Gas quality measurement in hydrogen grids

HAN waterstof event

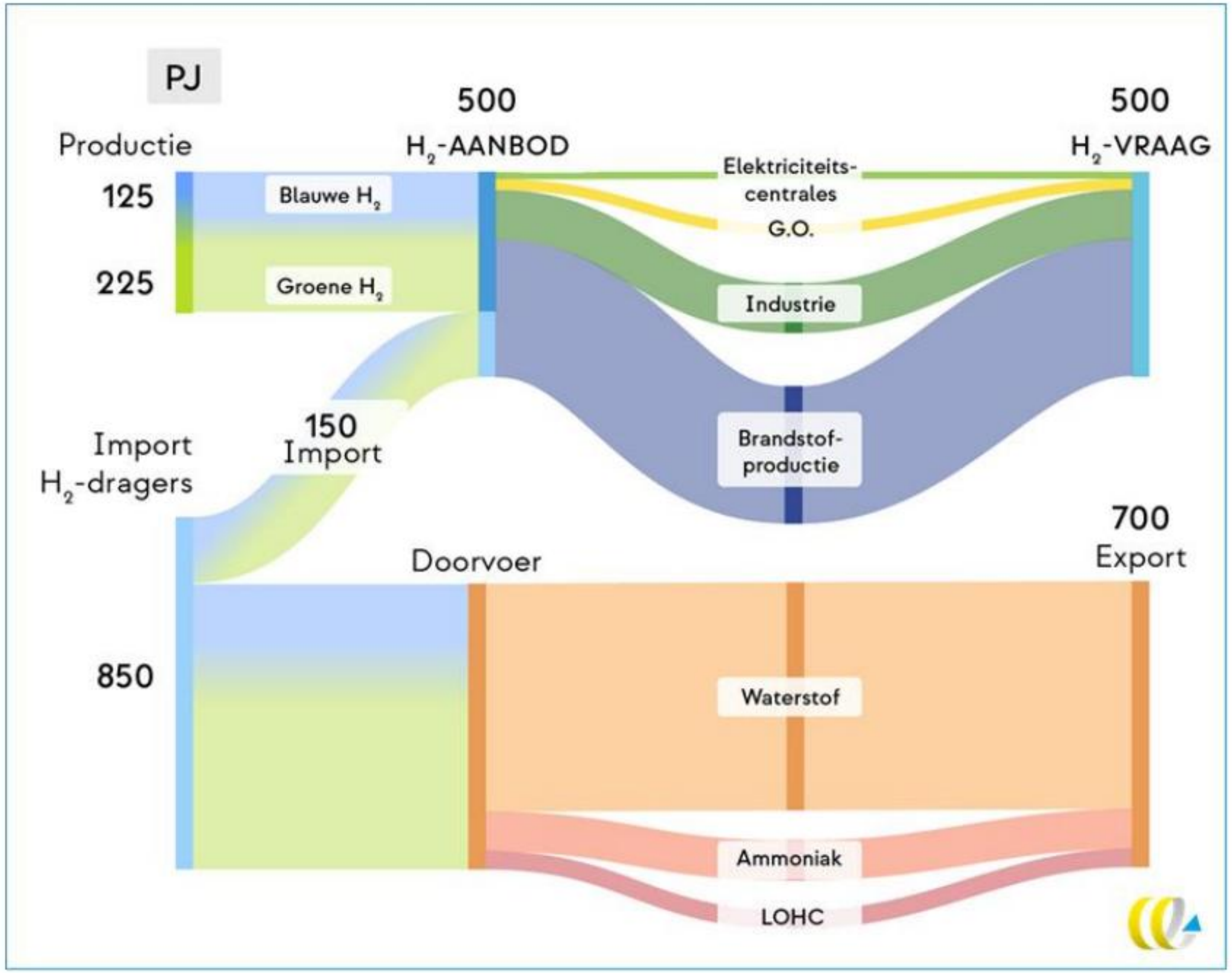
Huib Blokland | TNO

31 January 2026

Agenda

- Different types of grids
- Quality of pure hydrogen
- Quality of hydrogen admixed in natural gas
- Example of quality monitoring
- Gas quality technology in HyTROS

2050 projected hydrogen supply and demand



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To compare

Natural gas in 2025:

Demand = ~1000 PJ = 28 bcm

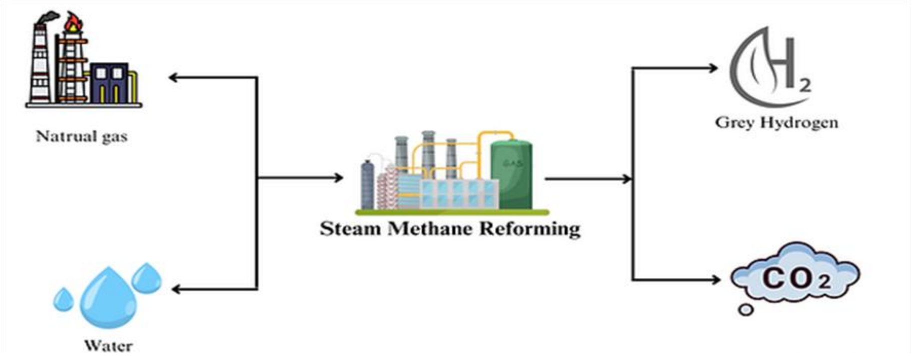
Quality measurement in hydrogen grids: two types

- **Pure hydrogen**
  - Always <100% purity, **contaminants**
  - Primary foreseen in the **transmission** grids (high pressure)
  - Delivery to **large industry, mobility**

- **Hydrogen admixed in natural gas**
  - Up to **20% hydrogen** blended (not in NL)
  - Both in **transmission** and regional **distribution** grids
  - Allowed percentage of hydrogen depends on **end-user**
  - Strong **variation per country**, e.g. NL 0.02% (TSO) to 0.5% (DSO)

Quality of pure hydrogen

- Depends on the source
  1. Mainly (now): **Steam Methane Reforming**
     - Blue or Gray Hydrogen
     - A lot of potential contaminants
  2. Green Hydrogen from **electrolysis** of green electricity (solar and wind)
     - Contaminants: mainly water and oxygen
  3. **Import** via energy carriers like Ammonia
     - 'New contaminants' NH3, ...

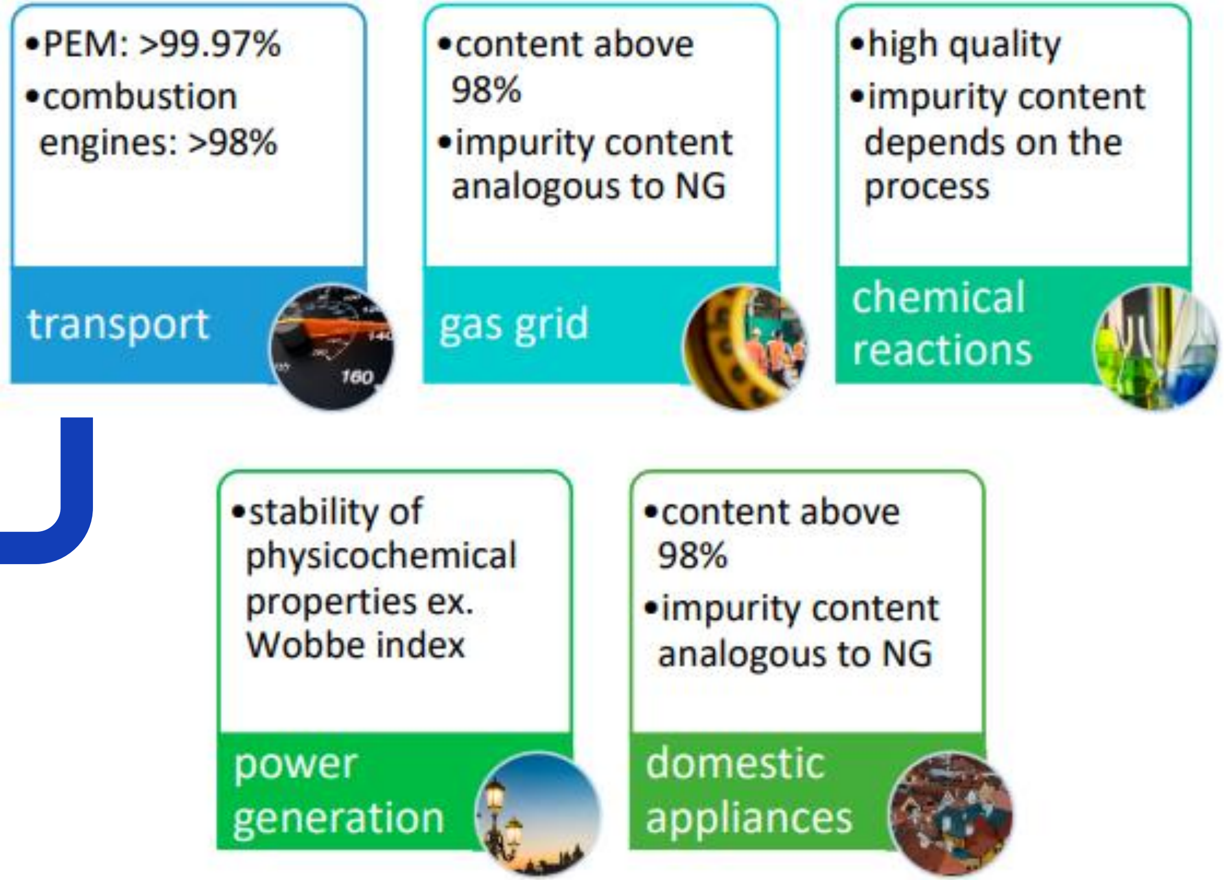


Parameters [%]	Coal Gasification	Natural Gas Reforming	Methanol Reforming	Coke Oven Gas	Methanol Purge Gas	Synthetic Residual Gas from NH_3	Biomass Gasification
H_2	25–35	70–75	75–80	45–60	70–80	60–75	25–35
CO	35–45	10–15	0.5–2	5–10	4–8	-	30–40
CO_2	15–25	10–15	20–25	2–5	5–10	-	10–15
CH_4	0.1–0.3	1–3	-	25–30	2–8	-	10–20
N_2	0.5–1.0	0.1–0.5	-	2–5	5–15	15–20	1
Ar	-	-	-	-	0.1–2	-	-
Total sulphur	0.2–1	-	-	0.01–0.5	-	-	0.2–1
H_2O	15.2	-	-	-	-	1–3	-
O_2	-	-	-	-	-	0.2–0.5	-
Other	-	-	-	-	2–5	10–15	0.3

Energies 2024, 17, 3794. https://doi.org/10.3390/en17153794

Quality of pure hydrogen

- Depends on the application



Energies 2024, 17, 3794. https://doi.org/10.3390/en17153794

Parameter	Permissible Value
Hydrogen fuel index (minimum molar fraction)	>99.97%
Total maximum content of gases other than hydrogen	<300 µmol/mol
Water	<5 µmol/mol
Total hydrocarbons excluding methane	<2 µmol/mol
Methane	<100 µmol/mol
Oxygen	<5 µmol/mol
Helium	<300 µmol/mol
Nitrogen	<300 µmol/mol
Argon	<300 µmol/mol
Carbon dioxide	<2 µmol/mol
Carbon monoxide	<0.2 µmol/mol
Total sulfur compounds	<0.004 µmol/mol
Formaldehyde	<0.2 µmol/mol
Formic acid	<0.2 µmol/mol
Ammonia	<0.1 µmol/mol
Total halogen compounds	<0.05 µmol/mol
Particulate matter content	<1 mg/kg

Quality of pure hydrogen

- No ‘universal standard’ for hydrogen grids

Component	Units	EASEE-gas *CBP*	CEN *TS 17977*	DNV KIWA *proposal*
Hydrogen (H_2)	mol%	≥ 98	≥ 98	≥ 99.5
Total Hydrocarbons (incl. CH_4)	mol%	≤ 1.5	≤ 2	≤ 0.5
Inerts (N_2, Ar, He)	mol%	≤ 2	≤ 2	≤ 0.5
Carbon Monoxide (CO)	ppm mol	≤ 20	≤ 20	≤ 20
Carbon Dioxide (CO_2)	ppm mol	≤ 20	≤ 20	≤ 20
Oxygen (O_2)	ppm mol	≤ 10	≤ 10	≤ 10
	mol%	-	≤ 0.1[1]	-
Total Sulphur (S)	ppm-mol	≤ 15[2]	≤ 7	≤ 3
Water (H_2O) (MOP > 10 bar)	ppm-mol	-	≤ 60	-
Water dewpoint	°C [at 70 bar]	≤ -8	-	≤ -8
Hydrocarbon dewpoint	°C [at 1 -70 bar]	≤ -2	≤ -2	≤ -2
Ammonia (NH_3)	ppm mol	-	≤ 13	≤ 10
Formic Acid	ppm mol	-	-	≤ 10
Formaldehyde	ppm-mol	-	-	≤ 10
Halogen compounds (Cl, Br, F)	ppb mol	≤ 50	≤ 50	≤ 50
Wobbe-index	MJ/m^3 (25°C/0°C)	-	-	45.99 - 48.35
	MJ/m^3 (15°C/15°C)	-	42.0 – 46.0	-

EASEE: European Association for Streamlining of Energy Exchange

CEN: European Committee for Standardization

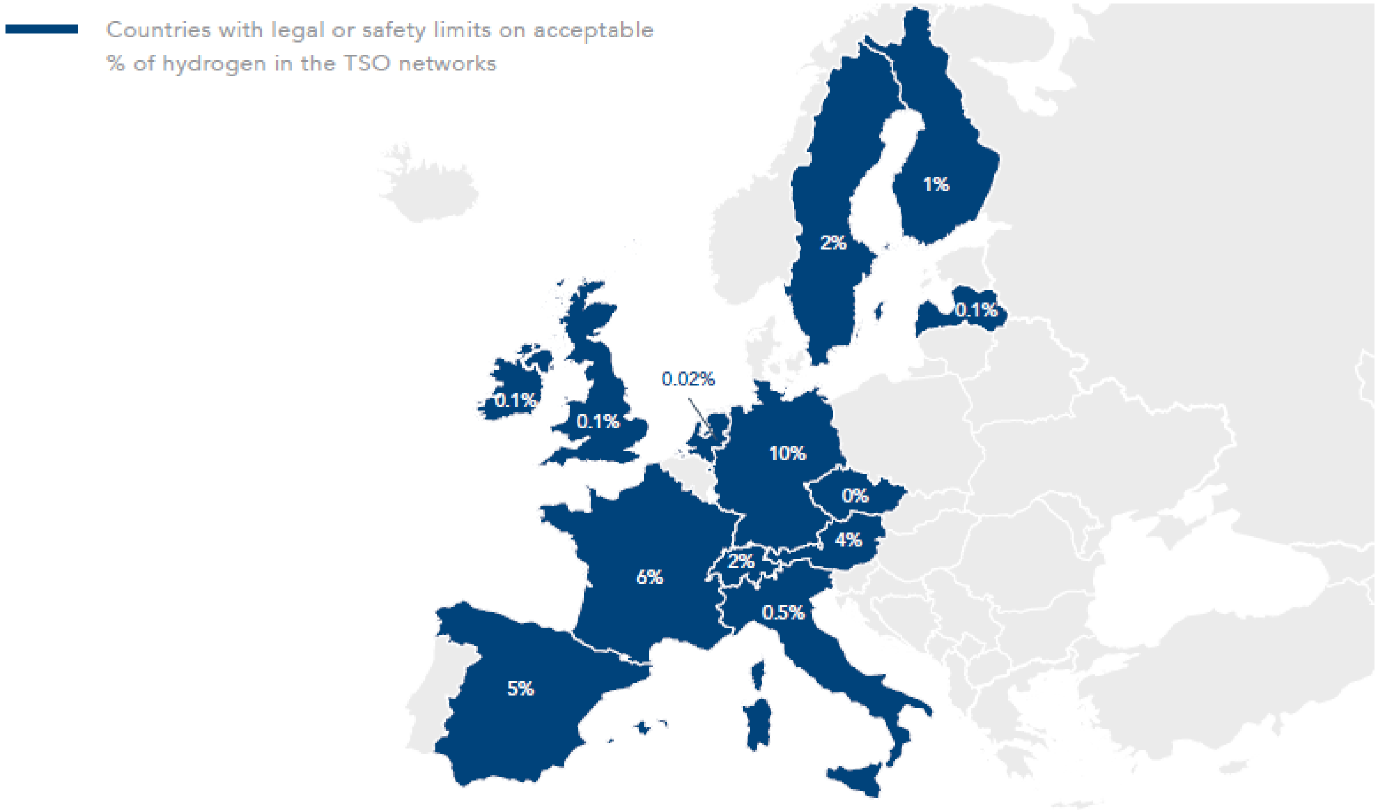
Quality of pure hydrogen

- **Challenges**
  - Quality variation by **production**
  - Huge variation for requirement at **end-users**
  - Quality **in the grid** depends on pipeline quality
  - No ‘**universal standards**’
  - **Economic balance**: purify at inlet or at outlet
  - More **local production** results in more local variation

➔ Increasing need for more hydrogen quality monitoring in the grid

Quality of hydrogen admixing in natural gas

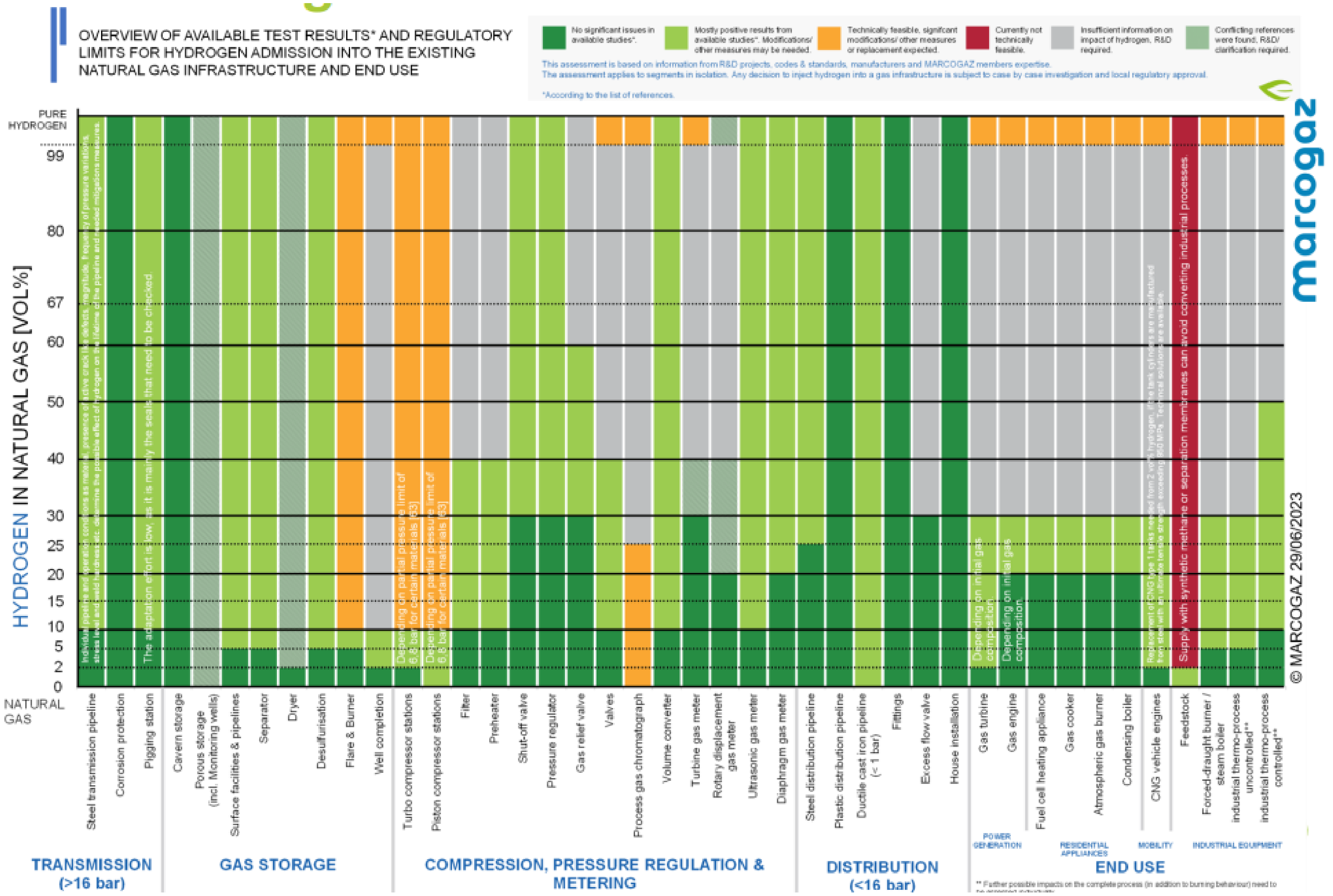
- Depends on national regulation



Clean Hydrogen Monitor 2020. Hydrogen Europe. October 2020.

Quality of hydrogen admixing in natural gas

- Depends on application



Quality of hydrogen admixing in natural gas

- **Challenges**:
  - Strong **variations** all over **Europe**
  - Huge variations in requirements per **application**
  - Huge impact on
    - **Billing** (10% of hydrogen blending means 3-4% less energy)
    - **Safety** regarding critical end-users

➔ Increasing need for more quality monitoring in the grid

Quality monitoring in hydrogen grids – summarized

- Huge **quality variations** in the grid
- Increasing need for **more monitoring** locations
- Currently mainly **Gas Chromatography** is used: expensive and off-line

➔ Driver for low-cost and inline gas quality measurement

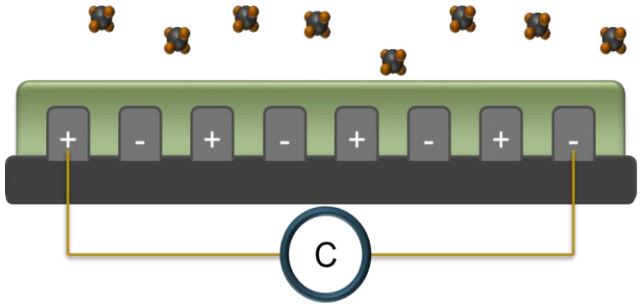
HyTROS: Prototype sensor for hydrocarbon detection in hydrogen

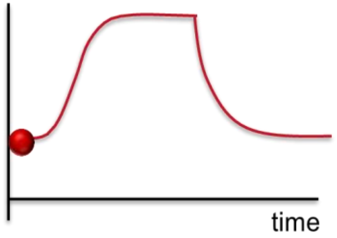
groenvermogennl | Innovatiemotor van de groenewaterstofeconomie

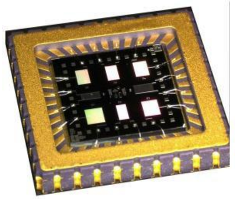
TNO Sensor technology background

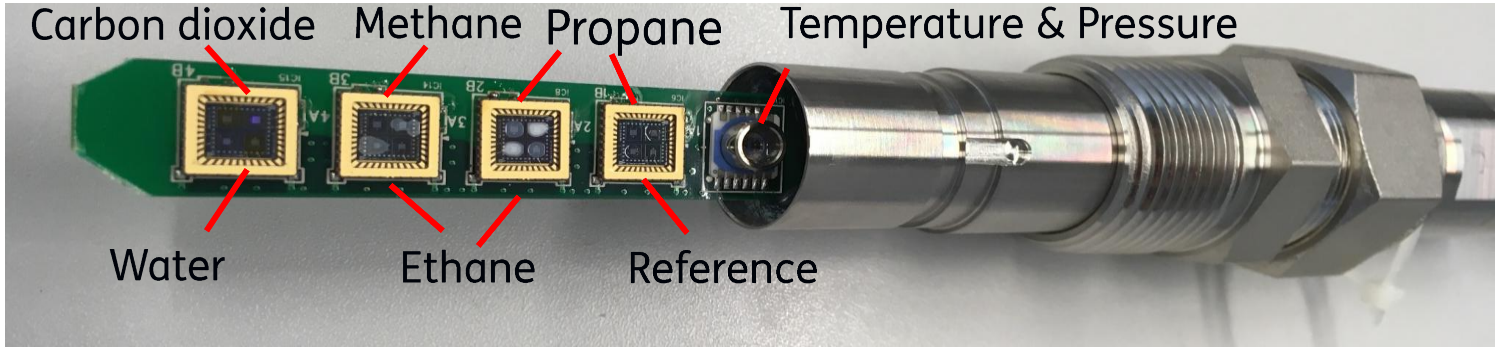
Sensor principle of measurement

- Responsive polymer coatings on an interdigitated electrode enables the development of a sensor array capable of determining the gas composition.
- Proprietary coatings selectively absorb (and desorb) gas components of interest, changing capacitance
- This can be used to calculate the calorific value and other key physical properties of the gas mixture









- 8-10 coatings were developed for:
  - Methane
  - Ethane
  - Propane
  - Carbon Dioxide
  - **Hydrogen**
  - *n* & *iso* butane
  - *n* & *iso* pentane
  - Nitrogen
  - Water

Demonstrators

Demonstrator 1

Natural Gas & Biogas

ENEXIS

Demonstrator 2

DSO Hydrogen admixing

HyDeploy

Demonstrator 2

TSO Hydrogen admixing

POSHYDON

Demonstrator:
Hydrogen blending in natural gas HyDeploy

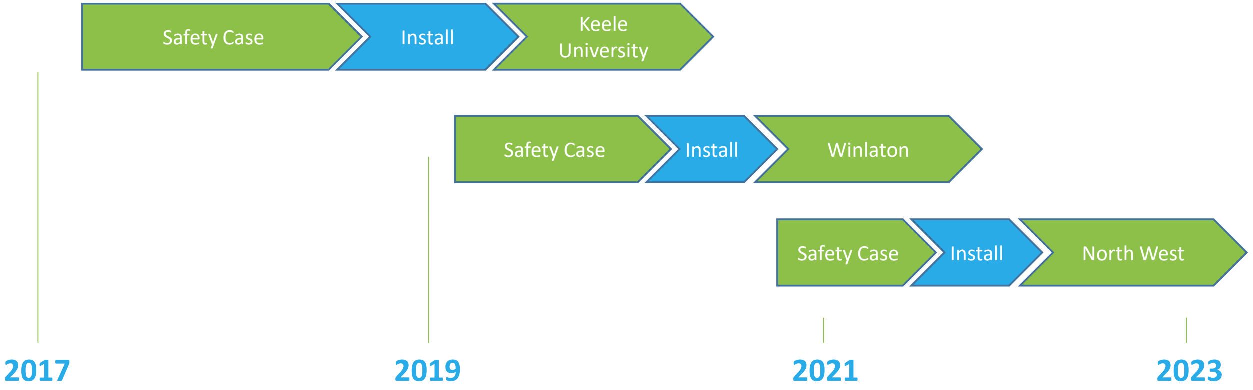
Project objective:

To enable bulk deployment of hydrogen blending within the UK **gas distribution grid** by demonstrating its safe transportation and use

HyDeploy

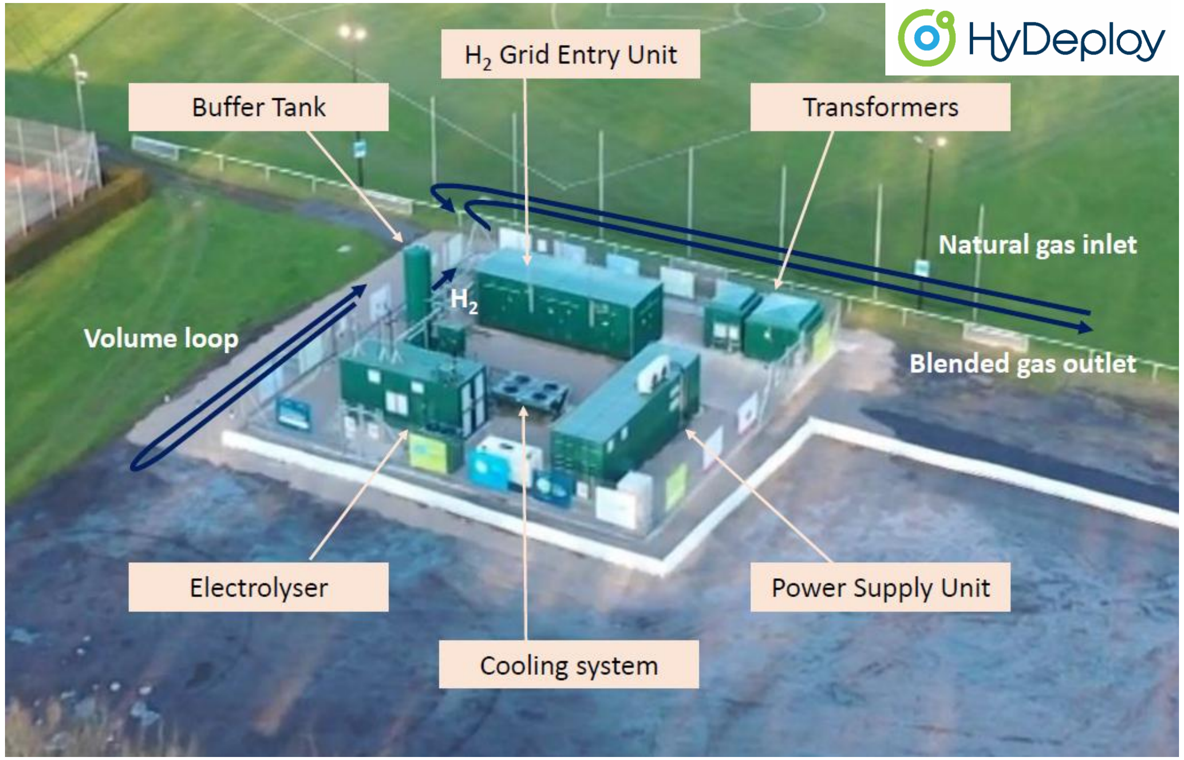
Cadent | Northern Gas Networks | Progressive energy

ITM POWER Energy Storage | Clean Fuel | HSE | Keele University



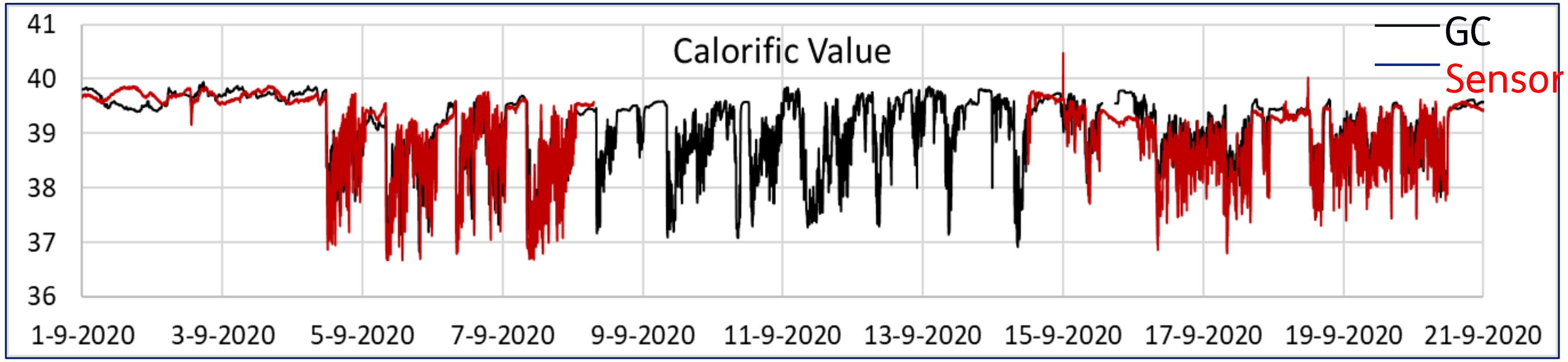
HyDeploy - Keele University Campus

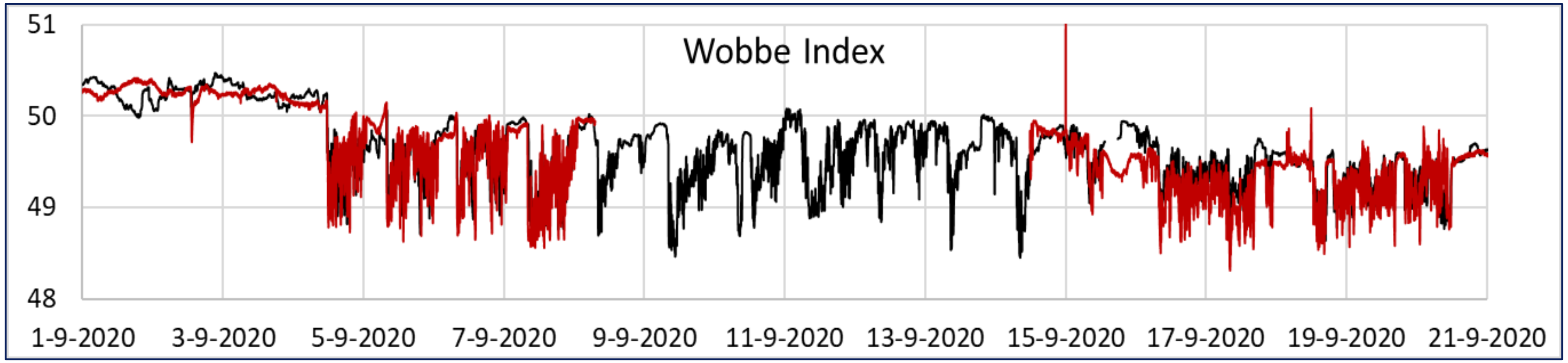
- Hydrogen is produced on site by electrolyser, and **blended up to 20% vol.** with the natural gas stream
- Feeds a university campus containing ~**100 end-users,** including domestic, commercial dwellings & appliances
- **Three gas sensors were installed** in the boiler house, about 1 km downstream of the gas blending location



HyDeploy Data – Calorific Value and Wobbe Index

- From the measured composition, the Calorific Value and Wobbe Index (and other physical properties) were calculated and compared





Demonstrator: PosHYdon – Hydrogen admixing in the TSO grid

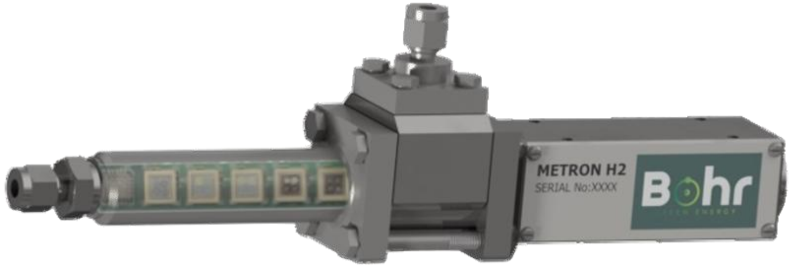
Project

Green hydrogen will be produced offshore on an operational platform, admixed to produced natural gas and via existing pipelines transported to shore.

PosHYdon will integrate three energy systems in the North Sea – offshore wind, offshore gas and offshore hydrogen – at Neptune Energy’s Q13a-A platform.

TNO sensor activities within PosHYdon project

- Goal: develop and test a sensor at 80bar and 0 – 1 % hydrogen in NG.
- In collaboration with Bohr.
- Tests in TNO laboratory under practical conditions for gas composition, pressure and temperature.
- **Tests finished in 2024: 0.1 % accuracy was demonstrated at 70-90 bar**



HyTROS – Sensor Scope

- Goal: feasibility to use TNO technology for measuring the **total sum of hydrocarbons** in hydrogen in TSO grid
- Based on **Hynetwork guidelines**
- Focus on **Methane**
- Sensor development and **functional tests** at TNO
- Sensor **hardware** will be provided by Bohr Engineering UK
- Sensor validation at **DNV high pressure loop**
- Also investigate the feasibility (by desk-top study) of this technology for DSO grids.

Table 1: Indicative quality specifiaction Hydrogen Network Netherlands

Constituents	Unit	Min.	Max.
Hydrogen (H_2)	mol/mol %	99,5	
Total sum of hydrocarbons in-cluding CH_4 (CXHY)	mol/mol %		0,5
Oxygen (O_2)	µmol/mol (ppm)		10
Total sum of inerts (N_2, He, Ar)	mol/mol %		0,5
Carbon dioxide (CO_2)	µmol/mol (ppm)		20
Carbon monoxide (CO)	µmol/mol (ppm)		20
Total sulphur including H2S (S)	µmol/mol (ppm)		3
Formic acid (CH_3OOH)	µmol/mol (ppm)		10
Formaldehyde (CH_2O)	µmol/mol (ppm)		10
Ammonia (NH_3)	µmol/mol (ppm)		10
Halogenated compounds	µmol/mol (ppm)		0,05
Water dewpoint (H_2O)	ºC @ 70 bara		-8
Hydrocarbon dewpoint	ºC @ 1 - 70 bara		-2
Wobbe index	MJ/m³ (n)	45,99	48,35
All other impurities	Shall not contain solid, liquid or gaseous material that might interfere with the integrity or operation of pipes or any gas appliance		

Table 2: Temperature

Property	Unit	Min.	Max.
Gas temperature	ºC	5	30

HyTROS - Sensor activities

Inventory

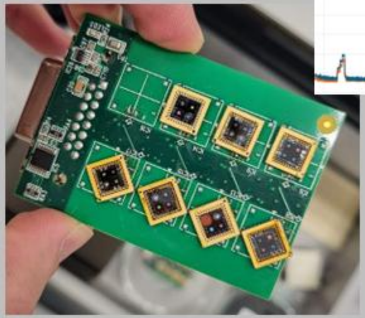
12 potential coatings

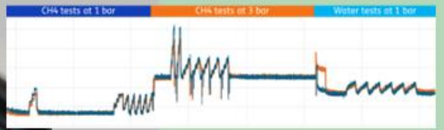
nr	Coating
1	Basolite Z1200/PIM
2	PIM
3	ZSM5_91/PIM
4	MIL101/PIM
5	MOF14/PIM
6	REF
7	NH4CZP8/PIM
8	ZSM5_26/PIM
9	Basolite F300
10	MOF/PIM
11	NH4CZP2/PIM
12	Na ZSM_38/PIM
13	REF

Screening low pressure (up to 3 bar)

PCB 1

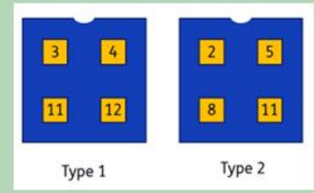
PCB 2





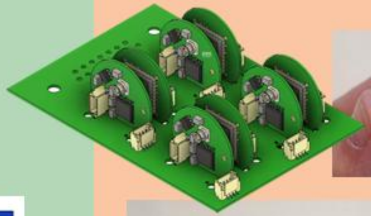
Selection best coatings

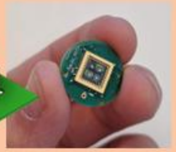
2 flavours coating combinations



Test new hardware Bohr

1 coin selected (four coatings)





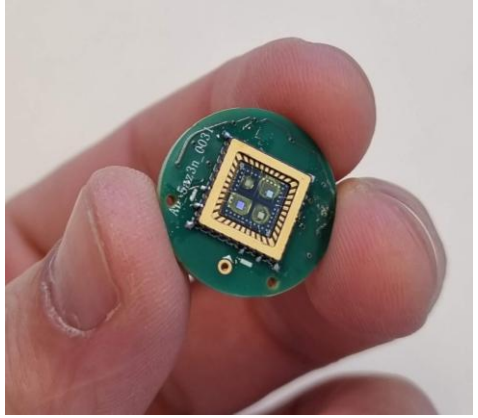
High pressure tests (up to 50 bar)

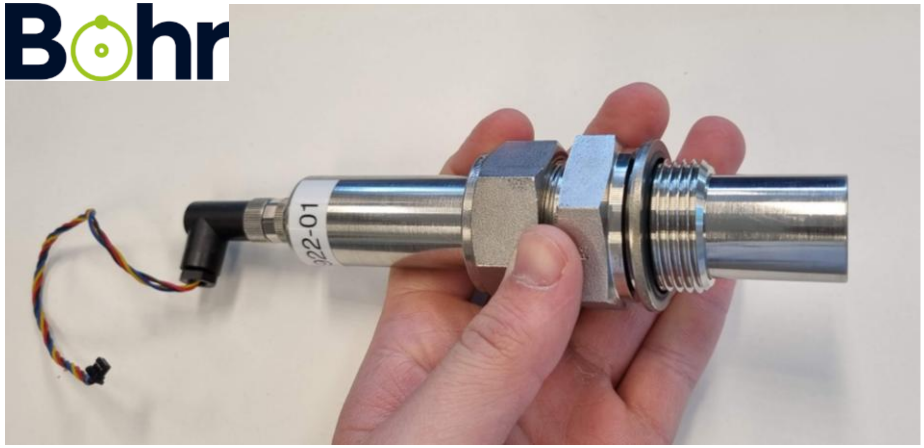
Integration in high pressure system

To DNV

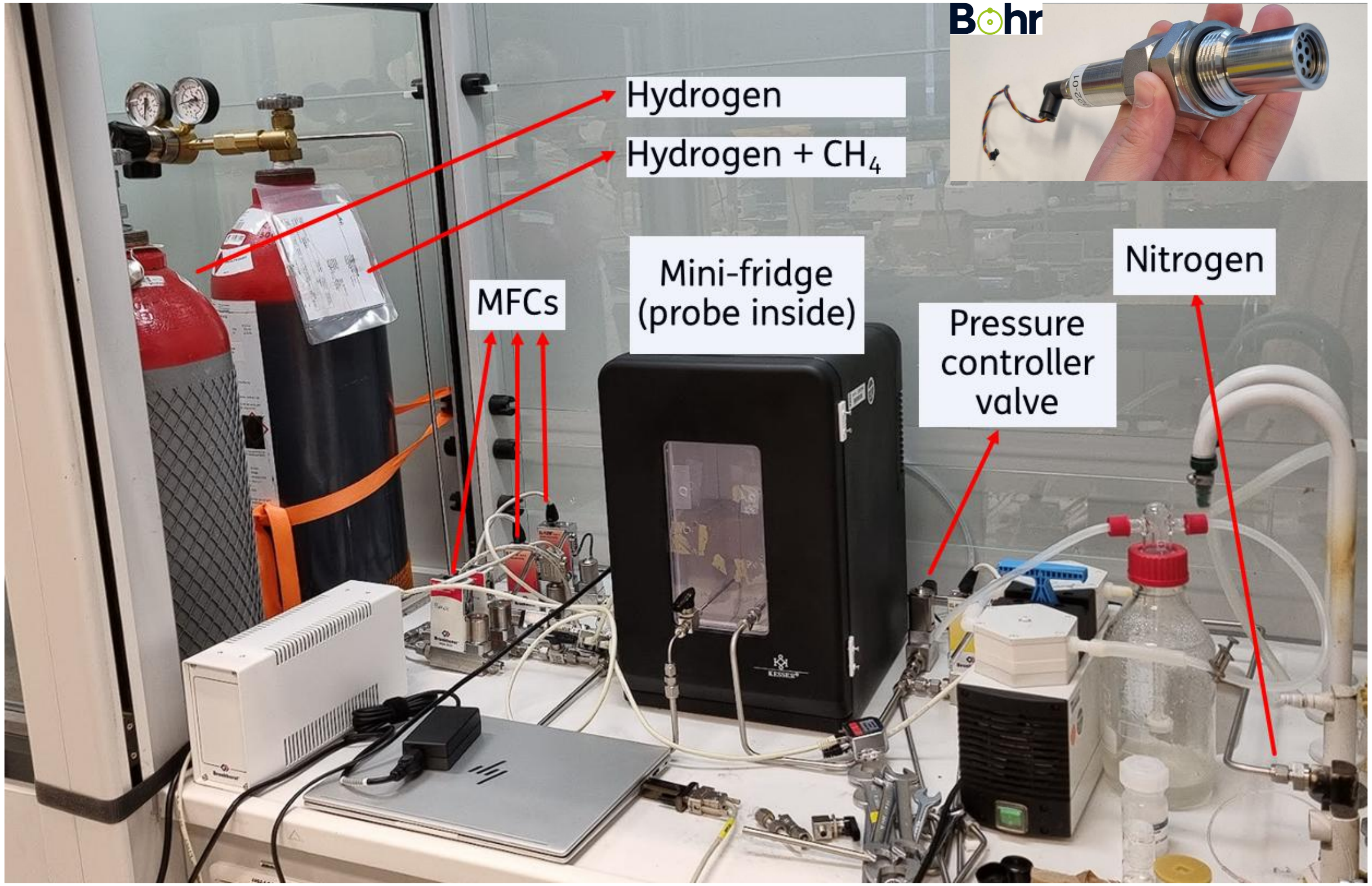
HyTROS – Sensor hardware

- Two metal probes with 1” Swagelok connector provided by Bohr
- Includes threaded adapter for DNV setup
- A coin fits in each probe, connected with a cable and held in place by a compression ring

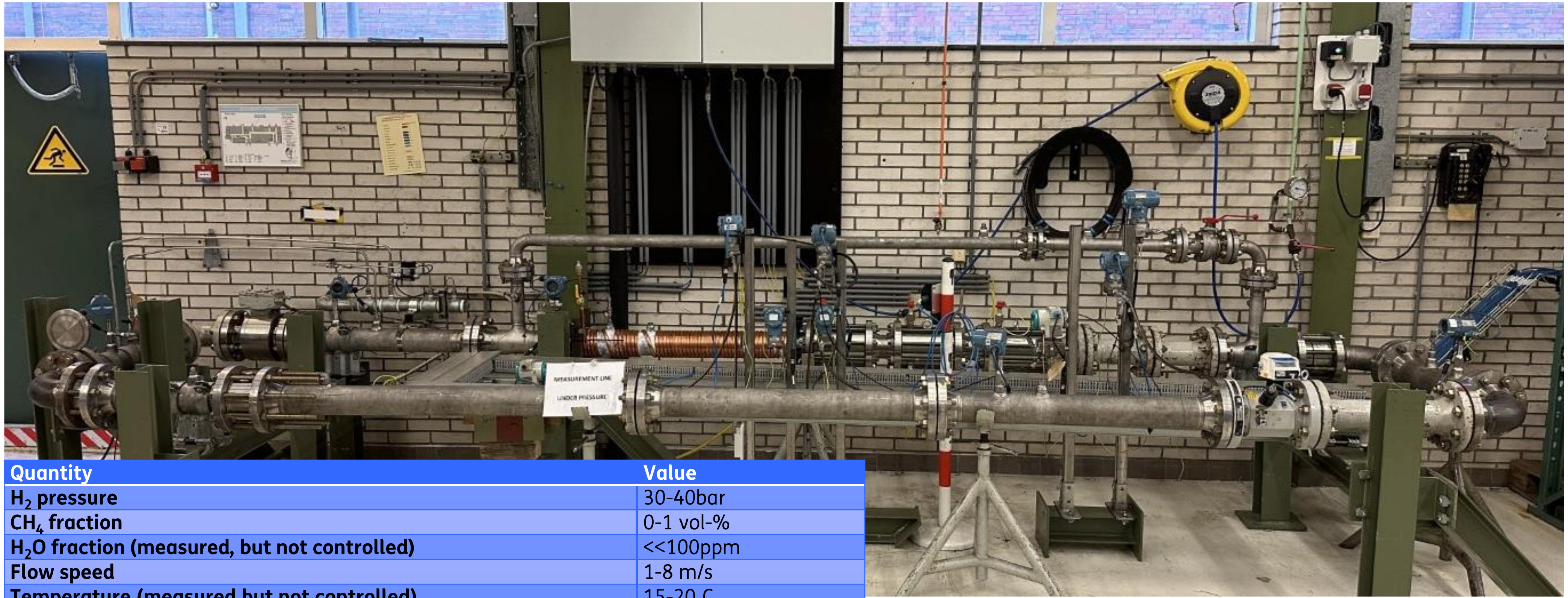




HyTROS - TNO high pressure set-up



HyTROS - next steps



Quantity	Value
H_2 pressure	30-40bar
CH_4 fraction	0-1 vol-%
H_2O fraction (measured, but not controlled)	<<100ppm
Flow speed	1-8 m/s
Temperature (measured but not controlled)	15-20 C
Test duration (excl. sensor installation and recovery)	2 weeks
Sampling interval of GC for CH_4 measurement	Few minutes
Sampling interval of IR spectrometer for H_2O measurement	30 minutes
Desired accuracy of TNO CH_4 sensor	+/- 0.1 vol-%

Wrap up

- Hydrogen quality in pure hydrogen grids:
  - Depends on the **source** (grey, blue, green)
  - High **variation** in requirements per end-user
  - No **international** standard
- Gas quality in hydrogen admixed to natural gas grids:
  - Strong **variations** all over Europe
  - Huge variations in **requirements** per application
  - Huge implact on **billing** and **safety**
- Increasing need for more quality monitoring in the grid: low-cost, online
- Example of technology development by TNO will be applied in the HyTROS project for measuring contaminants in pure hydrogen

Acknowledgements

- TNO team: Arjen Boersma, Joe Trimboli, Kees de Meijere, Javier Nunez
- Hardware provided by Bohr Engineering
- HyTROS Task1.5 partners: HAN, DNV, VSL, NetbeheerNL, Gasunie

Thank you!

TNO innovation for life

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