- Hydrogen gas is highly flammable and when contained, it can be explosive. Avoid ignition sources around and above the FCS to reduce the risk of fire or explosion in case of a fuel leakage;
- Hydrogen flames are invisible and emit a small amount of radiant heat which can be hard to detect. If there is a suspected hydrogen fire, do not approach the FCS, instead turn the hydrogen supply off and contact the local emergency service;
- A large hydrogen leak in a contained area can deplete the atmosphere of oxygen, resulting in an asphyxiation hazard. In the case of a large leak, do not approach the FCS or enter any small enclosed areas. Contact the local emergency service;
- Use compatible materials and suitable components to prevent leakage when designing the system;
- It is recommended to perform a leakage test of the fuel loop before starting up the system for the first time and after every service of the fuel loop. Refer to standard EN 62282-2 for leakage test procedure;
- Hydrogen is incompatible with many materials. A common example is embrittlement in metals, where the metal becomes fragile and can crack. Ensure that all pipe work and tubing, including any seals, are compatible with hydrogen.

According to the hydrogen sensor specifications, sensor calibration shall be checked as often as is practical and no less frequent than once every six months. The sensors can be accessed by removing the top panel.

If malfunctioning, the sensors shall be replaced. The hydrogen sensor used in the FCS is a HydroKnowz^{TM} Hydrogen Sensor from Neodym Systems. This sensor will shut the system off via internal relay if the hydrogen level is above 25% LEL (1% hydrogen in air). To replace the sensors, unplug the cable and remove the two bolts holding it in place.

It is recommended that a leakage check of the fuel system in accordance with IEC_62282-5-100 is included in the system maintenance program.

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4.1.2 Prevention of formation or over-oxygenated atmosphere

Abnormal running conditions can cause pinholes in the MEA which, in turn, will result in extensive heating and internal fire. This error state can be detected by monitoring cell voltages, temperature, hydrogen concentration in the process air outlet or by fire detection.

4.1.3 Suppression/reduction of ignition sources

If the measures to prevent fuel leaks fail or if the ventilation is inadequate, accumulation of fuel gas can occur. Avoid ignition sources to reduce the risk of igniting any accumulated fuel. It is consequently forbidden to smoke.

H2 Storage
The tank must be installed away from external and/or uncontrolled heat source and preserved from temperature outside of the operating temperature range (between 40°C up to 65°C) in order to prevent premature ageing. The tank must be installed in a ventilated place.

4.1.4 Protection against accidental impact

The H2 Tank must also be protected from any accidental impact, especially on the bosses. The tanks must be handled with care. If any damage is observed at the surface of the tank, empty it and contact MAHYTEC.

4.1.5 Protection against overpressure

A too high inlet hydrogen pressure can damage the feed line system components and in an extreme case, it can rupture the seals on the feed valve and cause a major hydrogen leak. Overpressure protection should be installed on the feed hydrogen line to prevent this from occurring.

The storage tank vents are mounted vertically at a minimum height of 3 m and are bended at 90° to avoid the introduction of water within the vent.
The hydrogen and oxygen vents are located at a minimum height of 1 m above the roof the container and are well separated to avoid oxygen-enriched hydrogen-air mixture. Each venting line is common to the electrolyser and the fuel cell and allows the depressurization of the system in less than 2 minutes in case of emergency shut-down.

4.1.6 Emergency and safety shutdown

Early detection of fuel leakage enables safe shutdown of the system before any risk is posed. It is strongly recommended to install adequate H2 gas sensors for this purpose. Standard IEC60079-29-1 Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases can be used to select appropriate gas sensors for H2 service.

Installation of fire detectors inside the system enclosure is strongly recommended to enable automatic shutdown. It is the end user's responsibility to select a suitable amount and type of fire detectors and their location within the enclosure.

If Power Cell S3 is shut down properly, restart is facilitated and durability maintained. It is important to release the load in a controlled way and remove moisture as well as impurities.

Impurities are adsorbed on the electrodes while the system is operated. With a well implemented shutdown strategy, the cathode can be regenerated by letting hydrogen diffuse through the membrane. When hydrogen reacts with oxygen, the cathode potential is decreased and impurities are released.

While an optimal shutdown strategy depends on the system layout, a typical shutdown could be performed as follows:

1. Release the load, or preferably, decrease the load to a very low level to avoid the OCV state. If the stack is loaded, the drawn current should be small enough to maintain the cell voltages at 0.8 V.
2. Reduce cooling power.
3. Increase cathode air flow to remove any liquid water.
4. Purge the anode loop to remove liquid water.
5. Turn off air supply and, if possible, close cathode inlet and outlet with valves.
6. Make sure that hydrogen is maintained at the anode until the cell voltages have dropped close to zero. It can take up to 10 min depending on cathode system design. Hydrogen can be maintained after the fuel supply is cut by closing the anode exhaust valve, maintaining a minimum fuel flow or periodically refilling the anode with hydrogen. If enough hydrogen is available for the reaction, a small load may be used to deplete the cathode from oxygen.

If Power Cell S3 is subjected to freezing after shutdown, a more thorough dry out procedure using cathode air is required. The dry out procedure should be performed before the cathode air supply is closed (step 5 above).

4.1.7 Transportation, handling and support

The following requirements apply for transport of the Fuel Cell System:

- No load shall be placed on top of the fuel cell system;
- All fluid connections shall be plugged prior to transport;
- Make sure that system is not flooded during transport by e.g. using a monitoring device;
- The FCS shall only be transported as per indication given on the shipping box, i.e. with respect to its orientation;
- If temporary storage needed, storage shall occur indoors and water-protected, and in a chemicals free emissions area.

The Fuel Cell System weighs approx. 150 kg. Care needs to be taken when lifting the FCS as Power Cell does not take any responsibility for personal injury or property damage from the installation process.

The H2 Tank (RGV525 tank) follows the 2010/35/UE regulation, so that is usable to transport hydrogen. Please refer to ADR AND 2010/35/UE, for safely fix the tank during is transportation.

Lifting horizontally can be done using belt able to withstand a load of 500 kg minimum.
Lifting vertically can be done using a hook and inner thread of boss, be careful to avoid friction on composite and opposite boss. Prevent shock by avoiding pendulum movement of the tank.

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4.1.8 Service and Maintenance

This section covers the items in the FCS that can be maintained by the user and the instructions for performing this maintenance. All routine tests need to be recorded in a common test protocol. For details refer to Chapter 3.3.1.

The Fuel Cell System should undergo a service every 1000 operating hours or every two years, whichever is shorter. The total operating time is tracked by the system and can be accessed via CAN parameter “Runtime” in CAN message “SysInfo1”. A service of the FCS includes changing the high temperature coolant and replacing the air filter. The only regular maintenance that the FCS requires is to ensure that the air inlet grills is free from debris such as leaves and grass, and that the area around the FCS is free of any combustible material.

While the fuel cell stack itself does not require any maintenance, it is recommended that a leakage check of the fuel system in accordance with IEC 62282-5 is included in the system maintenance program along with calibration of safety related equipment.

4.1.9 Safety of the installation

Before installing the FCS, read all the installation instructions and make sure that the installation location meets all requirements set out in this section. The FCS should be fully installed before it is electrically connected to the DCDC converter and the power supplies. Other installation requirements may come from local or national regulations and it is up to the end user to fulfil requirements set by these.

Directive 2014/34/EU (ATEX Directive) may apply to equipment surrounding the FCS; it is up to the user to ensure that the installation complies will all applicable national and local regulations.

Authorized staff is trained and are trained to relevant emergency procedures. Any work other than that directly connected with operating or maintenance of the system is realized under the control of a Safety Work Permit.

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5. Conclusions and Future Plans

In this report a risk assessment of the state of the art fuel cell and hydrogen storage was carried out towards the definition of guidelines for the specification of EVERYWH2ERE gensets.
The EVERYWH2ERE Gensets (particularly hydrogen), relies on five key considerations:

- Recognize hazards and define mitigation measures (plan);
- Ensure system integrity (keep the hydrogen in the system);
- Provide proper ventilation to prevent accumulation (manage discharges),
- Ensure that leaks are detected and isolated (detect and mitigate);
- Train personnel and ensure that hazards and mitigations are understood and that established work instructions are followed (manage operations).

Moving forwards from this report, the EVERYWH2ERE Project will move to the Work Package 4 – Demonstration and Monitoring, in particular a test validation of EVERYWH2ERE Gensets will be carried out at FRIEM premises in Italy, for that reason, in this document some safety aspects have been reported in Annex A.

This document is preparatory to the final version of D5.4 which will be redacted according to the outcomes of the demonstration.

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6. References

[1] WP1- “FC Gensets Specifications”, D1.7 – “Report on FC gensets requirements and specifications”.

[2] User instructions RGV525B – MAYHTEC, Doc. CL-MAN-005, Rev. A.

[3] EVERYWH2ERE - D2.2 – Design and Specification of the upgrade hydrogen storage components for the 25 kW genset

[4] EVERYWH2ERE – D3.2 – Design and Specification of the upgrade hydrogen storage components for the 100 kW genset

[5] WP2 – “System Integration and 25 kW Prototype Realization”, D2.1 – “Design and specifications of the upgraded fuel cell stack for the 25 kW Genset”

[6] WP3 – “System Integration and 100 kW Prototype Realization”, D3.1 – “Design and specifications of the upgraded fuel cell stack for an enhanced 100 kW subsystem”

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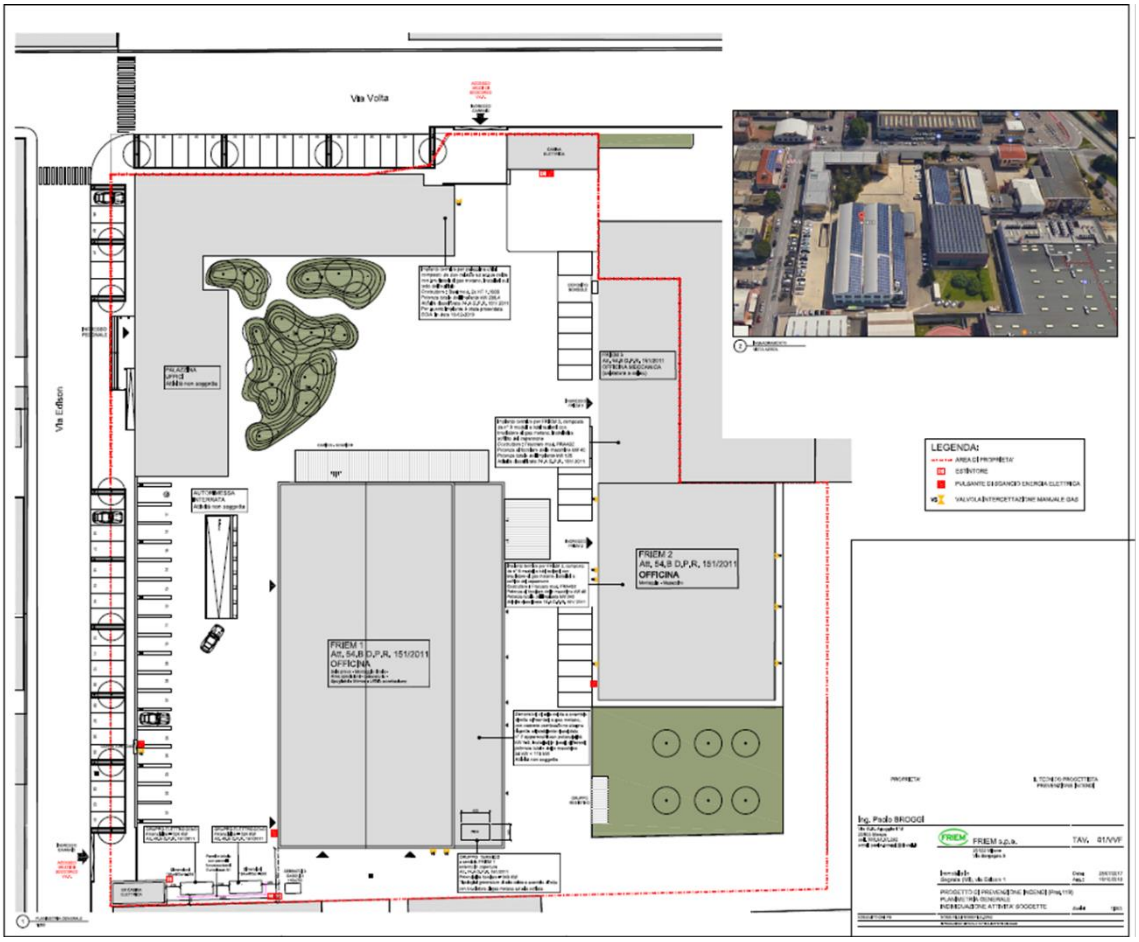
Annex A – Aspects related to Validation in FRIEM

The goal of validation testing is to simulate conditions to be expected in field testing, but still in somewhat controlled environment. This is useful to perform with a prototype system and gives benchmark information on what to expect from the field tests.

In our case of study, EVERYWH2ERE Gensets are transportable fuel cell electric generator powered by compressed hydrogen with output power rate of 25 kW and 100 kW composed from two main and separated units: H2 Storage and Fuel Cell Power System (FCPS).

The EVERYWH2ERE Gensets will be tested in FRIEM premises and labs (picture below).



For that reason, a good knowledge of hydrogen behaviour and a conception in accordance with regulations, European codes, standards and best practices allows to maintain a high safety performance. Viewed as a package, these documents address all key aspects of system design, construction, operation, and maintenance. Compliance with these requirements should reduce the system risk to a safe level.

Particular attention is given to the regulations, which consists of building and fire codes that are directly adopted by jurisdiction and are therefore the law in the jurisdiction in which they area adopted. Any code or standard referenced in the body of a building or fire code adopted by a jurisdiction becomes legally enforceable document in that jurisdiction. Since, the test validation will be carried out at FRIEM premises, Italian regulations will be in applied as follow:

Ministerial Decree of 23 October 2018 in Italy, Fire prevention technical rule for design, construction and operation of hydrogen. For the purpose of fire prevention, in order to achieve the primary safety objectives related to safeguarding of people and the protection of assets against risks of fire, the activities referred to in Art. 1 are made and managed so as to:

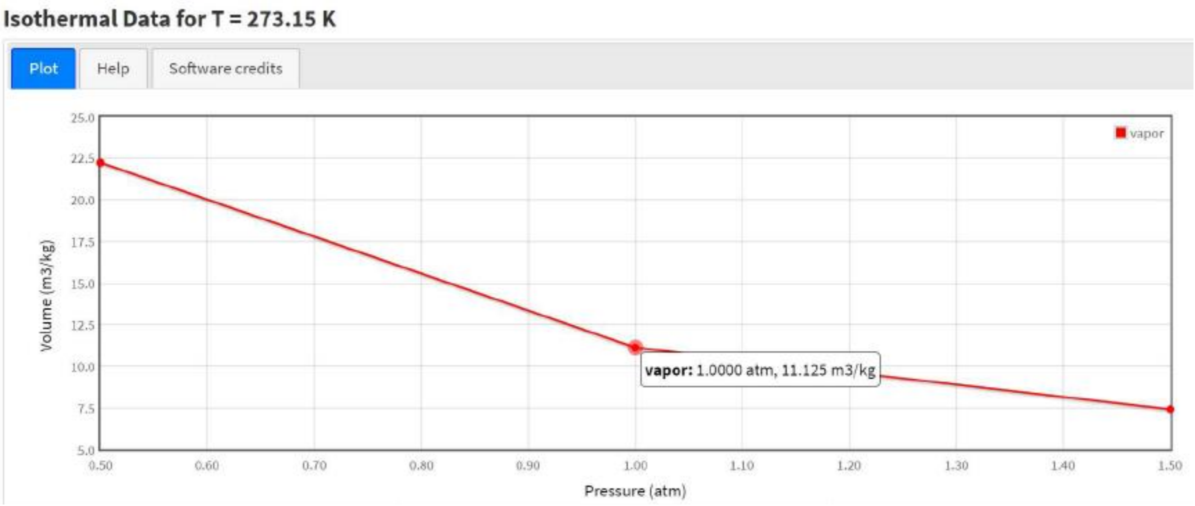
a) Minimize the causes of fire and explosion;
b) Limit, in case of accidental event, damage to the people;
c) Limit, in case of accidental event, damage to the contiguous buildings and premise.

The prohibition referred to the paragraph 1, letter b), does not apply to distribution plants powered by duct which are equipped with storage capacity greater than 500 Nm³ of gas; in such plants it is not allowed on-site production above 50 capacity Nm³ / h, not even for feeding of emergency.

The prohibition referred to the paragraph 1, letter c), does not apply to distribution plants powered by duct which have an accumulation capacity not exceeding 500 Nm³ of gas. Municipal planners admit the presence of distributors fuel in public green areas; in these plants are not allowed to produce on site at the capacity of 50 Nm³ / h or the use of cylinder wagons, not even for emergency power supply.

As reported by the Ministerial decree, there is a threshold of 500 Nm^3 and considering the NIST data as per below figure (where is reported the density of hydrogen), in our case of study, the quantity of hydrogen is about 45 kg. Therefore, the hydrogen can be stored as follow (without incurring the provisions of this decree):

- One (1) bundle of 38 kg;
- Two (2) bundle of 19kg.



In addition, **Decree of the President of the Republic, August 1, 2011, n. 151** simplify the discipline of fire prevention proceedings, a pursuant to article 49, paragraph 4 - quarter, of the decree-law May 31, 2010, n. 78, converted, with modifications, by the law 30 July 2010, n. 122. This regulation identifies the activities subject to fire prevention and discipline controls, for the deposit of projects, for the examination of projects, for visits techniques, for the approval of exemptions to specifications regulations, the verification of fire safety conditions which, according to current legislation, are attributed to the competence of the National Fire

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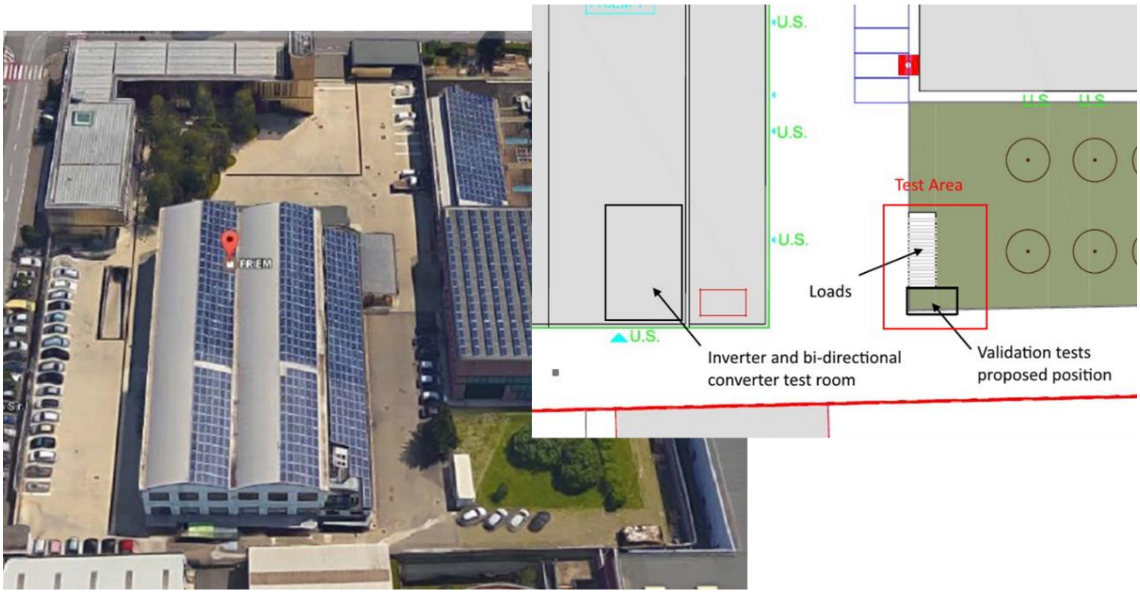
Department. storage of flammable gases below 0,75 m^3 (geometric quantity) not subject to fire fighters controls.
In our case study, it is feasible to operate until 15 bundle (each of them with a capacity of 0,05 m^3) without fire fighter controls.

In the following other two pictures describe FRIEM premises where the validation tests will be performed.



Annex B – Aspects related to Hydrogen in ATEX and other relevant Regulation

In EU, the principal regulations covering hydrogen facilities arise from the national legislation passed to implement the ATEX Directives[7],[8] and the Pressure Equipment Directive[9]. Their requirements are not specific to hydrogen and would equally apply to any fuel that is capable of generating a flammable atmosphere, for example natural gas or LPG, or equipment that contains a fuel under pressure. For some components of the installation, for example if the hydrogen is produced in-situ by the reformation of natural gas, the requirements of the Gas Appliances Directive[10] may also be applicable.

ATEX is the name commonly given to the framework for controlling explosive atmospheres arising from gases, vapours, mists or dusts, and the standards of equipment and protective systems used in them. It is based on the requirements of two European Directives. The first is Directive 94/9/EC11 (also known as ATEX 95 or ATEX Equipment Directive) on the approximation of the laws of member states concerning equipment and protective systems intended for use in potentially explosive atmospheres.

Any equipment (electrical or non-electrical) or protective system designed, manufactured or sold for use in potentially explosive situations has to comply with the essential health and safety requirements (EHSR) set out in the Regulations.

It is relevant to state that electrical equipment, as hydrogen is classified in ATEX as part of the group IIc, present in EVERYWH2ERE Fuel Cell Power System container and/or in the area of EVERYWH2ERE storage, must have a robust protection, as group IIc gases have a high ignition risks.

The second is Directive 99/92/EC[11] (also known as ATEX 137 or the ATEX Workplace Directive) on the minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres.

The key requirement of such directive is that risks from dangerous substances, e.g. flammable gases, are assessed and controlled.

As the ATEX Directives only apply to the workplace (i.e. FRIEM Validation laboratory), hydrogen fuel cells installed in domestic premises are outside their scope.

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[7] Directive 94/9/EC of the European Parliament and of the Council of 23 March 1994 on the approximation of the laws of Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres. Luxembourg 1994. (OJ L100, 19/04/1994)

[8] Directive 1999/92/EC of the European Parliament and Council of 16 December 1999 on the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), Luxembourg 1999. (OJ No L023, 28/01/2000).

[9] Directive 1999/92/EC of the European Parliament and Council of 16 December 1999 on the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), Luxembourg 1999. (OJ No L023, 28/01/2000).

[10] Council Directive 90/396/EEC of 29 June 1990 on the approximation of the laws of the Member States relating to appliances burning gaseous fuels. Luxembourg 1990. (OJ L196 26/7/1990).

[11] Directive 1999/92/EC of the European Parliament and Council of 16 December 1999 on the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), Luxembourg 1999. (OJ No L023, 28/01/2000).

SITING OF FUEL CELL SYSTEMS (Stationary)[12]

Requirements applicable to the siting of stationary fuel cell installations fuelled by hydrogen and of their attendant storage and hydrogen generation systems (the installation) will vary according to whether the installation is located in domestic dwellings, in commercial premises/buildings, or outside in the open air.

4.3.1 General requirements for both domestic/residential and commercial/industrial installations

The following general requirements apply to all systems whatever their location and should be taken into account in assessing that the risk is acceptable and has been reduced to as low as is reasonably practicable:

- The installation should be placed on firm foundations, capable of supporting it;
- Ensure that any area, enclosure or housing etc into which hydrogen may leak is designed to prevent the gas becoming trapped and is equipped with effective high and low level ventilation openings:
- The installation components, in particularly vent or exhaust outlets, should be sited giving due attention to adjoining doors, windows, outdoor air intakes and other openings into buildings;
- Air intakes shall be located in such a way that the fuel cell is not adversely affected by other exhausts, gases or contaminants;
- Exhaust outlet(s) should not be directed onto walkways or other paths of pedestrian travel
- Security barriers, fences, landscaping and other enclosures should not affect the required flow into or exhaust out of the installation;
- Any vents (from pressure relief valves or bursting joints, etc) should be piped to a safe area and any points of possible leakage should be in an area where any gas cannot accumulate or is freely ventilated. In addition care should be taken that vents do not release hydrogen adjacent to walls or along the ground as this may increase the extent of the flammable cloud or flame;
- Safety/separation distances where a release is foreseeable during normal operation should be determined on a case-by-case basis. Separation distances should be measured horizontally from those points in the system where, in the course of operation, an escape of hydrogen may occur. The most recent version of an appropriate code should be consulted for additional information on the appropriate use of separation distances. In circumstances where it is not practicable to use minimum separation distances, an acceptable situation may be achieved through the use of fire-resistant barriers, fire compartments, fire resistance, room-sealed appliances, appliance compartments, or other hydrogen safety engineering or risk reduction techniques;
- For all indoor locations the installation should comply with all applicable building regulations, particularly as they relate to heating and electrical appliances, fuel storage systems, conservation of fuel and power, protection against pollution, and more generally to securing reasonable standards of health and safety for people in or about buildings and any others who may be affected by buildings or matter connected with buildings.
- For all indoor fuel cell locations, liquefied and gaseous hydrogen storage should either be located outside in the open air, in an appropriate dedicated unoccupied storage building, in an appropriately ventilated enclosure, or in a purpose designed indoor or underground facility, and should conform to recognised guidance.

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[12] EVERYWH2ERE Gensets are not stationary fuel cell, but if operating for more than few hours can be potentially considered in such category

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Requirements specific to commercial/industrial premises

- The fuel cell and any associated equipment shall be suitably protected against unauthorised access, interference, vandalism or terrorist attack commensurate with the location and installation environment. Any security arrangements shall not compromise the requirement for effective ventilation.
- The fuel cell and associated equipment shall be suitably located to allow service, maintenance and fire department/emergency access and shall be supported, anchored and protected so that they will not be adversely affected by weather conditions (rain, snow, ice, freezing temperatures, wind, seismic events and lightning) or physical damage. Furthermore the placing of any components of the fuel cell system should not adversely affect required building exits, under normal operations or in emergencies.
- If practicable, the installation should be located in a normally unoccupied room built to appropriate fire-resistance standard and within an appropriate fire-resisting and noncombustible enclosure. Congestion, blockages and obstructions should be kept to an absolute minimum in the room as they may enhance flame acceleration in the event of an accident.
- The room in which the fuel cell and associated equipment are located shall provide a minimum of 30 minutes fire-resistance and be fitted with a suitable fire detection and alarm system.
- The installation should not be located in areas that are used or are likely to be used for combustible, flammable or hazardous material storage;
- Any potential sources of ignition, such as non-flameproof electrical light fittings, should be located well below any equipment from which hydrogen may leak and not immediately below horizontal bulkheads or impervious ceilings under which hydrogen may accumulate;
- For workplaces it is a legal requirement, for the employer to identify fire and explosion hazards, classify areas where explosive atmospheres may exist, evaluate the risks and specify of measures to prevent or, where this is not possible, mitigate the effects of an ignition.
- All equipment (electrical or mechanical) within the identified hazardous zone shall be CE certified. Whenever reasonably practicable, the fuel cell and other hydrogen handling equipment shall be located at the highest level within the enclosure and physically isolated from any electrical equipment that is not ATEX-complaint or other potential sources of ignition.
- Gas-tight compartments, bulkheads and ventilation should as far as possible be used to reduce the likelihood of leaking hydrogen reaching potential ignition sources.
- The installation should be located away from areas where potentially explosive atmospheres may be present;
- The ventilation exhaust or other sources of emission that may contain dangerous substances must be released to a safe place. An appropriate hazardous zone should be identified around any foreseeable release point;
- The following additional factors should be taken into account in assessing that the risk is acceptable and has been reduced to as low as is reasonably practicable: smoking permitted areas; uncontrolled public areas; security barriers; emergency exits.

Emergency planning

It is recommended that an emergency plan should be in place wherever compressed gaseous or cryogenic fluids are produced, handled or stored. This emergency plan should include the following:

- The type of emergency equipment available and its location;
- A brief description of any testing or maintenance programs for the available emergency equipment; • An indication that hazard identification labeling is provided for each storage area;
- The location of posted emergency procedures;

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• A list, including quantities, of compressed gases and cryogenic liquids and their materials safety data sheets (MSDS) or equivalent;
• A facility site plan including the following information:
o Storage and use areas;
o Maximum amount of each material stored or used in each area;
o Range of container sizes;
o The location of gas and liquid conveying pipes;
o Locations of emergency isolation and mitigation valves and devices;
o On and off positions of valves for those that are not self-indicating;
o A storage and distribution plan that is legible and drawn approximately to scale showing the intended storage arrangement, including the location and dimensions of walkways.
• A list of personnel who are designated and trained to act as a liaison with the emergency services and who are responsible for the following:
o Aiding the emergency services in pre-emergency planning;
o Identifying the location of compressed gases and cryogenic fluids stored or used;
o Accessing MSDS;
o Knowing the site emergency procedures.

EXPLOSION PREVENTION AND PROTECTION

For industrial installations ATEX National regulation apply, which require an hierarchical approach to explosion prevention and protection. They usually require the identification of the explosion hazards and the prevention or protection measures to be employed.

The measures taken should be appropriate to the nature of the operation being undertaken, in order of priority and in accordance with the following basic principles:

♣ The prevention of the formation of explosive atmospheres, or where the nature of the activity does not allow that;

♣ The avoidance of ignition sources where an explosive atmosphere could exist; or

♣ If ignition sources cannot be eliminated, the employment of measures to mitigate the effects of an ignition. This approach to explosion safety, using a range of explosion prevention measures and, if the explosion risk cannot be entirely eliminated, explosion protection measures, is referred to as integrated explosion safety. Guidance on the integrated explosion safety approach can be found in BS EN 1127-1:200743, which outlines the basic elements of risk assessment for identifying and assessing hazardous situations. The standard also specifies general design and construction methods to help designers and manufacturers to achieve explosion safety in the design of equipment, protective systems and components.

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