D1.1

Technical requirements and Design Basis

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The OPTHYCS project has received funding from the Clean Hydrogen Partnership under Grant Agreement No 101101415. This Partnership receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.

Funded by the European Union

TECHNICAL REFERENCES

Project Acronym	OPTHYCS
Project Title	OPTIC FIBRE-BASED HYDROGEN LEAK CONTROL SYSTEMS
Type	HORIZON JU Research and Innovation Actions
Call Identifier	HORIZON-JTI-CLEANH2-2022-1
Topic	HORIZON-JTI-CLEANH2-2022-02-02
Project Coordinator	ENAGAS TRANSPORTE
Project Duration	36 months

Deliverable No.	D1.1
Dissemination Level	PU
Work Package	WP1 – TECHNICAL REQUIREMENTS, REGULATORY FRAMEWORK AND USER CASES AND KPIs DEFINITION
Task	T1.1 – Overall baseline specifications and technical requirements
Lead beneficiary	TECNALIA
Contributing beneficiary(ies)	Partner 1 (ENA), partner 2 (GRTG), partner 4 (LUM), partner 5 (FEB), partner 6 (FH2A)
Due date of deliverable	30/04/2023
Actual submission date	31/05/23

VERSIONS

Revision Version	Date	Changes	Changes made by Partner
0.1	28 April 2023	First release	--
0.2	29 May 2023	Revision	ENAGAS
1.0	30 May 2023	Final version	TECNALIA

Table of Content

List of acronyms

KUC: Key user case

KPI: Key performance indicator

LEL: Lower explosion limit

HRS: Hydrogen refueling station

LNG: Liquefied natural gas

RT: Room temperature

EXECUTIVE SUMMARY

This Deliverable D1.1 presents the first definition of the basic requirements for the sensing technologies to be developed in OPTHYCS in order to meet with the specifications for the different user cases of hydrogen related technologies.

Therefore, for the three key user cases (KUCs) defined in the project (gas grid pipelines, hydrogen refuelling stations and midstream sites), a set of specific key performance parameters (KPIs) have been defined, including working conditions at the demonstration sites, leak specifications and sensing requirements. These KPIs will guide the technical work to be developed in the project in order to achieve the final proposed objectives.

The definition of the detailed specifications and target values for each of these KPIs in the KUC proposed in OPTHYCS have been carried out. This information will serve as a technical reference for the following definition of the feasibility of the proposed hydrogen sensing solutions in each KUC to be developed in WP2.

1. INTRODUCTION

OPTHYCS project is focused on the development of new hydrogen sensing technologies, based on optical fiber technologies, which will lead to an increase in the safety level of hydrogen, as well as minimizing potential hydrogen releases to limit climate impact. These hydrogen sensors will be able to be adapted to existing installation and new infrastructures and will be tested during the project in several Key User Cases (KUCs), both with pure hydrogen and natural gas/hydrogen blends: open and enclosed pipelines, hydrogen refueling stations, midstream sites and existing natural gas wells, and the results achieved in these use case locations will be used to tailor the solutions to the safety, environmental and cost-effectiveness considerations.

Therefore, OPTHYCS project is structured in six workpackages, as presented in the table below:

Work package	Description	WP Leader	Timeline (months)
WP1	Technical Requirements, Regulatory Framework and Use Cases and KPIs Definition	ENAGAS	1-9
WP2	Development of Sensoring Solutions	LUMIKER	4-23
WP3	Development of Interrogator and Interpretative Software	FEBUS OPTICS	4-26
WP4	Use Cases testing, validation, impact analysis and scalability	GRTgaz	16-36
WP5	Dissemination, Communication Exploitation and Clustering	GERG	1-36
WP6	Project Management	ENAGAS	1-36

The first **WP1: Technical Requirements, Regulatory Framework and Use Cases and KPIs Definition** is devoted to defining the requirements for hydrogen detecting limits, quantification and safety operation during handling H_2 leakages to achieve the target objectives of the project. The main objectives of this WP1 are the following:

- To define the technical requirements of the different technologies involved in the project, in compliance with the KUCs, to meet the technical, environmental and safety objectives proposed in OPTHYCS.
- To define the regulatory framework to assure the compliance with the current safety and environmental standards and regulation.
- To define techno-economic requirements for each sensor technology to ensure cost effectiveness of the solution.

Within WP1, there are four tasks that cover the different objectives presented above. These tasks are the following:

Task	Description	Task Leader	Timeline (months)
T1.1	Overall baseline specifications and technical requirements	TECNALIA	1-4
T1.2	Regulatory framework definition	ENAGAS	1-6
T1.3	Safety, environmental and economical requirements based on regulations	ENAGAS	3-9
T1.4	Specifications for the validation plan for each user case	GRTgaz	3-9

Finally, it is worth mentioning the two milestones proposed in OPTHYS that are related to the work in this WP1, and which target the objectives proposed for this WP:

Milestone	Number and Name	WP	Date	Means of verification
MS1	Technical design basis and specifications ready for WP2&3 start	1	M4	D1.1
MS2	Requirements for safety, environmental and economic aspects and user cases defined	1	M9	D1.2, D1.3, D1.4

This deliverable D1.1 is related to the work done in Task T1.1, which relies on the **definition of the requirements for the design of the different technologies for H_2 sensing**, ensuring efficient monitoring of the safety and sustainable operation in the different hydrogen infrastructures (KUCs). These requirements are based in one hand on the different technical specification of the KUCs and on other hand in achieving the KPIs required for this application (based in the topic description) and following KPIs related to environmental protection.

The information provided in this D1.1 about the different specifications and technical requirements has been structured considering the detailed characteristic of the Key User Cases proposed in OPTHYCS for the demonstration and validation of the new hydrogen sensor technologies and following the specific Key Performance Indicators (KPIs) provided in the topic description.

As a result, a table of KPIs for the different KUCs has been formulated, which serves as a technical reference for the following definition of the feasibility of the proposed sensoring solutions in each KUC in WP2.

2. DEFINITION OF KEY PERFORMACE INDICATORS (KPIs)

In this section the main key performance indicators will be defined in terms of, working conditions of the hydrogen systems implied in the different key use cases, leakage cases, and sensing requirements.

(1) WORKING CONDITIONS:

Taking into account the different key use cases, parameters like gas pressure, gas temperature or gas flow have an important impact in the magnitude of a possible leakage or emission of gas to the environment and could change significatively the possible explosion risk when this emission occurs. Higher pressures, temperatures or flows imply higher risks in the joints of the components like pipes or valves or in the creation of defects by fatigue of the materials.

Parameters involved:

- Gas pressure
- Gas temperature
- Gas flow
- Surrounding temperature (air o underground)

(2) LEAK SPECIFICIATIONS:

Once the leakage has happened on the hydrogen infrastructure it is important to evaluate the magnitude of the gas emission to the environment in order to evaluate the possible risks to the surrounding area, or the action plans in order to mitigate the problem. For that, it is necessary to stablish the type of possible leakages implied on hydrogen infrastructures (pipelines, refueling stations, etc.) and the possible key locations (as well as the leak concentration).

Parameters involved:

- Leak type
- Leak location
- Leak concentration

(3) SENSING REQUIREMENTS:

Regarding the development of the sensors, the most common properties to be addressed are accuracy, detection threshold which is the minimum input signal that produces and output sensor response. Additional parameters are time response, time recovery, range, quantification accuracy, resolution and working hours without maintenance or re-calibration. Finally, it should present no interferences with other natural gas components, gas odorants or molecular oxygen.

Parameters involved:

- Concentration measurement accuracy (ppm)
- Detection threshold
- Time of response
- Recovery time
- Range for measurement
- Quantification accuracy
- Resolution
- Working hours (without maintenance)

(4) OTHERS:

Information about sensor installation, integration with SCADA systems, compliance with standards and regulations,…

On the integration with SCADA systems, it might not be always needed. It will be assessed when this integration could imply a reasonable added value. In any case, it would be necessary to define which types of protocols will be used to communicate with third parties, which are market standards (analog signal, MODBUS TCP/IP, etc.).

All these properties will be summarized for each key use case of the project in following sections.

3. DESCRIPTION OF KEY USER CASES (KUCS)

The different Key Use Cases (KUCs) proposed in OPTHYCS will represent the framework for real-life conditions of the different types of storage, transport, and distribution facilities, in terms of gas conditions (H_2 and blending, including different gas pressure ranges, H_2 concentration, and possible interference (ethane and CO_2 among others) from other components present in the NG/H_2 mixture), confinement conditions (enclosed vs. buried, vs. open air) and use of such infrastructure (gas grids, HRS, compressor and metering stations).

Each KUC represents the theoretical and most representative scenario to be subsequently tested in each validation site:

- **KUC1**: Gas grid pipelines
- **KUC2**: Hydrogen refuelling stations (HRS)
- **KUC3**: Midstream sites

These type of testing infrastructures can be operated both with pure H_2 or with HG/H_2 blending, as presented in the table below:

KUCs	Infractructure	Gas	Confinement	Leader
KUC 1.1	GAS GRID PIPELINES	Blending	Enclosed	GRTGaz + ENAGAS
KUC 1.2		Pure H2	Enclosed	GRTGaz + ENAGAS
KUC 2.1	HRS	Pure H2	Open air	FH2A + GRTGaz + ENAGAS
KUC 3.1	MIDSTREAM SITES	Blending	Enclosed	GRTGaz + ENAGAS
KUC 3.2		Pure H2	Enclosed	GRTGaz + ENAGAS

3.1 KUC1 GAS GRID PIPELINES

Gas grid are very long assets, with thousands of km for transmission and distribution network. To perform periodic leak survey, different strategies can be applied regarding the environment: helicopters, drones, vehicle, by foot, etc. Detecting leak using optical fibre is one of the relevant solutions for long distances, as it does not require human displacement, and the survey is continuous and remote. The gas operators can have information on leak in real time and provide the quicker answer to fix it and avoid possible consequences of a gas leak.

This use case aims to represent hydrogen leakage detection mainly for buried pipelines, but also covers the use of aerial lines, which have some differences (e.g. external temperature or hydrogen flow).

Transmission pipeline for natural gas have a diameter between 100 up to 1200 mm. They are made of steel and if the diameter is above 400mm, the pipeline has an internal coating (applicable in France). In Spain, the transmission pipelines have an external coating for protection purposes.

In the case of pipeline retrofit (blend - **KUC1.1**) or repurposing (pure H_2 - **KUC1.2**), the risk of hydrogen leakage cannot be ignored due to the known compatibility problems of H_2 with the pipeline materials. Then, to address this risk, efficient hydrogen sensor that can detect leaks and gas permeation are required to guarantee the safety of gas infrastructures.

The following characteristics can be considered for the KUC1.1 and KUC1.2:

Gas	*Nominal pipe size*	*Material*	*Location*
NG/H_2 blend (KUC1.1)	12” – 48”	carbon steel	Buried (1 m depth)
Pure H2 (KUC1.2)	26” – 30”	carbon and low-alloy steels	Buried (1 m depth) and aerial

Currently, all countries’ regulations impose to detect leak before its reached 20% of the LEL of the gas. While the LEL of the methane is 5%, it is 4% for H_2. For the case of blend of NG/H_2, the LEL is expected to be between 4 to 5% (keeping the most stringent case is to consider a LEL of 4%). Consequently, keeping the same level of 20% of LEL to discover a leak for H_2 case, the sensors need to detect, at least 0.18% of gas in air.

Different types of leaks need to be considered: in terms of the location of the defect compared to the Optical Fibre (OF) (close to the OF and opposite to the OF), the size of the defect to be considered are 1mm and 5 mm; 1 mm is typical for a small leak and 5 mm is typical of the corrosion leak. Expected pressure to be considered is around 20 bar, which will prove the conversion of natural gas pipelines for pure H_2. Regarding pipeline intrinsic defects, pinholes due to corrosion will be addressed. A future study could also address leaking connection as a second step. Hydrogen permeation will be indirectly addressed as during tests it could happen.

3.2 KUC2 HYDROGEN REFUELLING STATION (HRS)

The main gas leakage points in the HRSs are usually in the high-pressure cascade regulating valve panel, in the main connections of the high-pressure storage, and in the dispenser itself, in those elements whose connections are not soldered (valves, instruments). Leakage can also occur in the compressor discharge line if the compressor vibrations cause a leakage.

The material by far more used in the handling of H_2 is 316L type austenitic stainless steel due to its excellent resistance to hydrogen embrittlement in gaseous hydrogen environments. This is the material used in FH2a's HRS, and during its 10 years of use, no material-related incidents have been detected. But it is undeniable that the high pressures handled in an HRS, together with the numerous connections between elements (storage at various pressures, compressor, dispenser, chiller) are potential sources of leaks that need to be monitored. A recent study shows that approximately the amount of H_2 leakage in a HRS is nowadays around 3% of the H_2 delivered, the main reasons being: a) purging: Heat exchanger, hoses, (dispenser, trailer), b) compressor membrane loss, and c) commissioning, buffer inspection, leakages etc. And that value is expected to be reduced to 2% by 2030 via procedures optimisation, and minimisation of possible leakage. In this respect, early detection of leakage is essential to achieve these objectives.

Not only releases to the atmosphere are a matter to consider, also the safety aspect is of utter importance. The occurrence of hydrogen leaks is very small, but any small leak in very high-pressure systems can lead to an explosion under the right conditions of mixing with air. An early leak detection system can provide sufficient warning for preventive maintenance to avoid incidents in these installations where security must be at the highest level, as they are normally open to the public.

At present, the HRS included in the project has only one H_2 leak detection sensor (electrochemical type) inside the dispenser, which stops the installation in the event of a leak (emitting a loud audible alarm). The rest of the installation is in the open air and has no detection, so any leak in storage or in the compression zone goes unnoticed; the detection of possible leaks in these locations is complicated by the difficulty of locating the sensor in such a way that it can cover a large area. Although there is no leakage detection, the area is equipped with a flame detection camera for protection. It is expected that the technology proposed in this project will allow reliable monitoring of leaks in those areas that are currently not sensorised.

The sensor technology proposed in the project is intended to contribute to improving the safety of people and equipment in a HRS, as well as reducing H_2 emissions into the atmosphere. Regarding the last concept, the project will contribute to reduce the releases of H_2 to atmosphere in an HRS scope from around 3% of H_2 delivered nowadays to 2,5% by 2030, through early and efficient detection of leaks in the most prone areas. Therefore, the detection is not specifically oriented towards safety (which is also the case, of course), but rather towards the detection of small leaks, so that these are detected directly as early as possible, not indirectly (by monitoring pressure in pipes or cylinders, for example).

Regarding safety of equipment, of particular relevance could be the early detection of leaks in the compression stages, which would allow scheduling preventive maintenance activities in a safer way and in anticipation of a possible equipment breakdown. Contribute to improving people's safety and equipment in a HRS.

3.3 KUC3 MIDSTREAM SITES

When dedicated hydrogen infrastructure is built by repurposing gas pipelines or building new infrastructure, it will need midstream facilities such as H_2 compressor stations, pressure and regulating stations, valve stations, above-ground facilities of underground gas storage and port terminals. Like today, efforts to reduce emissions through the successful implementation of new technologies developed to detect H_2 emissions in this type of installations will be key. This challenge needs to be addressed both for the case of dedicated hydrogen transport or if blending hydrogen with natural gas.

Continuous monitoring of emissions will allow operators to quickly detect unexpected emissions and minimise emissions to the lowest level. There are not many continuous monitoring approaches currently in the market focusing on the detection of emissions of all sizes, an option for example is the use of cameras with OGI technology, which are expensive and have a high detection threshold. A cost-reflective and low maintenance continuous monitoring approach will be an important tool to minimise environment impact of these new installations. The list of installations where this technology could be implemented is:

- **Compressor stations.** These facilities will rise the gas pressure according to the demands of the transmission system. Size, number, and type of compressors at each site will vary depending on the size and length of the network where they are built. Current compressor stations are in nodes of the transmission network, and they raise the gas pressure to 72 or 80 bar, to maximise the pipeline transmission capacity. Their size and number of compressors depend on the needs of the transmission network it relates to. A compressor station may comprise several thousand potential sources of gas leakage.

- **Metering stations**. These facilities are the first step to adapt the supply to the final pressure at which gas is used by companies and individuals. In current metering stations the gas delivered to the distribution network is measured and its pressure its reduced. There are gas meters to constantly measure the gas that is delivered. For H_2 transmission networks, dedicated metering stations will be built at the points of delivery.

- **City gates.** These facilities refer to the points of interconnection between the natural gas transmission pipeline network and the local gas distribution system that serves customers in a particular city or region. At these interconnection points, gas is typically measured, monitored, and regulated before being distributed to customers through local pipelines. City gates are critical components of the natural gas infrastructure because they allow gas to be transported efficiently and reliably from production areas to end-users, such as residential and commercial customers.

When blending of H_2 takes place, current gas midstream sites will operate with H_2/NG mixtures with variable concentrations of H_2. These new technologies should be assessed to detect emissions from this gas too, to guarantee that all leaks are detected once blending takes place. These installations are complex with many connections and joints between different elements and different type of equipment (turbomachines, valves, meters, vents, pressure regulators, pressure and temperature transmitters, heat exchangers, filters, compressor seals, gas sampling systems, etc.).

Current LNG terminals or current gas underground storages have different characteristics than the sites described above, although some of its areas or equipment is similar (such as the compressors or the delivery areas), so the technology developed could as well be implemented in those areas or equipment. Regarding future H_2 underground storages, while the tests in the project do not encompass their unique working conditions, these applications could be considered in the future. These storage facilities experience higher pressures and temperatures compared to other midstream sites. This aspect becomes particularly relevant for OPTHYCS, as the sensitivity of sensors may vary at higher temperatures.

The objective for these installations is to achieve a system able to continuously monitor hydrogen and hydrogen/natural gas blends emissions, providing alerts when a new source is identified or when emission levels increase a given threshold. The aim is to have a cost-effective site-level continuous solution that will be key to limit to the lowest level possible environment impact at installations. The system should give an indication of the location of the equipment or component that is leaking. Note that, for this use case, the aim is to test the ability of the device to detect unintended or fugitive emissions that may not go above safety thresholds but that, if not detected and repaired, would harm the environment because of the GWP of H_2.

4. ANALYSIS OF REQUIREMENTS FOR THE KUCs

4.1 KUC1 GAS GRID PIPELINES

WORKING CONDITIONS:

	NG/H_2 blends	Pure H_2
Gas pressure	40 to 80 bars	10 to 100 bars
Gas temperature	5 to 30 °C	5 to 30 °C
Gas flow	Variable. In the range of thousands of Nm^3/h)	Variable. In the range of thousands of Nm^3/h) *In general lower for aerial lines than buried lines*
External temperature	Buried lines: ground temperature Aerial lines: ambient temperature	Buried lines: ground temperature Aerial lines: ambient temperature

LEAK SPECIFICATIONS:

	NG/H_2 blends	Pure H_2
Leak type	Leak reproduced inducing a defect (hole, 1 to 5 mm dia.)	
Leak location	Two types of leaks: (1) close to the optical fibre (within 2 cm from the defect) (2) opposite to the optical fibre	
Leak concentration	≥ 0.4% (+/- 0.18%) of H_2 in air (once diluted in air)	

SENSING PROPERTIES

	NG/H_2 blends	Pure H_2
Concentration measurement Accuracy	± 10% (ppm) ± 20% (ln/min) Able to detect 0.04% of H_2 in air	
Detection threshold	0.4 ln/min in blending operation	1.2 ln/min in pure H_2

	10 ppm (if we measure exactly at the leaking element) / 1 ppm otherwise	10 ppm (if we measure exactly at the leaking element) / 1 ppm otherwise
Response time	Maximum 1 sec at a concentration of 0.4% by volume	
Recovery time	Maximum 20 seconds	
Range of measurement	Up to 100% LEL	
Resolution	1-10 ppm	
Maintenance (recalibration) interval	Min. 1 year	
Potential interferences	The presence of other gases in the gas leaked should not interfere in the performance of the sensors	
Reliability	Low percentage of false alarms and missing leaks	

OTHER REQUIREMENTS

- Easy sensor installation in pipelines (compatibility with the infrastructure)
- Easy sensor integration with SCADA systems
- Fully automatic sensor operation
- Compliance with national and EU regulations
- Compliance with EN standards for gas detection and hydrogen sensors
- Possibility to be CE marked once commercialized

4.2 KUC2 HYDROGEN REFUELLING STATION (HRS)

WORKING CONDITIONS:

	Pure H_2
Gas pressure	HRS 350 bar: 20 to 350 bar HRS 700 bar: 25 to 900 bar
Gas temperature	HRS 350 bar: RT to 85°C HRS 700 bar: -40 °C to 85°C
Gas flow	Compressor: 1 kg/h Charging station: 0.5 kg/min
External temperature	Ambient temperature

LEAK SPECIFICATIONS:

	Pure H2
Leak type	Leak reproduced in valves or fittings
Leak location	Compressor HP side / inside dispenser / high pressure storage
Leak concentration	≥ 0.4% (+/- 0.18%) of H_2 in air (once diluted in air)

SENSING PROPERTIES

	Pure H2
Concentration measurement Accuracy	± 10% (ppm) ± 20% (ln/min) Able to detect 0.04% of H_2 in air
Detection threshold	1.2 ln/min in pure H_2 10 ppm (if we measure exactly at the leaking element) / 1 ppm otherwise
Response time	Maximum 1 sec at a concentration of 0.4% by volume
Recovery time	Maximum 20 seconds
Range of measurement	Up to 100% LEL
Resolution	1-10 ppm
Maintenance (recalibration) interval	Min. 1 year
Potential interferences	The presence of other gases in the gas leaked should not interfere in the performance of the sensors
Reliability	Low percentage of false alarms and missing leaks

OTHER REQUIREMENTS

- Easy sensor installation in HRS (compatibility with the infrastructure)
- Easy sensor integration with SCADA systems
- Fully automatic sensor operation
- Compliance with national and EU regulations
- Compliance with EN standards for gas detection and hydrogen sensors
- Possibility to be CE marked once commercialized

4.3 KUC3 MIDSTREAM SITES

WORKING CONDITIONS:

	NG/H_2 blends	Pure H_2
Gas pressure	– City gates: 16 to 80 bars – Compressor stations: 40 to 80 bar	– City gates: 10 to 100 bars – Compressor stations: 40 to 100 bar
Gas temperature	2 to 30 °C	2 to 30 °C
Gas flow	– City gates: variable, from 4000 to 150000 Nm^3/h – Compressor stations: variable, in the range of thousands of Nm^3/h)	
External temperature	– City gates: ambient temperature – Compressor stations: ambient temperature/higher inside the compressor rooms (50-60 °C)	

LEAK SPECIFICATIONS:

	NG/H_2 blends	Pure H_2
Leak type	Leak reproduced inducing a defect (hole, 1 to 5 mm dia.)	
Leak location	Adequate location of 100% of leaks with a size higher than the detection threshold with a precision of 1 m	
Leak concentration	≥ 0.4% (+/- 0.18%) of H_2 in air (once diluted in air)	

SENSING PROPERTIES

	NG/H_2 blends	Pure H_2
Concentration measurement Accuracy	± 10% (ppm) ± 20% (ln/min) Able to detect 0.04% of H_2 in air	
Detection threshold	0.4 ln/min in blending operation 10 ppm (if we measure exactly at the leaking element) / 1 ppm otherwise	1.2 ln/min in pure H_2 10 ppm (if we measure exactly at the leaking element) / 1 ppm otherwise
Response time	Maximum 1 sec at a concentration of 0.4% by volume	
Recovery time	Maximum 20 seconds	

Range of measurement	Up to 100% LEL
Resolution	1-10 ppm
Maintenance (recalibration) interval	Min. 1 year
Potential interferences	The presence of other gases in the gas leaked should not interfere in the performance of the sensors
Reliability	Low percentage of false alarms and missing leaks

OTHER REQUIREMENTS

- Easy sensor installation in HRS (compatibility with the infrastructure)
- Easy sensor integration with SCADA systems
- Fully automatic sensor operation
- Compliance with national and EU regulations
- Compliance with EN standards for gas detection and hydrogen sensors
- Possibility to be CE marked once commercialized

5. CONCLUSIONS

The different key performance indicators of the project have been evaluated for each key use case independently. The summary and conclusions are showed in the following table.

<table>
<tr><th colspan="2" rowspan="2">KPIs</th><th colspan="2">KUC1 - gas grids</th><th colspan="2">KUC2 - Hydrogen refuelling stations</th><th colspan="2">KUC3 - Midstream sites</th></tr>
<tr><th>Pipelines (buried)</th><th>Aerial lines</th><th>300 bar</th><th>700 bar</th><th>City gates</th><th>Compressor & metering stations</th></tr>
<tr><td rowspan="4">WORKING CONDITIONS</td><td>Gas pressure</td><td colspan="2">NG/H2: from 40 to 80 bar
H2: from 40 to 100 bar</td><td>H2: from 20 to 350 bar</td><td>H2: from 20 to 350 bar</td><td>NG/H2: from 16 to 80 bar
H2: from 10 to 100 bar</td><td>NG/H2: from 40 to 80 bar
H2: from 40 to 100 bar</td></tr>
<tr><td>Gas Temperature</td><td colspan="2">NG/H2: from 5 to 30 °C
H2: from 5 to 30 °C</td><td>H2: from RT to 85 °C (compressor output)</td><td>H2: from -40 °C to 85 °C (compressor output)</td><td colspan="2">NG/H2: from 2 to 30 °C
H2: from 2 to 30 °C</td></tr>
<tr><td>Gas Flow</td><td>Variable depending on the use of the system. In the range of thousands of Nm³/h</td><td>Variable depending on the use of the system. In the range of thousands of Nm³/h. Lower for H_2.</td><td>Compressor flow: 1 kg/h;

Charging process: 0.5 kg/min</td><td>TBD</td><td>Will depend on size of the site (depends on the gas demand in the distribution network), from 4000 to 150000 Nm³/h</td><td>Flow will vary depending on the use of the system. In the range of thousands of Nm³/h</td></tr>
<tr><td>External temperature</td><td>Temperature of the soil underground</td><td>Ambient temperature</td><td>Ambient temperature (no underground piping)</td><td>Ambient temperature (no underground piping)</td><td>Ambient temperature</td><td>Ambient temperature / higher temperature within the compressor rooms: 50/60°C</td></tr>
<tr><td rowspan="3">LEAK SPECIFICATIONS</td><td>Leak type</td><td colspan="2">Defect size from 1 to 5 mm</td><td colspan="2">Leaks in valves and fitting</td><td colspan="2">Defect size from 1 to 5 mm</td></tr>
<tr><td>Leak location</td><td colspan="2">OF (within 2 cm from the defect) / Opposite to OF</td><td>Compressor HP side /inside dispenser/ high pressure storage</td><td>TBD</td><td colspan="2">Adequate location of 100% of leaks with a size higher than the detection threshold with a precision of 1 m.</td></tr>
<tr><td>Leak concentration</td><td colspan="6">≥ 0.4% (+/- 0.18%) of H_2 in air (once diluted in air)</td></tr>
</table>

KPIs		KUC1 - gas grids		KUC2 - Hydrogen refuelling stations		KUC3 - Midstream sites	
		Pipelines (buried)	**Aerial lines**	**300 bar**	**700 bar**	**City gates**	**Compressor & metering stations**
SENSING PROPERTIES	Concentration measurement accuracy (ppm)	+-10					
	Quantification accuracy (ln/min)	+-20%					
	Detection Threshold ln/min	0.4 ln/min in blending operation, 1.2 ln/min in pure H2		1.2 ln/min in pure H2		0.4 ln/min in blending operation, 1.2 ln/min in pure H_2	
	Detection Threshold ppm H2	10 ppm (if we measure exactly at the leaking element) / 1 ppm otherwise		10 ppm (if we measure exactly at the leaking element) / 1 ppm otherwise		10 ppm (if we measure exactly at the leaking element) / 1 ppm if we measure at a certain distance	
	Response time	Maximum 1 sec at a concentration of 0.4% by volume					
	Recovery time	1 min (max. twice the time of response)		20 seconds for pure H_2		20 seconds for both blending and pure H_2	
	Range of measurements	up to 100% LEL					
	Resolution	1 or 10 ppm					
	Maintenance down time / availability	At least a 1-year period without maintenance/recalibration will be desirable, zero-drift					
	Potential interferences	The presence of other gases in the gas leaked should not interfere in the performance of the sensors					
	Reliability	For an optimal reliability, the system should have a low percentage of false alarms and a low percentage of missing leaks (leak detection rate / false alarm rate)					
OTHER		Other desired characteristics: market-oriented designed and feasibility/compatibility with the construction, operation and maintenance of the gas infrastructure, fully automatic/easy operation, easy installation, easy to integrate with SCADA systems, long service life, no impact of weather conditions (such as solar radiation or rain), compliant with applicable national and European regulations, compliant with EN standard for gas detection and H_2 sensors, need to be CE marked once commercialized. For DAS/DTS technologies, flexibility to work with different fiber optic cables is desirable.					