WORKSHOP 1

with HRS operators and manufacturers

on the 3 case-study configurations and WP2 methodology

8th June 2021

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under Grant Agreement No 101006794. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe research.

Agenda

Time	Topic	Speaker
9:30 – 9:35	Welcome	Alexandru Floristean, Hydrogen Europe
9:35 – 9:45	From the risk assessment to the general best practice guidelines – process	Quentin Nouvelot, ENGIE
9:45 – 9:55	Presentation of the 3 case study configurations	Elena Vyazmina, Air Liquide
9:55 – 10:20	Configuration #1 – Ready-to-deploy multi-fuel station (discussion)	Elena Vyazmina, Air Liquide
10:20 – 10:45	Configuration #2 – On-site H_2 production multi-fuel station (discussion)	Elena Vyazmina, Air Liquide
10:45 – 10:55	BREAK	
10:55 – 11:20	Configuration #3 – High capacity and high filling multi-fuel station (discussion)	Elena Vyazmina, Air Liquide
11:20 – 11:30	Final remarks on the 3 configurations	Elena Vyazmina, Air Liquide
11:30 – 11:55	Experimentation – leakages, clouds and ignition (presentation & discussion)	Christophe Proust, INERIS
11:55 – 12:00	BREAK	
12:00 – 12:20	Experimentation – fire and explosion (presentation & discussion)	David Torrado, Health and Safety Executive
12:20 – 12:30	Workshop follow up and questionnaire	Alexandru Floristean, Hydrogen Europe

Safety and Permitting for Hydrogen at Multifuel Retail

MultHyFuel

"(…) lack of guidelines and instructions for local authorities can cause **delays**, **extra costs** and **divergent interpretations** from case-to-case, further complicating the obligations of HRS operators."
2018, https://www.hylaw.eu/

Definition of **commonly applicable, effective, and evidence-based guidelines** to facilitate the construction of HRS in multi-fuel refuelling stations through

- Identification of relevant gaps in the current legal and administrative framework;
- Acquisition of experimental data from engineering research;
- Active engagement with a community of stakeholders in the overall process.

Hydrogen Europe
Air Liquide creative oxygen
BESPOKE RESEARCH AND CONSULTANCY FROM HSE
INERIS maitriser le risque pour un développement durable
ENGIE Lab CRIGEN
ITM POWER Energy Storage | Clean Fuel
kiwa
snam
Shell Hydrogen
ZSW

FCH Fuel Cells and Hydrogen Joint Undertaking

Stakeholder engagement plan

- Involvement of target stakeholders from the early stages for **validation** of solutions proposed and final results.
- A series of **workshops** will be organised at strategic stages of the project.

WS #	Topic	Planned Date
1	Validation of the 3 case study configurations defined in T3.1	8th June 2021
2	Validation of refined case study models and WP2 methodology	Dec 2021
3	Results from WP2 and WP3	Apr 2023
4	Development of the best practice guidelines	Jul 2023
Final	Adoption of best practice guidelines	Dec 2023

Workshop 1

Target group:

HRS operators and manufacturers

Key main goals:

- Validation of the 3 case study configurations
  - Design options proposed
  - Safety measures present in most refuelling stations
- Scanning of potential data sources relevant for leakage and ignition characterization
- Feedback on the dispenser replica design to be used in the experimental work

Meeting Set-Up and Etiquette

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- **Please make sure to have your name and company's name as your username**
- **Please remain muted throughout the course of the workshop when you are not speaking. If you would like to take the floor, please use the "raise hand" function provided in the zoom platform.**
- **To engage and provide feedback, feel free to use the chat or participate orally unmuting your microphone**
- **This meeting will be recorded. To ask for the recording please send an e-mail to info@multhyfuel.eu**

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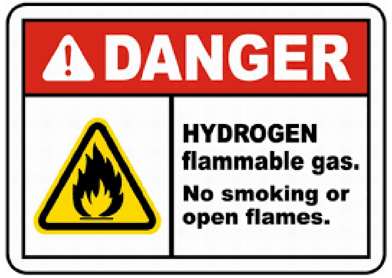
WP3 - From the risk assessment to the general best practice guidelines

- Objectives
- Methodology
- Construction of 3 case-study configurations
- Tasks and timeline

WP3 Objectives

- Develop best practice guidelines that can be used as a common approach to **risk assessments** (e.g. suggested methods/tools for risk modelling, Atex, safety distances)
- Address the **safe design** for hydrogen refuelling stations in a multi-fuel context
- Determine recommendations for the safe implementation of **H2 dispensers in multi-fuel stations** (separation distances, safety barriers) to be used in standards and regulation relative to HRS



	Consequence				
Likelihood	Insignificant	Minor	Moderate	Major	Severe
Almost Certain	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	Extreme	Extreme
Possible	Medium	Medium	High	High	Extreme
Unlikely	Low	Medium	Medium	High	High
Rare	Low	Low	Medium	High	High

WP3 Methodology

- **Task 1:** State of the art about **refuelling station technologies** to define case study models
- **Task 2:** Benchmark of **risk assessments** on H2 & conventional stations to recommend tools/methods for risk assessment in Multhyfuels context
- **Task 3 & 4:** Preliminary and detailed **risk assessments** on **3 case study configurations**
- **Task 5:** Identification of **critical scenarios and safety barriers** to be studied in WP2 (experimentations)
- **Task 6:** Review of critical scenarios with inputs from WP2 to **define separation, safety distances, hazardous areas**
- **Task 7:** Writing **best practices guidelines** for multi fuels stations based on findings of WP3

3 case-study configurations

- **How they were built:**
  - Based on current and future needs
  - Spread a maximum of design options on the 3 cases study configurations in order to bring more value to the risk analysis and the project
  - Keeping in mind feasibility and relevance

- **How they will be used:**
  - Preliminary and detailed risk assessment
  - Identification of critical scenario to orientate and focus WP2 modeling and experimental work
  - Assessment of additional safety barriers when needed

Tasks and timeline

- Stackeholders implication: case study configurations, benchmarking, results, best practices

	WORKPACKAGE	LEADER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
WP1	Detailed investigation of current status	HE																																				
Task 1.1	Definition of scope for regulatory analysis (Cross-country research framework)	HE				D1.1																																
Task 1.2	Research into permitting requirements and public guidance on required risk assessments	HE																																				
Task 1.3	Comparative assessment and gap analysis	HE									D1.2																										D1.3	
WP2	Practical research to address gaps in current understanding	INERIS																																				
Task 2.1	Leakage characterisation of H2 dispensers	INERIS																	D2.2			D2.1																
Task 2.2	Fire and explosion hazards	HSE																				D2.3									D2.4							
WP3	Generate best practice guidance	ENGIE																																				
Task 3.1	State of the art of technology	AL				D3.1																																
Task 3.2	State of the art on risk assessment methodologies	ENGIE				D3.2																																
Task 3.3	Preliminary risk analysis	ENGIE							D3.3																													
Task 3.4	Detailed risk assessment	AL											D3.4																									
Task 3.5	Identification of critical scenarios	INERIS												D3.5																								
Task 3.6	Risk assessment review of critical scenarios and hazardous areas	AL																													D3.6							
Task 3.7	Best practice guidelines redaction	HSE																																			D3.7 D3.8	
WP4	Engagement	HE																																				
Task 4.1	Establish Networks of Public Authorities, HRS Operators and Makers, component Manufacturers and standards developing organisations (SDOs)	HE		D4.1																																		
Task 4.2	Inception phase	HE																																				
Task 4.3	Workshop with HRS Operators and HRS Makers on state of the art; case study models	HE						D4.2																														
Task 4.4	Workshop with public authorities on refined case study models and WP2 methodology	HE													D4.3																							
Task 4.5	Workshop with HRS Operators, Makers and component manufacturers on results of WP2 and WP3	HE																													D4.4							
Task 4.6	Workshop with public authorities and standards developing organisations (SDOs) on development of best practice guidance	HE																																D4.5				
Task 4.7	Meeting on adoption of best practice guidance (WP3)	HE																																				D4.6
WP5	Dissemination, Communication and exploitation	ITM																																				
Task 5.1	Definition of the communication, dissemination and exploitation planning	ITM			D5.1																																	
Task 5.2	Creation of the project visual identity and communication channels and materials	ITM						D5.2																														
Task 5.3	Continuous implementation of dissemination and communication measures	ITM												D5.1											D5.1													D5.1

2021 = risk assessments / 2023 = critical scenarios & best practices

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Refuelling station configurations

- 3 configurations pre-described
  - Configurations to be considered for risk assessment
  - Configurations defined regarding the various needs of potential fuelling stations
- **Configuration #1 – Ready-to-deploy multifuel station**
  - Based on existing, « simple » and already used technologies
- **Configuration #2 – On-site H2 production multifuel station**
  - Based on on-site hydrogen production and associated requirements
- **Configuration #3 – High capacity & High filling multifuel station**
  - Based on future large needs of hydrogen for mobility

MultHyFuel

Context/definitions

- **Multi-fuel station** *(MultHyFuel def.):* a station providing several types of fuels for vehicles refuelling, answering, this way, to the existing and future needs. Will use the same codes, visuals and functions as a conventional station - which is also already a multi-fuel station - but integrating hydrogen.

- Apart from the process area, the main parts of the station are:
  - **Dispensing forecourt**, where the dispensers are located, distributed on one or several dispensing islands, cover or not by one or several canopies to protect the customer,
  - **Dispensing islands**, usually an elevated curb (the "island") where the dispensers are located; one island is a fuelling post for one vehicle, or two vehicles located on both sides of the island,
  - **Dispenser**, composed of one or several nozzles delivering potentially different types of fuels.

Dispensers


eNGie


HYDROGEN-NX
水素 70MPa
Hydrogen


Air Liquide
2


Hydrogen
Hydrogen
tell me more


2
Shell
Hydrogen

Summary of the different options

Spread into the 3 case study configurations

Topic	Option 1	Option 2	Option 3
H_2 source/supply	Liquid	Trucked in (tube trailer left on site)	Production on-site
Dispenser pressure	700 bar	350 bar	
Dispenser type	Single hose	dual hose (but NO simultaneous filling possible)	dual hose (simultaneous filling possible)
Peak dispenser flow	60 $g.s^{-1}$	120 $g.s^{-1}$	300 $g.s^{-1}$
Pipe work	Underground (buried)	Underground (trench)	Above ground (elevated)
Canopy	Unique canopy covering the entire dispensing forecourt	Multiple canopies with space between each island roof	no canopy
HP storage location	containerized	outside in semi-confined compound (options blast wall / fire wall / other to be define later)	outside in open compound
Dispenser location	H_2 dispenser on same island than other fuel	H_2 dispenser on dedicated island	Multi-fuel dispenser fully integrating all fuel including H_2
Heat exchanger	Inside dispenser	Next to dispenser on the island	
Vent lines	on canopy roof	from compound	

Config #1 – Ready-to-deploy	Config #2 – On-site H_2	Config #3 – High

When the same option is present in several configurations, the colour appears in the font and in the background of the cell

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Configuration #1

Ready-to-deploy multifuel station

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Sensitive parameters
(to be discussed, completed and set)

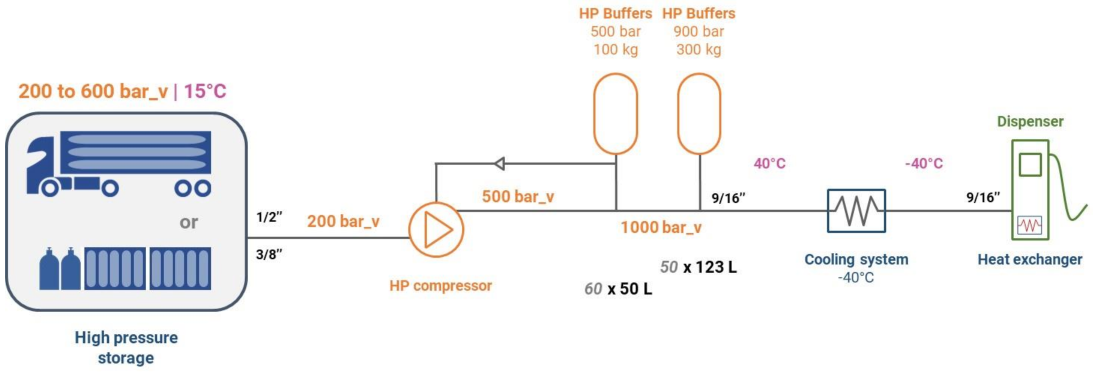
- *Maximum storage pressure*
- *Storage volume ⇔ HRS capacity (kg.d^{-1})*
- *Gaseous storage confinement*
- *Maximum filling flow rate*
- *Maximum pressure to be considered for HDV (350 vs 700 bar)*
- *…*

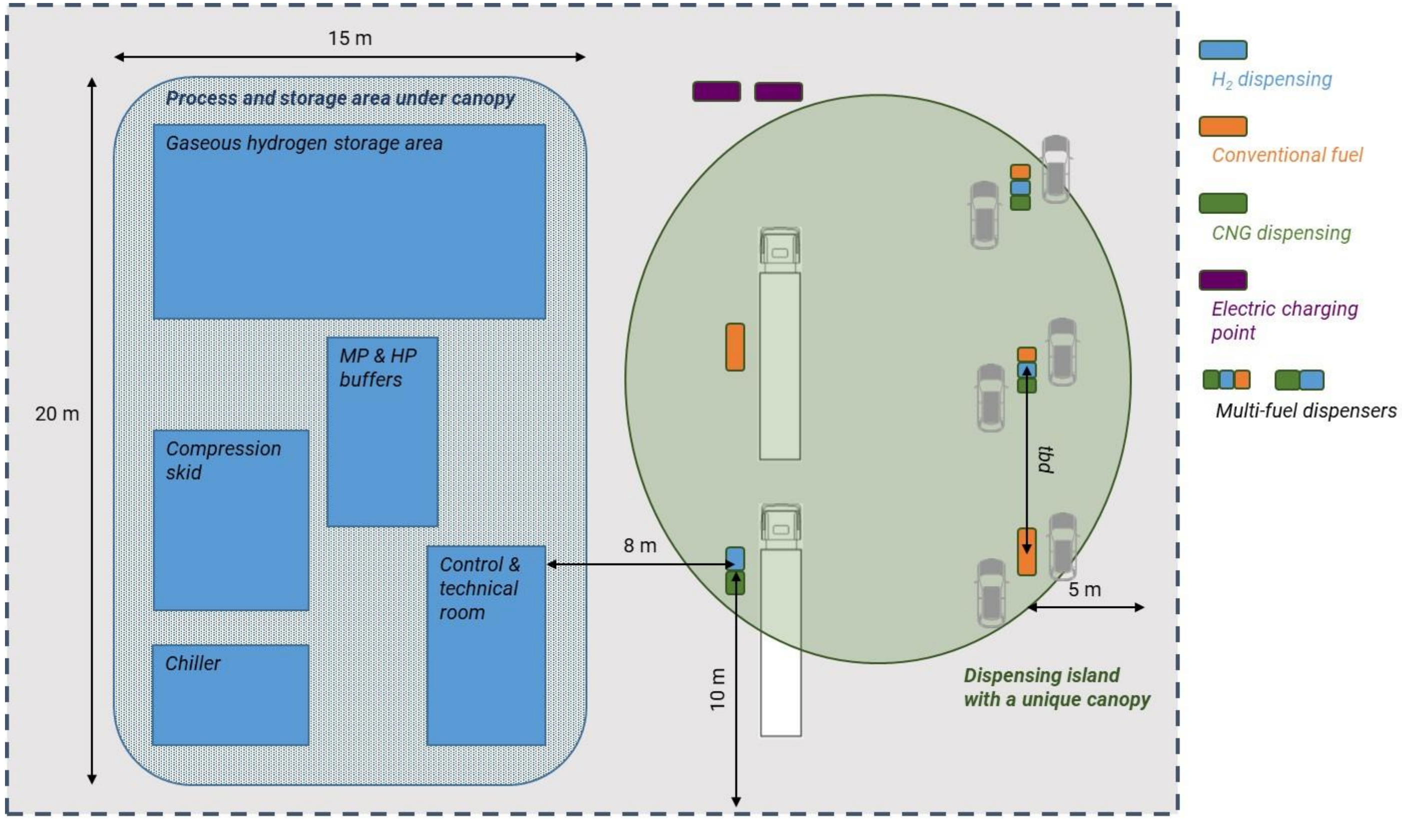
- **H_2 sourcing**
  - Gaseous supply chain
    Swap → full versus empty packaging
- **H_2 storage – inventory 1 t-H_2**
  - H_2 trailers – from 200 type-I tubes up to 600 bar type-IV cylinders
  - H_2 bundles – 200 bar type-I cylinders
  - **A canopy-like covering process area** to limit sound and visual pollution
- **From storage to dispenser**
  - "Classic" process skid(s) for gaseous hydrogen feeding, including
    Compression – two stages
    High pressure buffers (type II) – up to 900 bar
    Chiller for H_2 cooling – Heat exchanger inside the dispenser
  - Pipe maximum diameter: 9/16’’
  - Capacity: 500 kg.day^{-1}
- **H_2 dispensing**
  - "Classic" dual dispenser & Multi-fuel dispensers for L&HDV (i.e. 1 dispenser-block with several nozzles (H_2 + CNG)) - **A unique canopy** on the forecourt to protect islands
    - For car – pressure: 700 bar, maximum flow rate: 60 g.s^{-1}
    - For buses and heavy duty vehicles – pressure 350 bar, maximum flow rate: 120 g.s^{-1}

Configuration #1

Ready-to-deploy multifuel station

- Station PFD & Layout





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Configuration #2

On-site H_2 production multifuel station

Ez capacity (to be checked and confirmed)

- *1 MW* — *200 $Nm^3.h^{-1}$ H_2*, *400 $kg.d^{-1}$ H_2*
- *2.5 MW* — *500 $Nm^3.h^{-1}$ H_2*, *1 $t.d^{-1}$ H_2*
- *1.25 MW* (Hobro) — *230 $Nm^3.h^{-1}$ H_2*, *500 $kg.d^{-1}$ H_2*, *1000 FCEV*
- *Waiting for Nick H. inputs…*

Density (at 15°C)

P_atm	*0.085 $kg.m^{-3}$*
20 bar	*1.66 $kg.m^{-3}$*
30 bar	*2.48 $kg.m^{-3}$*
200 bar	*14.94 $kg.m^{-3}$*
500 bar	*31.64 $kg.m^{-3}$*
700 bar	*40.17 $kg.m^{-3}$*
900 bar	*47.30 $kg.m^{-3}$*
1000 bar	*50.46 $kg.m^{-3}$*

Sensitive parameters
(to be discussed, completed and set)

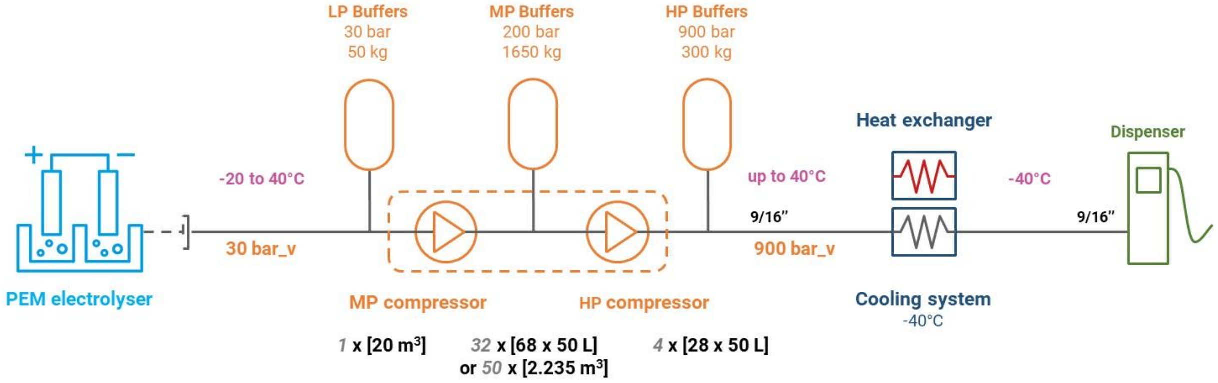
- *Electrolysis characteristics (power…)*
- *Single or multiple storages*
- *Storage volume ⇔ HRS capacity ($kg.d^{-1}$)*
  - *Single storage maximum volume*
  - *Multiple storages – number and volume*
- *Maximum pressure for H_2 storage*
- *…*

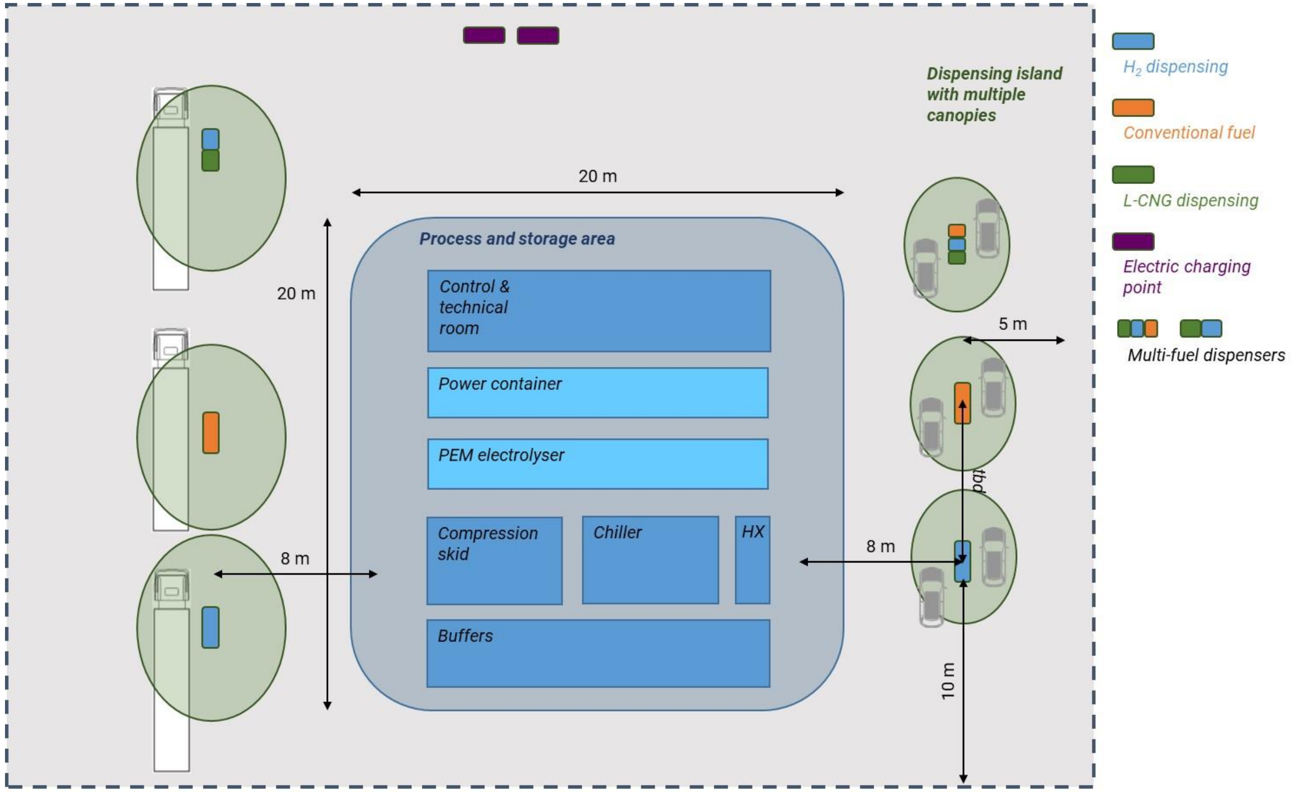
- **H_2 sourcing**
  - On-site gaseous H_2 production
    - PEM Electrolysis
      - Power: 3 MW
      - H_2 outlet pressure: 30 bar
- **H_2 storage – inventory 2 t-H_2**
  - Compression from 30 bar to 200 bar or more
  - Stationary H_2 high pressure storage
    - Storage pressure: 50 kg-H_2 at 30 bar (20 m^3) single | 200 bar (1650 kg - 110 m^3) multiple (50 L or 2.2 m^3)
      50 to 300 kg-H_2 at 900 bar (300 kg - 6 m^3) multiple
    - Storage kind: Multiple storages
- **From storage to dispenser**
  - "Classic" process skid(s) for gaseous hydrogen feeding, including
    - Compression – two stages
    - High pressure buffers (type II) – up to 900 bar
    - Chiller for H_2 cooling – External heat exchanger
  - Pipe maximum diameter: 9/16''
  - Capacity: 1 $t.day^{-1}$
- **H_2 dispensing**
  - "Classic" dual & Multi-fuel dispenser for cars - **Multiple canopies** on the forecourt to protect islands
    - For car – pressure: 700 bar, maximum flow rate: 60 $g.s^{-1}$
    - For buses and heavy duty vehicles – pressure 350 bar, maximum flow rate: 120 $g.s^{-1}$

Configuration #2

On-site H_2 production multifuel station

- Station PFD & Layout





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Configuration #3

High capacity *& High filling multifuel station*

Today LH_2 trailer capacity

- *2 t-H_2*

Liquid density (at LV-eq)

10 bar	*49.89 kg.m^{-3}*	*-241.8°C*
11 bar	*46.94 kg.m^{-3}*	*-241.1°C*
12 bar	*42.96 kg.m^{-3}*	*-240.5°C*
12.9 bar	*34.75 kg.m^{-3}*	*-240.0°C*

Sensitive parameters

(to be discussed, completed and set)

- *Liquid storage: Bunkering or Swap*
- *Storage maximum volume ⇔ HRS capacity (kg.d^{-1})*
- *Multiple storages – number and volume*
- *Vaporizer technology → Atmo and T-in-T*
- *Maximum filling flowrate*
- *Station: HDV only, or LDV AND HDV*
- *…*

- **H_2 sourcing**
  - Liquid supply chain
    Bunkering → trans-filling in a stationary vessel
- **H_2 storage – inventory 4 t-H_2**
  - Stationary liquid storage – medium pressure and cryogenic temperature
    - 10 bar (80 m^3) multiple
- **From storage to dispenser**
  - Process skid(s) for liquid hydrogen feeding, including
    - Liquid pumping
    - Vaporizer – atmospheric vaporizer and tube-in-tube vaporizer
    - High pressure buffers (type II) – up to 900 bar
    - Chiller for H_2 cooling
  - Pipe maximum diameter: 1’’
  - Capacity: 2 t.day^{-1}
- **H_2 dispensing**
  - "High flow" specific dispenser // dual - **No canopy**
    - Higher flow rate: up to 300 g.s^{-1}
    - Pressure: 700 bar & 350 bar (heavy duty vehicles ONLY)

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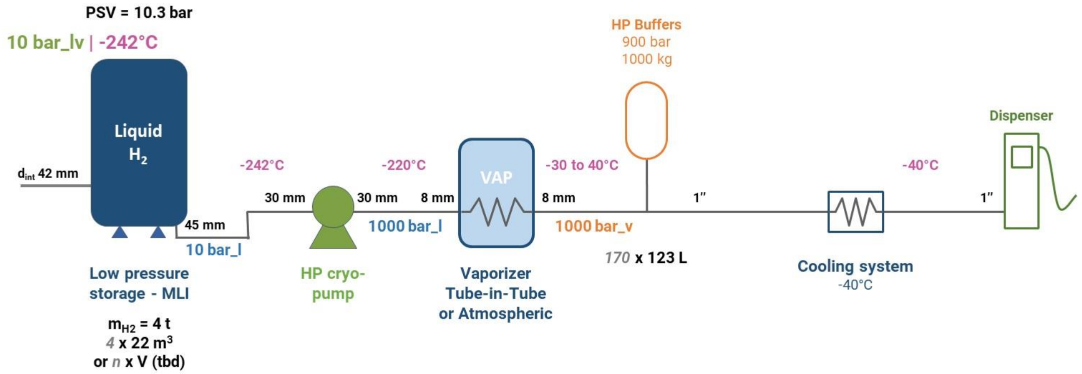
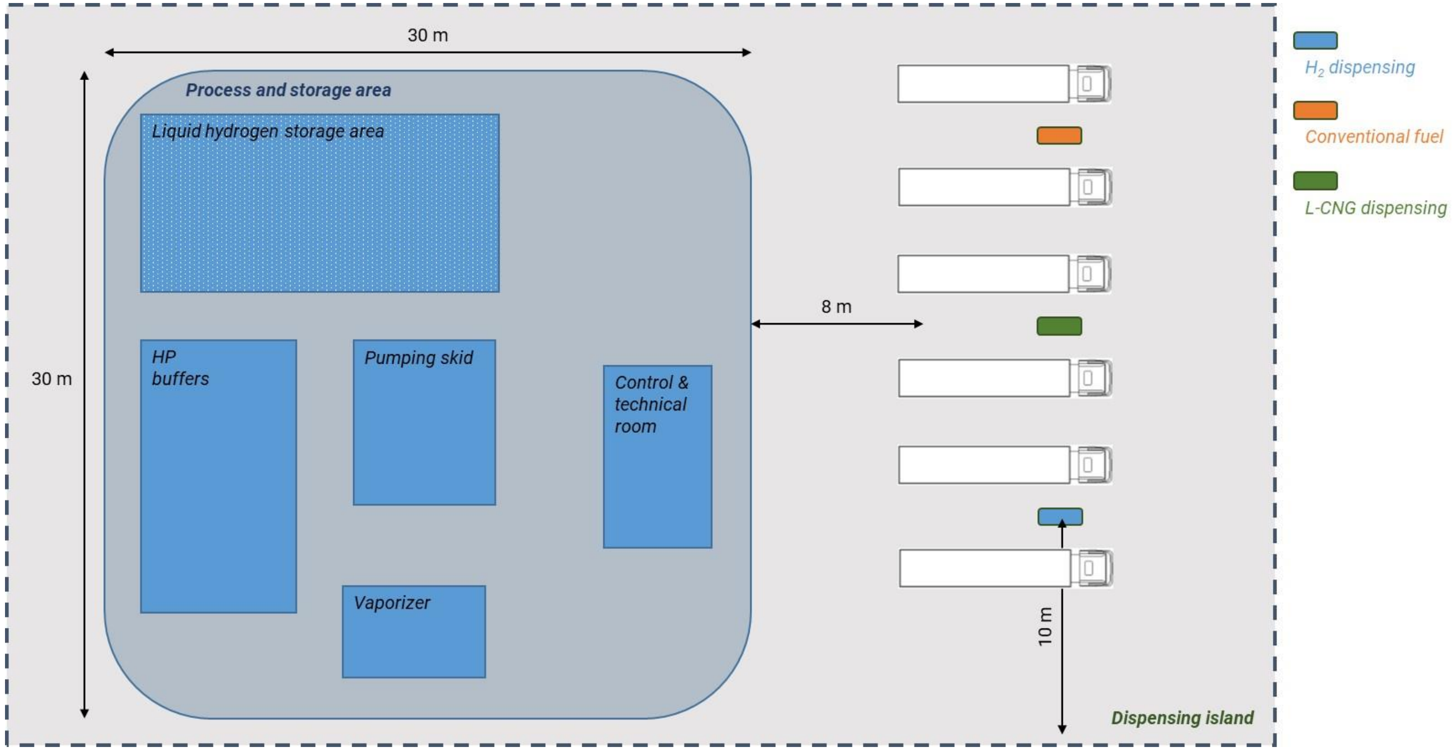
Configuration #3

High capacity & High filling multifuel station

- Station PFD & Layout





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Summary of the different options

Spread into the 3 case study configurations

Topic	Option 1	Option 2	Option 3
H_2 source/supply	Liquid	Trucked in (tube trailer left on site)	Production on-site
Dispenser pressure	700 bar	350 bar	
Dispenser type	Single hose	dual hose (but NO simultaneous filling possible)	dual hose (simultaneous filling possible)
Peak dispenser flow	60 $g.s^{-1}$	120 $g.s^{-1}$	300 $g.s^{-1}$
Pipe work	Underground (buried)	Underground (trench)	Above ground (elevated)
Canopy	Unique canopy covering the entire dispensing forecourt	Multiple canopies with space between each island roof	no canopy
HP storage location	containerized	outside in semi-confined compound (options blast wall / fire wall / other to be define later)	outside in open compound
Dispenser location	H_2 dispenser on same island than other fuel	H_2 dispenser on dedicated island	Multi-fuel dispenser fully integrating all fuel including H_2
Heat exchanger	Inside dispenser	Next to dispenser on the island	
Vent lines	on canopy roof	from compound	

Config #1 – Ready-to-deploy	Config #2 – On-site H_2	Config #3 – High

When the same option is present in several configurations, the colour appears in the font and in the background of the cell

Non-exhaustive inventory of equipment

Inside the dispenser and close to

Designation	Inlet diameter	Outlet diameter	Working pressure	Specificities
Gas Detector	-	-	-	Catalytic
Check Valve	1/4" DRC	1/4" DRC	250 bar	-
Heat Exchanger	3/8" C&T	3/8" C&T	975 bar	Insulated
Hose	3/8'' C&T	3/8'' C&T	875 bar	Length 4 m
Flow Valve	1/4" C&T	1/4" C&T	975 bar	-
Flow Valve	9/16" C&T	9/16" C&T	975 bar	-
Double Block and Bleed	9/16" C&T	9/16" C&T	975 bar	Vent connection 1/4" C&T
Pressure Control Valve	9/16" C&T	9/16" C&T	975 bar	Vent connection 1/4" NPT
Pressure indicator and transmitter	1/4" C&T	1/4" C&T	975 bar	Ex
Pressure Safety Valve	-	-	975 bar	6 mm - Vent connection 1" NPT
Restricted Orifice	1/4" C&T	1/4" DRC	975 bar	0.7 mm
Solenoid Valve	6-8 mm	4-6 mm	10 bar	-
Temperature Transmitter	1/4" C&T	-	-	Ex
Shock Detector	-	-	-	-
Break-Away	3/8'' C&T	3/8'' C&T	875 bar	-
Nozzle	3/8'' C&T	3/8'' C&T	875 bar	-

DRC = Double ring compression fitting | C&T = Cone and thread fitting | NPT = National pipe thread fitting

Safety features (1/3)

Inside the dispenser and close to

What	Where	For what
Qualified and validated hose and fittings	Process and dispenser	Avoid accidental leakages
Periodic replacement of the hose	Dispenser	Avoid accidental leakages
H_2 detection	Inside the process container Inside the dispenser Compression area	Activate warning, and shut-off valves if required in case of accidental leakage
Flame (UV/IR) detector	In the process container Outside, close to the dispenser	Activate warning, and shut-off valves if required in case of accidental ignited release
Automatic shut-off valve	Several between H_2 storage and dispenser	Limit H_2 inventory in case of accidental release
Process pressure monitoring	General	Detect abnormal pressure drop due to leak or piping rupture
Naturally ventilated confined spaces	Process container Dispenser	Avoid to reach flammable limits of H_2-air mixture in case of accidental release
Forced ventilation	Process container for some models	Avoid to reach flammable limits of H_2-air mixture in case of accidental release if natural ventilation not possible or not efficient enough
ATEX certified equipment	In confined spaces where leaks can occur (i.e. skids and dispenser)	Avoid ignition sources
Hose grounded	Dispenser	Prevent sparks caused by static electricity during refuelling and so avoid ignition

Safety features (2/3)

Inside the dispenser and close to

What	Where	For what
Automatic leak test before filling	General	Avoid accidental leakages
Flow restrictors	General	Limit flow rate in case of release or piping rupture
Automatic closing time	General	Close H_2 feeding valves in case of hose rupture or leak
Hose break-away device	Dispenser	Avoid major leak by closing feeding flexible in case of tearing by forgetting to disconnect the vehicle
Shock protection (bollard)	Dispenser	Protect the dispenser from major mechanical aggression by vehicle accidental stamping and avoid catastrophic leak
Emergency punch stop	Few meters from the dispenser	Close H_2 feeding valves in case of emergency
Conductive (grounded) concrete slab	Dispenser	Prevent sparks caused by static electricity during refuelling
Pressure safety valve	Stationary storage	Avoid major leak by releasing overpressure to safe location
Fence	Storage	Avoid external aggression
Walls; for some configurations (depending on geographic requirements and/or HRS location)	Close to storage and/or process skid(s)	Physical protective barrier against thermal effects and/or overpressure effects in case of fire or deflagration
Video camera(s)	Dispenser and/or process area	General monitoring of unmanned station (to monitor process accidental event, dysfunction, intrusion, misbehaviour, vandalism…)

Safety features (3/3)

Inside the dispenser and close to… TO BE COMPLETED during WS

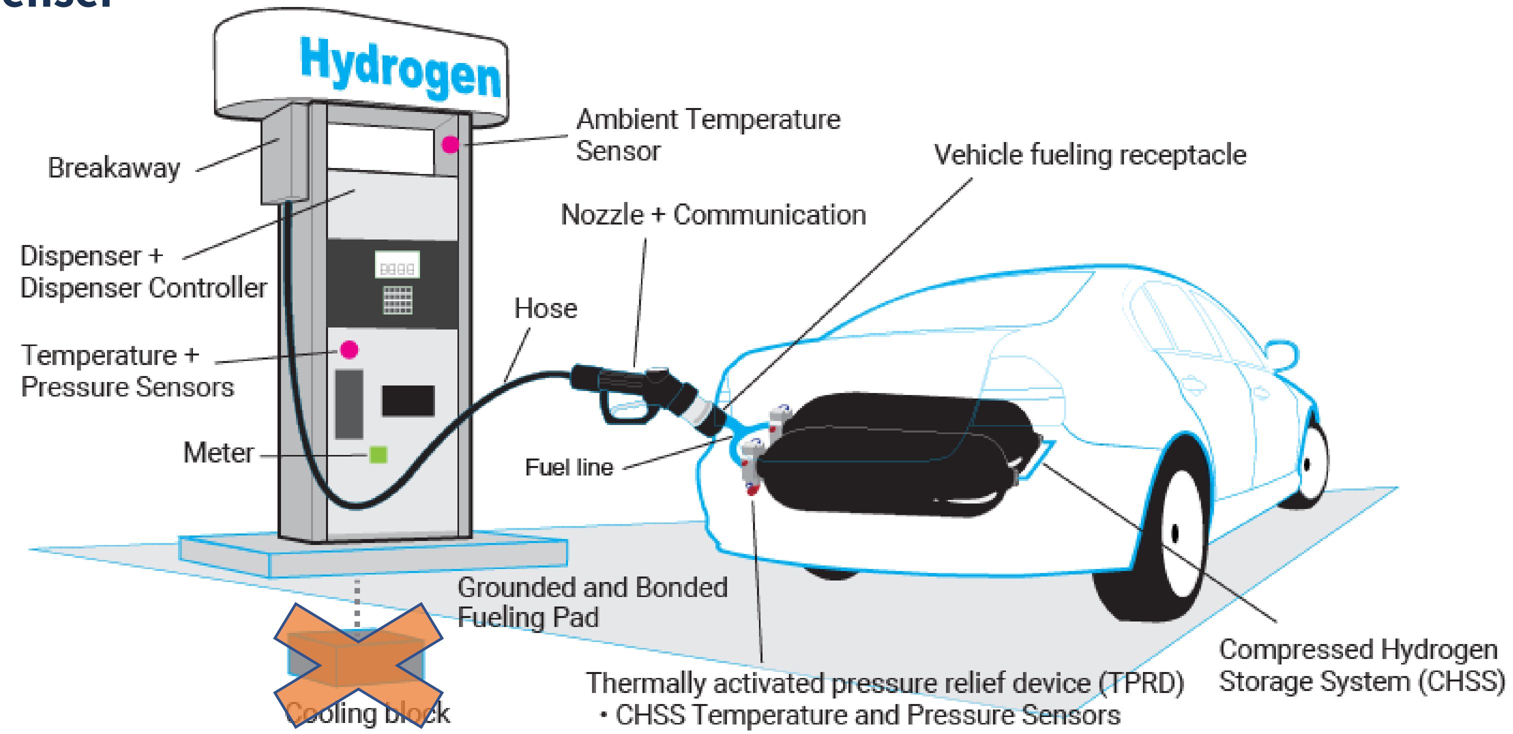
What	Where	For what
…	…	…
…	…	…
…	…	…

Dispenser-Vehicle interface

- **Natural ventilation of the dispenser // mechanical ventilation for some models**
- **Gas detector inside the dispenser**
- **Flame detector, outside, close to the dispenser**
- **Emergency shut-off buttons**
- **Video camera**

Car nozzle

Bus nozzle



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WP2 - Experimentation

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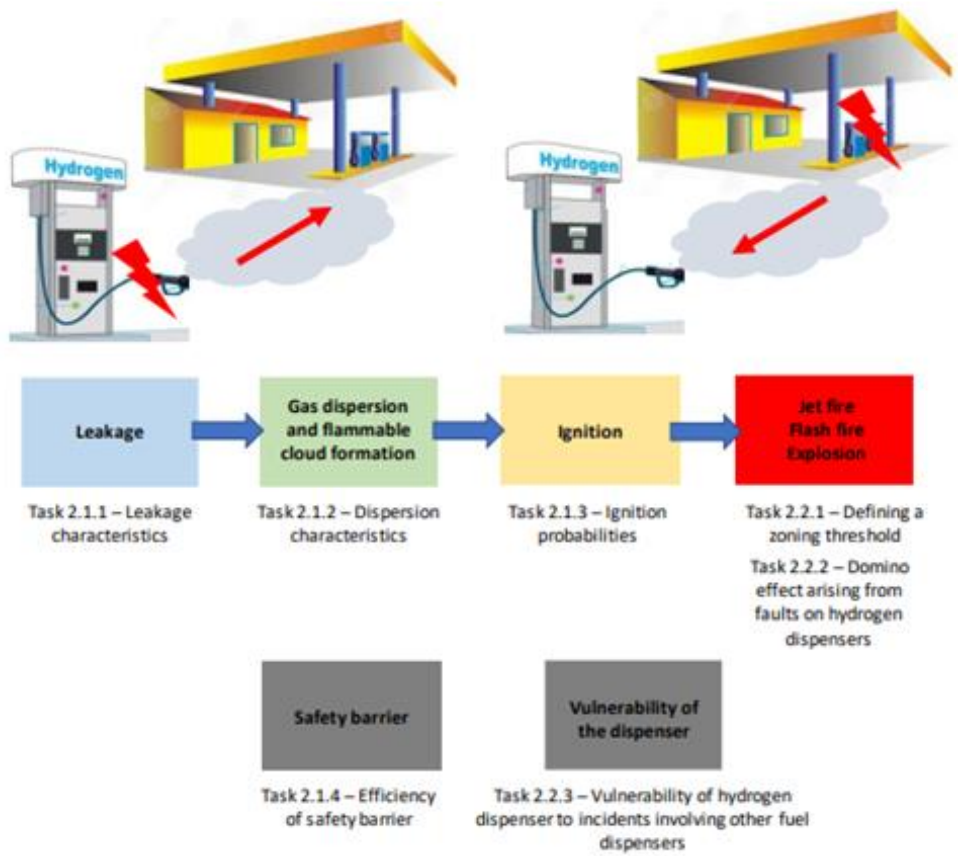
- Filling the gaps to permit the risk assessment exercise and design mitigation for critical scenarios:
  1. What are the failure frequencies (given technologies and usage) ?
  2. What are the leakage flowrates for those failure modes?
  3. What are the cloud characteristics (complex conditions)
  4. In which conditions will the cloud ignite ?
  5. What are the explosion and fire consequences ?
  6. What are the real performances of the safety barriers ?

- 1 … 4 and 6 => tasks 2.1.X
- 5 => tasks 2.2.X



Task 2.1.1 – Leakage Dispersion

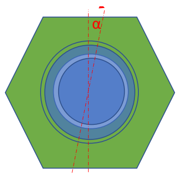
MultHyFuel

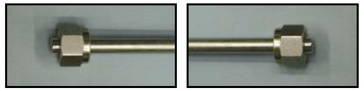
Input from task 3.1

Input from task 3.3

development of the prediction tool → verification/calibration of the method with experiments and field data → quantify the selected "failure configurations“/**first matrix** (frequency/flowrate) → systematic testing of challenging "failure configurations" (frequency/flowrate) → Adaptation of the tool/final matrix (**Deliverable 2.1**)

Your input ?





- Application:
  - Vis/écrou à 800 MPa limite élastique (σ_e)
  - L= 5.D
  - p=D/10
  - f=0,1
  - Serrage à 80% de cette limite (F)
  - Contrainte de pression (ΔF) = 1% de F

800 MPa

$$\frac{\Delta L}{L} = \frac{n.p}{L} = \frac{n}{50} = \frac{0{,}8 \cdot \sigma_e}{E}$$

200 000 MPa

$$\frac{\beta}{2 \cdot \pi} = n$$

- => nombre de filets n engagés dans l'écrou pour atteindre F=> angle de serrage (**n=0,16**)

0,3   0,8 x 0,01

$$\overline{\alpha} = 4 \cdot (1 + \nu) \cdot \frac{f \cdot \eta \cdot \sigma_e}{E}$$

- => angle de glissement sous ΔF (**α=0,000016 rad**)

$$N_{cyles} = \frac{\beta}{\alpha}$$

- => nombre de cycle pour atteindre desserrage (**10000 cycles**)

Cycling of hydrogen pressure between 0 and 1.050 bar

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Task 2.1.2 – Dispersion Characteristics

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Step 1 – Model validation

Validation Datasets:

- Identify experimental datasets for model validation
- Agree subset of cases to be used in validation exercise with task partners

Validate CFD Models:

- All task partners to undertake model validation simulations with selected CFD models
- Overall evaluation of model performance

Step 2 – Realistic release scenarios

Realistic Releases:

- Identify realistic release configurations in collaboration with Task 3.3

Simulations of scenarios

- Divide scenarios amongst task partners, 2/3 cases per partner
- Simulate the identified realistic release cases to produce outputs needed for task deliverable

Step 3 – Production of written deliverable

Produce D2.2

- To be led by HSE
- D2.2 to include summary of models used, model validation exercise and quantification of model performance
- For realistic release cases, model outputs of flammable cloud extent and time spent within flammable range to be produced and summarised in report

Task 2.1.3 – Ignition “Likelihood”

MultHyFuel

- It would certainly be difficult to market H2 dispensers if ignition might occur for any kind of leak. Fortunately, experience shows that ignition of hydrogen leaks is not, by far, systematic.

Input from task 3.3 and 2.1.2

Theoretical investigation:
1. Mechanisms/thresholds
2. Presence of the ATEX

Ignition likelihood
as function of scenario

Confrontation to field data
(=> deliverable D2.3)

Your input ?

Task 2.1.4 – Efficiency of safety barriers

- For critical scenarios , especially those with the largest consequences, safety barriers (breakaway, hose rupture detection with H2 shutdown, abnormal pressure detection safety loop, …) might be required and will be defined in WP3.
- *Suggested safety barriers to be tested :*
  - *Passive breakaway systems*
  - *Excess flow valves*
  - *Active detection via pressure drop, excess flow*
  - *Possibly active detection + shut off valve*

Selection of 4 safety barriers to be fully tested (from deliverable 3.5) and explosion and fire (measured) consequences (task 2.2.2) → **Testing in realistic and measuring the performance (repeatability and residual consequences)**

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MultHyFuel

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Fire and Explosion

MultHyFuel

The Fire and Hazards study aims to experimentally study (in real conditions) the consequences of a set of critical events on the hydrogen dispenser and surroundings fuelling stations.

General Objectives:

1. Design and perform practical research to address gaps in the current understanding of Hydrogen Refuelling Station needs in a Multi-Fuel environment.
2. Support the Risk Assessment WP3 with experimental data on critical scenarios and safety requirements

Zoning Threshold (Task 2.2.1)

Determine if there is an appropriate upper limit on the size of a leak based on a Minimum Harm Criteria and if Negligible Extent applicable

Domino effect arising from faults H_2 dispensers (Task 2.2.2)

Determine how releases of H_2 within and around the dispenser may create escalating events to the surroundings.

Determine consequences associated to critical scenarios

Vulnerability of H2 dispensers to incidents from adjacent fuels (Task 2.2.3)

Improve understanding on how vulnerable H_2 dispensers are to incidents of existing hydrocarbons installations

Zoning Threshold

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Negligible Extent – Possible for Hydrogen Dispenser?

Use definitions from latest IEC 60079-10-2020

Work backwards from $0.1 m^3$ and 50% LFL (H_2 equivalent) → hole sizes for leaks

Assess whether the hole sizes generated are sensible/plausible/practicable in practice and to replicate experimentally

What would the safety distances be for various minimum harm criteria ?

Review collate minimum harm criteria for UK first (overpressure, heat flux and noise)

Review with provided data for other EU countries to increase range of threshold

Create Harm Criteria distance vs hole size using suitable model

PHAST

Perform experimental validation if model validation is required, using experimental setup designed for task 2.2.2.

Fire and Explosion – Experimental work

MultHyFuel

Study the consequences of critical events that can be difficult to estimate and might have a considerable impact to structures and people. The experimental work is divided in two main parts:

- Events arising from the dispenser, creating potential escalating events to the surroundings (Domino effects – task 2.2.2)
- Events form the forecourt that might affect the hydrogen dispenser (Vulnerability of H_2 dispenser – task 2.2.3)

Agreement on dispenser's replica and Forecourt → Design, Procurement and Installation → Testing of events arising from H2 Dispenser → Testing of events in the forecourt affecting the Dispenser

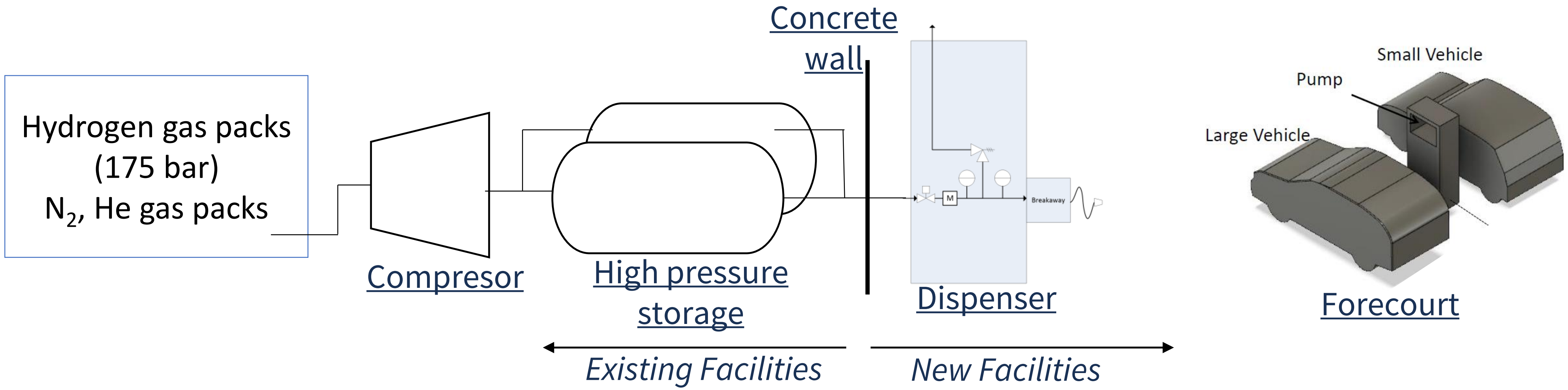
Scope of experimental work

The Work Package 2.2 aims to study scenarios that may generate significant consequences using a generic dispenser and forecourt arrangement.

- Liquid hydrogen and on-site generation are not within the scope of the tasks of this workpackage. The experimental work will focus on critical scenarios associated with gaseous hydrogen.
- The experimental work will focus in scenarios around the dispenser, i.e. downstream the shut-off valve after accumulator (high pressure storage) to dispenser and surroundings.
- Storage and compression will be performed with our existing facilities and ideally would not be modified.
- Mostly consequences of scenarios that can be difficult to estimate will be measured (not all configurations and range of variables can be covered)

METHODOLOGY

Description experimental set-up



- **Compression and high pressure storage:** Existing facilities on site (Max. Pressure 1000 barg, 2 x 50 L capacity)
- **Hydrogen dispenser:** Design and Manufacture of a “standard” replica of the dispenser. Realistic dimensions, internal distribution and main components.
- **Forecourt:** Representration of a realistic forecourt, specially congestion around the hydrogen dispenser. It may include other pumps, vehicles (or structures representing them), vent stack, structures, etc.

High Pressure compression/storage rig

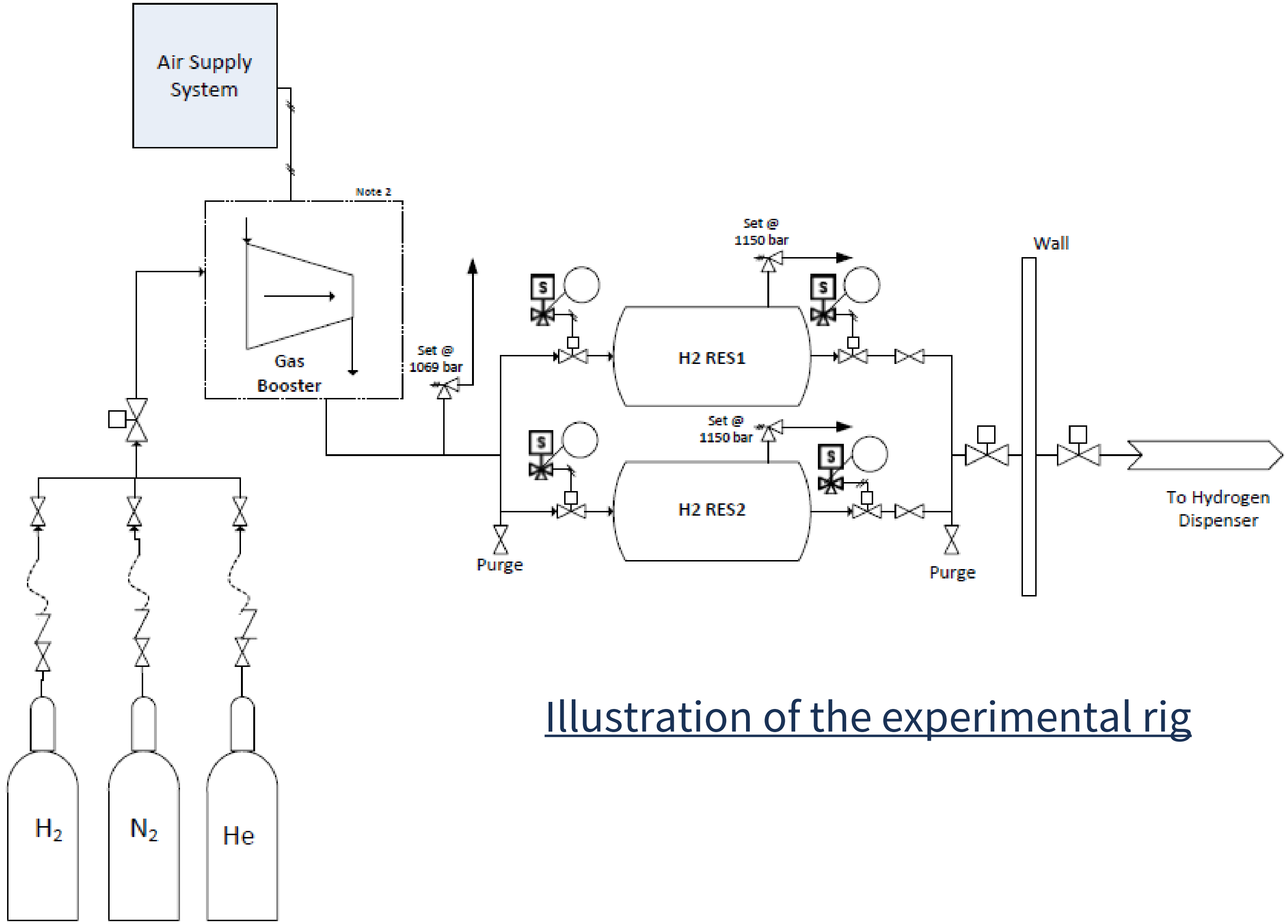


Illustration of the experimental rig

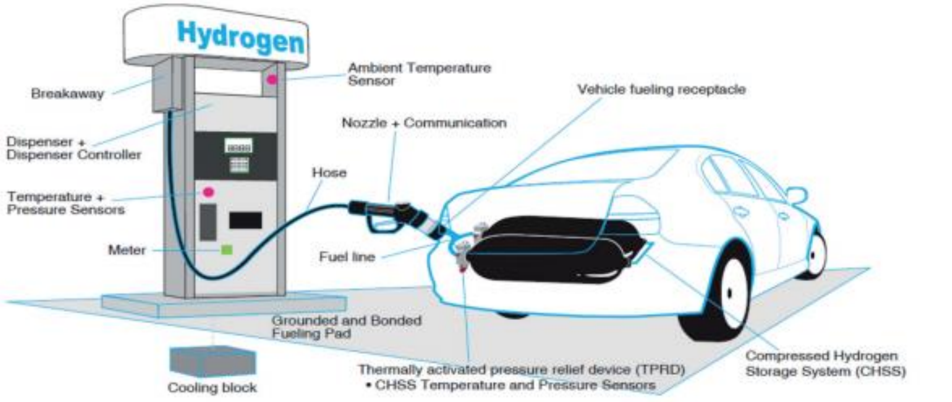
Hydrogen vessels
Volume: 50L/each
Design Pressure: 1100 barg
Max. Operating pressure: 1000 barg
Vessels certified – Pressure Equipment Regulations

Gas booster + Air Supply system.

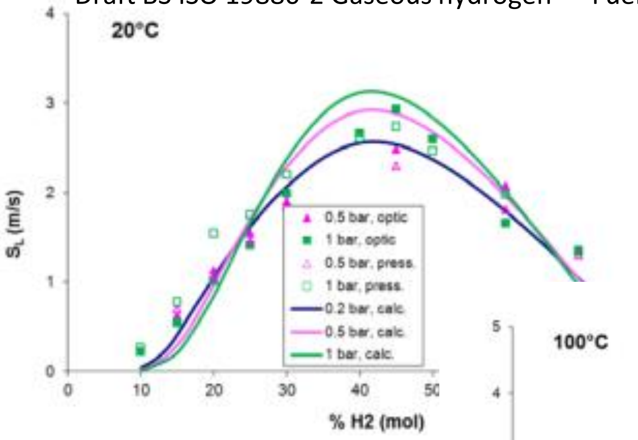
- Maximum operating pressure: 1000 barg
- Control system for safe increase in pressure
- PRV in gas booster + PRV in vessel

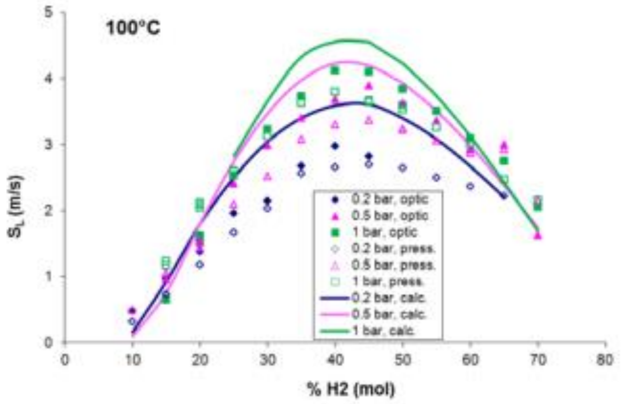
Heat Exchanger considerations

- **Pre-cooling stage**:
  - Very important for car filling process and the position of the heat exchanger may change depending the application and manufacturer.
  - Gas temperature has an effect on the explosion severity. For the consequences study, performing ignitions at ambient temperature will produce a **slightly conservative scenario** (i.e. Higher burning velocity).
  - For unignited tests where the dispersion is relevant, corrections will be made to match the same mass flow rate (i.e. Larger nozzle size).
  - The blockage generated by the heat exchanger would be represented by a metallic element (only relevant if heat exchanger is defined to be located inside the dispenser).



Draft BS ISO 19880-2 Gaseous hydrogen — Fueling stations. Part 2: Dispensers

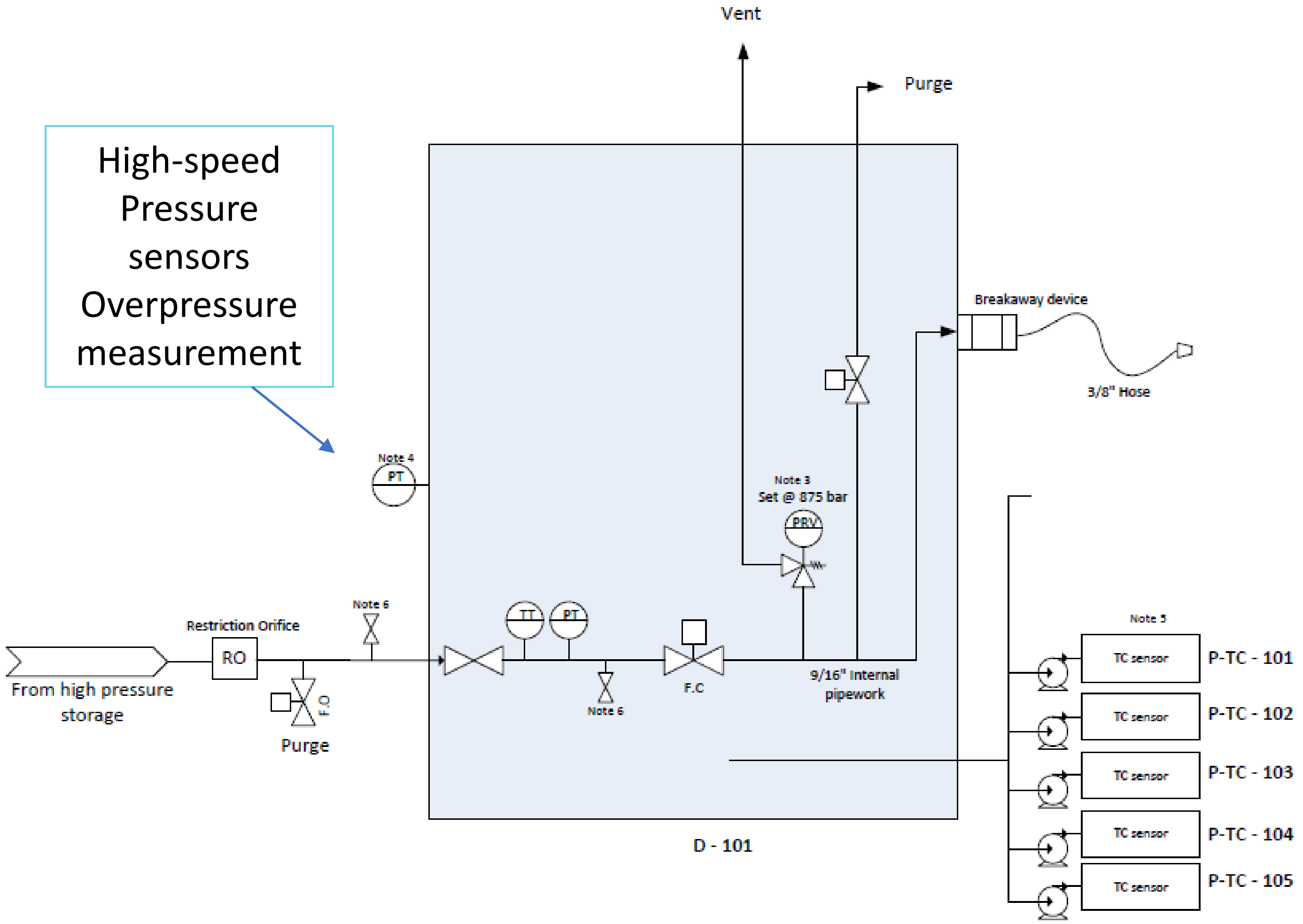




DISPENSER DESIGN

Preliminary Design of the Dispenser

High-speed Pressure sensors Overpressure measurement



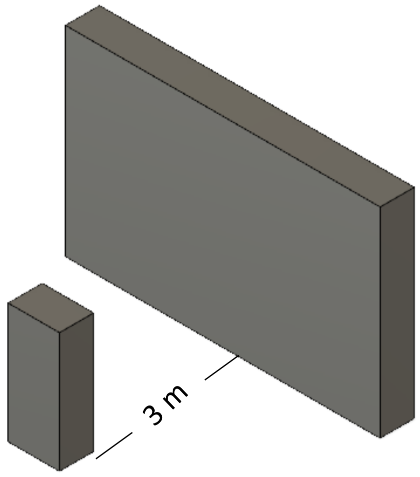
Component	Size/comment
Shut – Off valve	9/16”
Flow meter	Sized for the main pipework
PRV	Set @ 875 bar
Pressure transmitter	¼”
Temperature transmitter	¼”
Restriction Orifice	Calculated for maximum flowrate

Thermo-conductivity sensors/Sampling pumps for hydrogen concentration measurements

Preliminary Design of the Dispenser

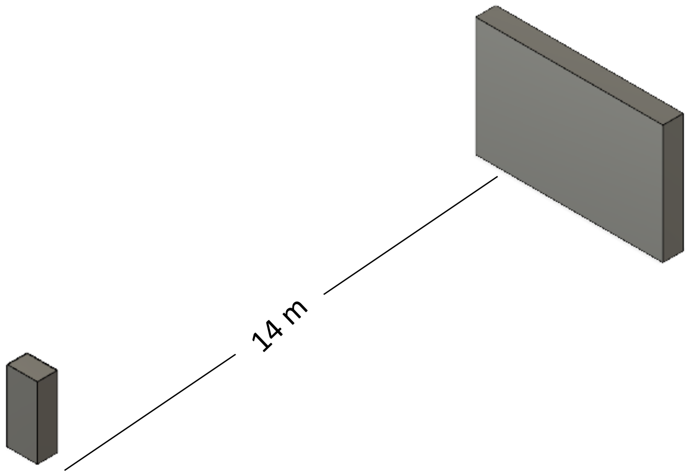
Key Parameters:

Parameter	Range
Volume	1 – 2.5 m^3
Blockage ratio	50 – 65 % of internal volume
Ventilation	One opening Two Openings: Top and bottom. Examples: Single (20 x 50 cm)/Multiple openings (10 x 20 cm) Open top



Close to wall

- Simple structure: Rectangular shape – one body
- External dimensions: 2000 mm x 500 mm x 1000 mm (1 m^3)
- Accesible for component's modification
- Two possible locations:
  - Next to the existing concrete wall
  - Separated from the concrete wall (8 – 15 m), representing distances betwen H_2 Dispenser and a building



Far from wall

Preliminary Design of the Dispenser

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Beneficial to be realistic :

- Hose
- Nozzle
- Breakaway system

- Response of the elements to critical scenarios
- Vulnerability to external incidents (e.g. Pool fire)

https://www.weh.uk/refuelling-components-hydrogen.html

Key parameters:

- Diameter and length (hose)
- Pressure rating
- Earthing

EXAMPLE OF TESTS

Preliminary list of tests – task 2.2.2:

Unignited test	Measurement
High pressure small bore H2 leak within dispenser – low momentum cloud to form around the dispenser	$[H_2]$, P_{disp}
High pressure large bore H2 leak within dispenser – low momentum cloud to form around the dispenser	$[H_2]$, P_{disp}
Hose Failure – High pressure hydrogen delivery (if credible scenario)	$[H_2]$, P_{disp}
Ignited test	**Measurement**
Stoichiometric H2 cloud inside the dispenser (if credible scenario)	P, $[H_2]$, Thermal image
Small bore H2 leak within dispenser – low momentum cloud to form around the dispenser – External ignition	P, $[H_2]$, Thermal image
Small bore H2 leak within dispenser – low momentum cloud to form around the dispenser – Internal ignition	P, $[H_2]$, Thermal image
Large bore H2 leak within dispenser – low momentum cloud to form around the dispenser – External ignition	P, $[H_2]$, Thermal image
Large bore H2 leak within dispenser – low momentum cloud to form around the dispenser – Internal ignition	P, $[H_2]$, Thermal image
Small bore H2 leak within dispenser – jet fire impinging on components/structure of dispenser	P, $[H_2]$, Thermal image
Hose Failure – High pressure hydrogen delivery (Delayed ignition and Jet fire)	P, $[H_2]$, Thermal image

Preliminary list of tests – task 2.2.2:

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Unignited test	Measurement
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High pressure large bore H2 leak within dispenser – low momentum cloud to form around the dispenser	$[H_2]$, P_{disp}
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Small bore H2 leak within dispenser – low momentum cloud to form around the dispenser – External ignition	P, $[H_2]$, Thermal image
Small bore H2 leak within dispenser – low momentum cloud to form around the dispenser – Internal ignition	P, $[H_2]$, Thermal image

Proposed strategy:

- Manufacture two or three replica of the dispenser:
  - For tests where the high pressure releases and dispersion characteristics are important, a replica with high pressure rated equipment and reallistic elements will be used.
  - For scenarios generating potentially considerable damages and the conditions can be replicated without high pressure rating conditions, a second replica will be used.

Preliminary list of tests – task 2.2.3:

Explosion tests	Measurement
LPG and Petrol sprays – Influence of congestion Analyse mechanical effect on the dispenser	$[H_2]$, P_{disp}
Fire tests	**Measurement**
Petrol/Diesel Pool Fire (different tray's sizes and separations) Vulnerability of dispenser as a function of intensity	P, $[H_2]$, Thermal image
LPG jet - Vulnerability of dispenser as a function of intensity	P, $[H_2]$, Thermal image

Variables of the forecourt:

- Seperation between "islands"
- Congestion arrangement (vehicles position, structures, walls)
- VCE and fire characteristics (review of incidents)

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Questionnaire

MultHyFuel

Survey Monkey Questionnaire: https://www.surveymonkey.com/r/WG3C6KM

Configuration #1 – Ready-to-deplay multifuel station
Evaluation and comments

Configuration #2 - On-site H2 production multifuel station
Evaluation and comments

Configuration #3 - High capacity & High filling multifuel station
Evaluation and comments

The 3 case study configurations and mitigation measures
General comments and any other design options we should include

WP2 methodology
Data sourcing

Detailed questions on mitigation measures
Input on what mitigation measures are included in your refueling stations

MultHyFuel Workshop #1 Survey

Configuration #1

Ready-to-deploy multi-fuel station
Please read the Information Pack you have received with the description of each configuration before answering the questionnaire. The 3 configurations together were created to capture a maximum number of design options, not to represent exact stations already deployed.

* 3. How do you evaluate the storage capacity defined for this configuration (500 kg/day)?

- ◯ Too low
- ◯ Satisfactory
- ◯ Too high

4. Comments on the storage capacity (optional):

* 5. How do you evaluate the amount of hydrogen stored on site (1 ton)?

- ◯ Too low
- ◯ Satisfactory
- ◯ Too high

Thank you for participating!

Next steps:

- Workshop report will be sent within the next two weeks
- Should you have any other feedback: info@multhyfuel.eu
- Stay tuned at https://multhyfuel.eu/

Thank you for your attention!

info@multhyfuel.eu

MultHyFuel

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