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Department for Science, Innovation & Technology

Challenges of hydrogen metering

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Contents

The net zero challenge: drivers

There are a number of drivers for reaching net zero emissions; these can be worldwide, continental or national:

- Paris Agreement (COP21): Aims at limiting the global temperature increase to well below 2°C, whilst ultimately aiming for 1.5°C
- Renewable Energy Directive (RED I, RED II): A directive that mandates levels of renewable energy use for individual countries within the European Union
- European Green Deal: A set of policies with the overarching aim of making Europe climate neutral by 2050
- Climate Change Act: Ensure that the net UK carbon account for the year 2050 is zero

The net zero challenge: UK Perspective

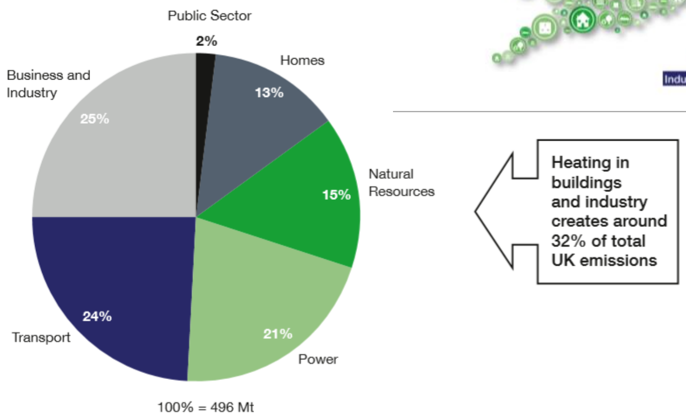
In the UK, heating and transport are responsible for 56% of total emissions.

There is tremendous potential for reducing emissions through the decarbonisation of both heat and transport.

The UK Government Clean Growth Strategy recognises:

- The role of electrification (electricity from solar, wind etc, battery electric vehicles, heat pumps)
- The role of biomass and bioenergy
- The role of hydrogen
- The role of carbon capture, utilisation and storage

Figure 2: UK emissions by sector, 2015[27]



Source: BEIS

UK Hydrogen Economy 2020s Roadmap:

Early 2020s (2022-2024)	Mid-2020s (2025-2027)	Late 2020s (2028-30)	Mid-2030s onward

Hydrogen economy 'archetype'

Early 2020s (2022-2024)

Production
Small-scale electrolytic production

Networks
Direct pipeline, co-location, trucked (non-pipeline) or onsite use

Use
Some transport (buses, early HGV, rail & aviation trials); industry demonstrations; neighbourhood heat trial

Key actions and milestones

- Launch NZHF early 2022
- Phase 1 CCUS cluster decision 2021
- Finalise low carbon hydrogen standard 2022
- Finalise business model 2022
- Heat neighbourhood trial 2023
- Value for money case for blending Q3 2022

Mid-2020s (2025-2027)

Production
Large-scale CCUS-enabled production in at least one location; electrolytic production increasing in scale

Networks
Dedicated small-scale cluster pipeline network; expanded trucking & small-scale storage

Use
Industry applications; transport (HGV, rail & shipping trials) village heat trial; blending (tbc)

- Aiming for 1GW production capacity 2025
- At least 2 CCUS clusters by 2025
- Heat village trial 2025
- Hydrogen heating decision by 2026
- Decision on HGVs mid-2020s

Late 2020s (2028-30)

Production
Several large-scale CCUS-enabled projects & several large-scale electrolytic projects

Networks
Large cluster networks; large-scale storage; integration with gas networks

Use
Wide use in industry; power generation & flexibility; transport (HGVs, shipping); heat pilot town (tbc)

- Ambition for 5GW production capacity 2030
- 4 CCUS clusters by 2030
- Potential pilot hydrogen town by 2030
- Ambition for 40GW offshore wind by 2030

Mid-2030s onward

Production
Increasing scale & range of production – e.g. nuclear, biomass

Networks
Regional or national networks & large-scale storage integrated with CCUS, gas & electricity networks

Use
Full range of end users incl. steel; power system; greater shipping & aviation; potential gas grid conversion

- Sixth Carbon Budget

Hydrogen refuelling stations

- Existing HRS by country

Country	No. of HRS
Germany	>100
France	26
UK	12
Denmark	8
Austria	6
Norway	6
Switzerland	5

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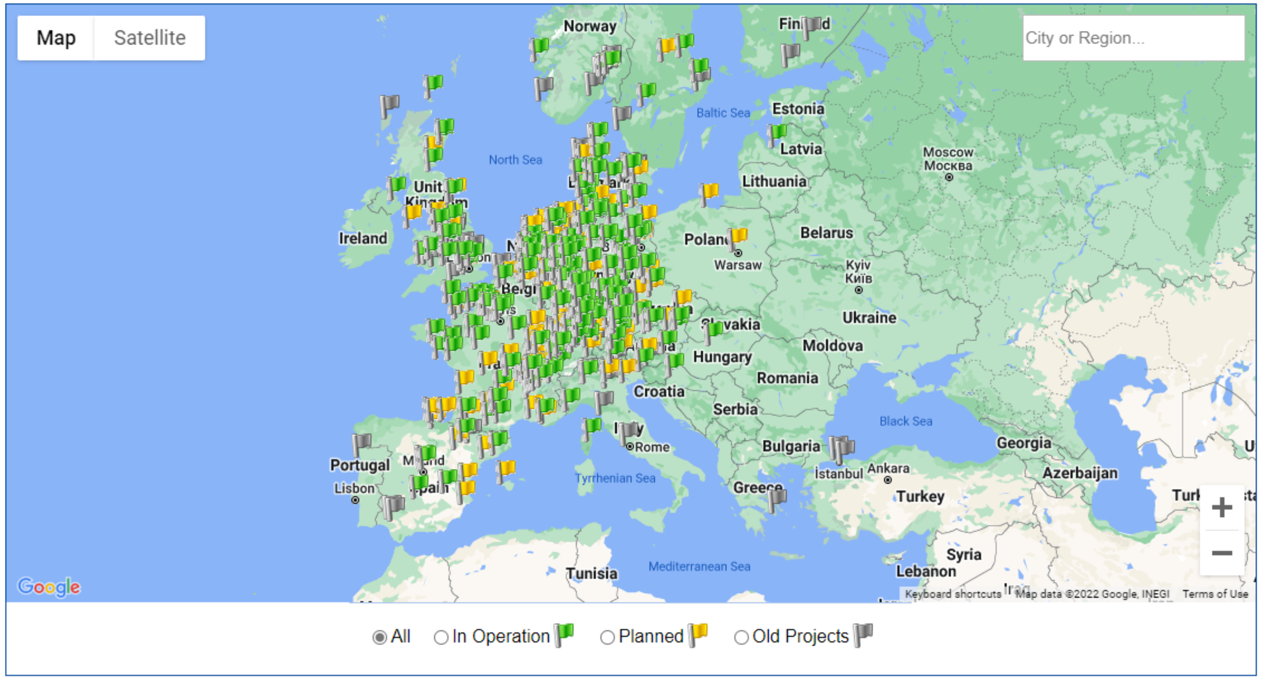


- Many more are planned, with a focus on Heavy-duty vehicles (buses, HGVs, bin lorries)

The situation for existing vehicle refuelling

The existing regulatory requirement for ‘liquid fuels’ (petrol, diesel, etc) is that errors ‘at the nozzle’ must be -0.5% to +1.0% (at the minimum measured quantity, MMQ of 5 L) **[Class 0.5 fuel dispensers under OIML R 117]**

If a UK consumer disputes the dispensed volume, Trading Standards will investigate

- The equipment and skills to test fuel dispensers is well established
- Volumetric collection with standard measures, traceable to SI

In 2018, the UK exchequer received:

- £28 bn in fuel duty – 0.5% of which is £140 m
- >£1.5bn in VAT on fuel

The situation for hydrogen FCEV refuelling

- The accuracy requirements for dispensers at hydrogen refuelling stations (HRS) are set out in the international recommendation OIML R139

- Challenging due to the operating conditions at hydrogen refuelling stations, which are specified in the worldwide accepted standard SAE J2601

- There is no standard specification for the equipment which should be used for HRS verifications

OIML R 139: What is different about hydrogen?

Note: Except for hydrogen CGF measuring systems, the metrological requirements concerning the measurement of gases within the scope of this Recommendation are independent of the type of gas being measured. The testing methods for type evaluation or further verification of compliance as described in Part 2 may differ where necessary between all the different gasses.

Maximum Permissible Error (MPE) for accuracy tests

- Sets out the accuracy requirement at the dispenser
- Maximum permissible errors for the measuring system and the flow meter specifically
- 2 new accuracy classes introduced for hydrogen
  - Class 2 is preferred, but national authorities can opt for Class 4
  - Maximum permissible errors for both are higher than for other compressed gaseous fuels

5.2 Maximum permissible error (MPE)

5.2.1 Without prejudice to 5.2.3, the maximum permissible error on mass indications, positive or negative, is equal to the values presented in Table 1:

Table 1 - MPE values

Accuracy class		MPE for the meter [in % of the measured quantity value]	MPE for the complete measuring system [in % of the measured quantity value]	
			at type evaluation, initial or subsequent verification	in-service inspection under rated operating conditions
For general application	1.5	1	1.5	2
For hydrogen only	2	1.5	2	3
	4	2	4	5

Note 1: National Authorities may decide whether subsequent verifications should be conducted and whether a different maximum permissible error should be applied for subsequent verification.

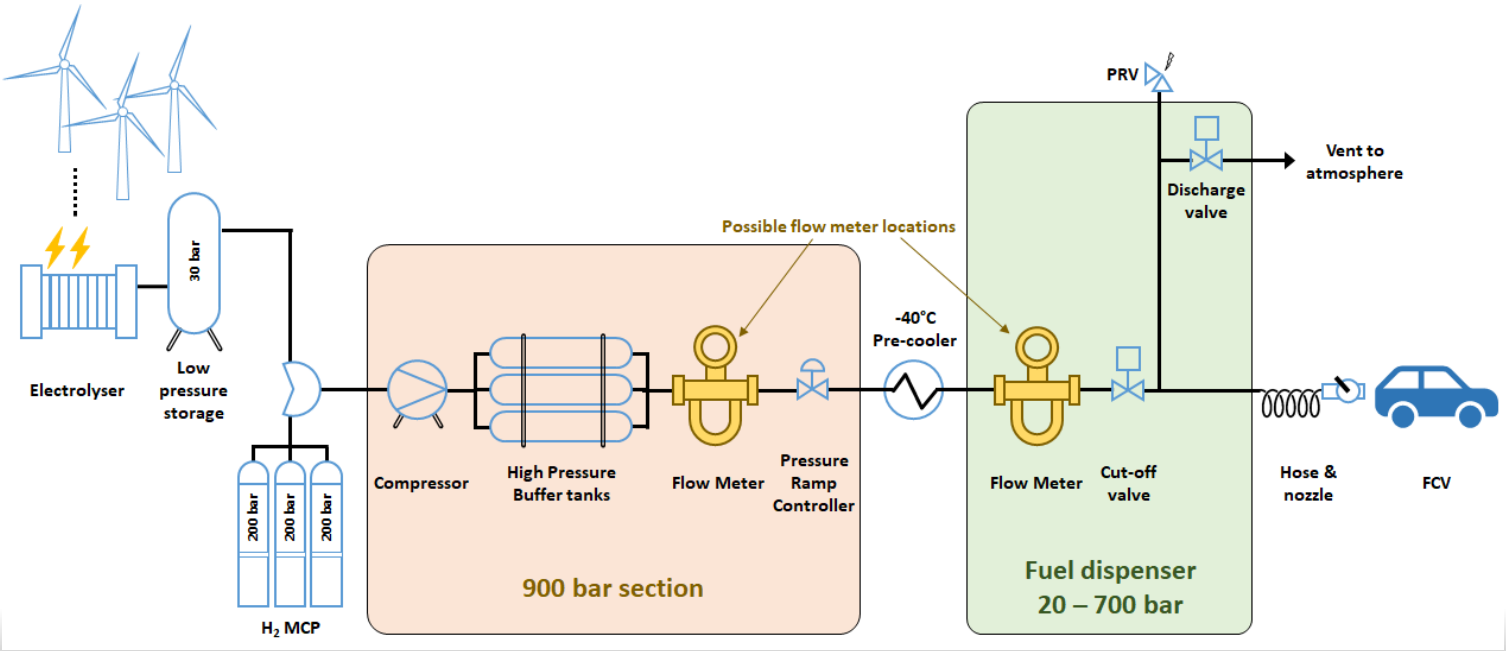
Note 2: "In service inspection" refers to an inspection at any moment within the period of time between verifications (refer to OIML D 16, 2.25).

HRS Operating Ranges

- Pressures up to 875 bar (for HRS with a nominal working pressure of 700 bar)
- Temperature changes from -40°C (pre-cooling) to 85°C (maximum allowed vehicle tank temperature)

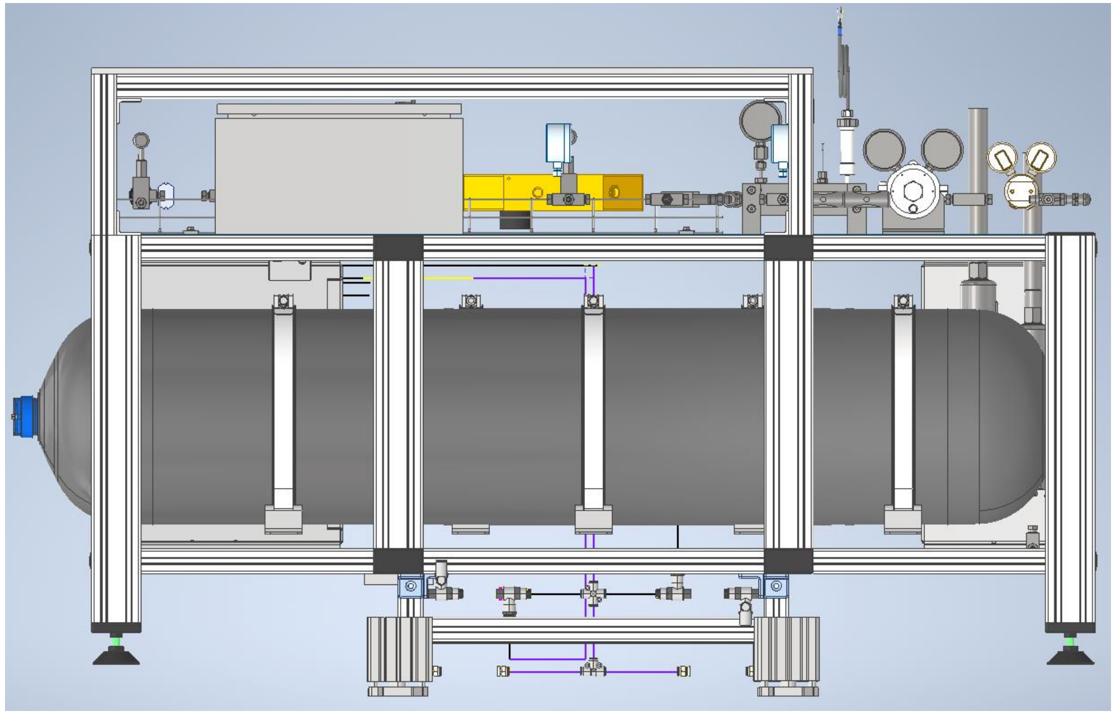
Property	Value
Fluid temperature (hydrogen)	-40 to +60 °C (max. vehicle tank temperature 85 °C)
Pressure:	0.5 – 87.5 MPa (up to 1.25 x NWP) [96.3 MPa station PRV set point → 1.1 x 1.25 x NWP; Max. station pressure: 1.2 x 1.25 x NWP (SAE J2760)]
Density:	0.52 (@0.5 MPa, -40 °C) – 118.17 kg/m^3 (@70 MPa, +60 °C)
Flow rate:	Up to 0.06 kg/s (3.6 kg/min)
Filling quantity – normal fuelling:	2 to 10 kg
Filling quantity – interrupted fuelling:	0 to 2 kg (in case of a user interruption or emergency stop)
Pressure drop:	<1 MPa @ maximum flow rate
Ambient temperature:	-40 to +50 °C
Ambient pressure:	Normal atmospheric pressure

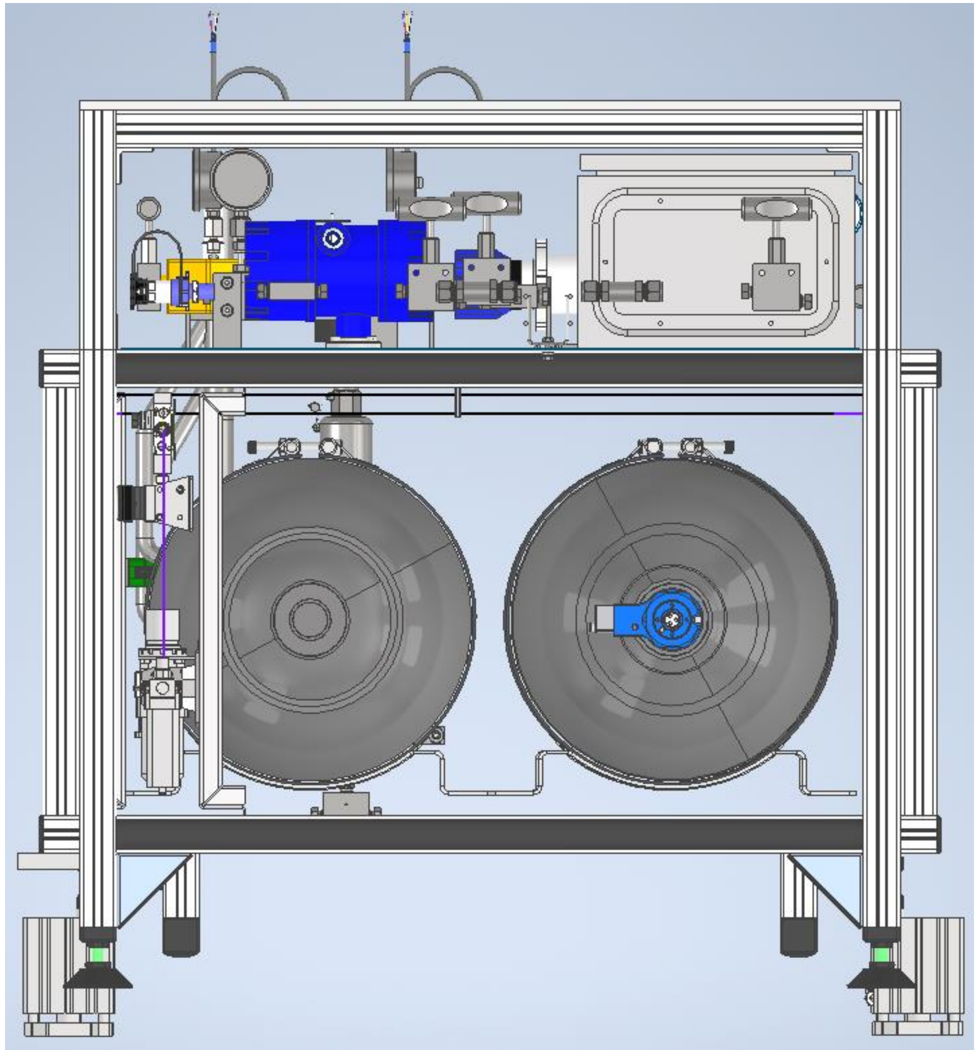
Ref: SAE J2601 – Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles



HRS Theme – Hydrogen Field Test Standard (HFTS)

- Build completed, now in the commissioning stage
  - Gravimetric system, 0.3% (k = 2) target uncertainty at 1 kg MMQ §
  - Dual tank (103 L and 51 L), total 6 kg H_2 capacity at 700 bar





HRS = Hydrogen Refuelling Station

‡ Factory Acceptance Test

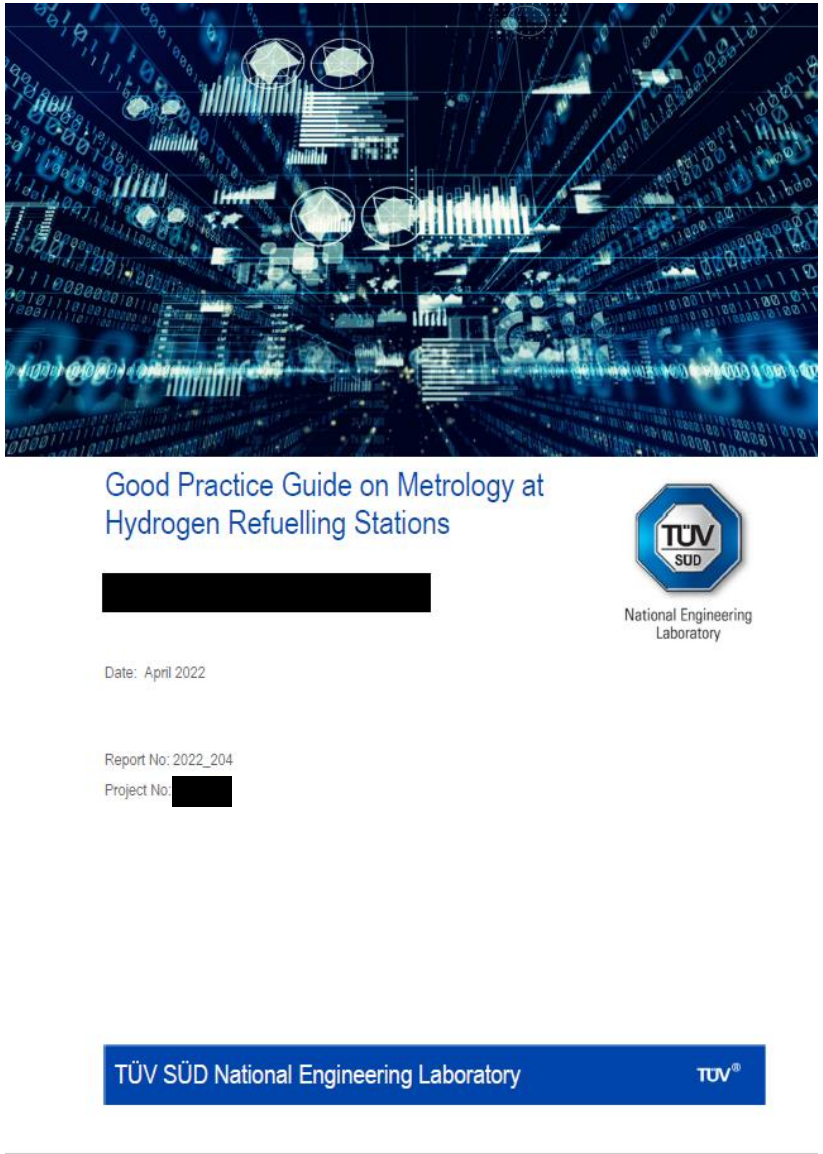
§ Minimum Measured Quantity, as dictated by OIML R-139

HRS Theme – Hydrogen Field Test Standard (HFTS)

Good Practice Guide

Guidance on:

- Regulatory requirements: implementation of OIML R139 in UK, Europe & other territories
- Overview of operating conditions at hydrogen refuelling stations, and implications of accuracy of dispensed hydrogen
- Review of state-of-the-art for commercially available H_2 dispenser flow meters: suppliers, measurement capability, cost, certifications, influence of temperature, pressure, fluctuating flow
- Review of alternative flow meter technologies that may be used in future
- Hydrogen purity requirements for fuel cells and HRS, overview of gas analysis methods and sampling techniques
- Calibration and verification options: for meters prior to installation and for field verifications of the station



Good Practice Guide on Metrology at Hydrogen Refuelling Stations

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Date: April 2022

Report No: 2022_204

Project No: [redacted]

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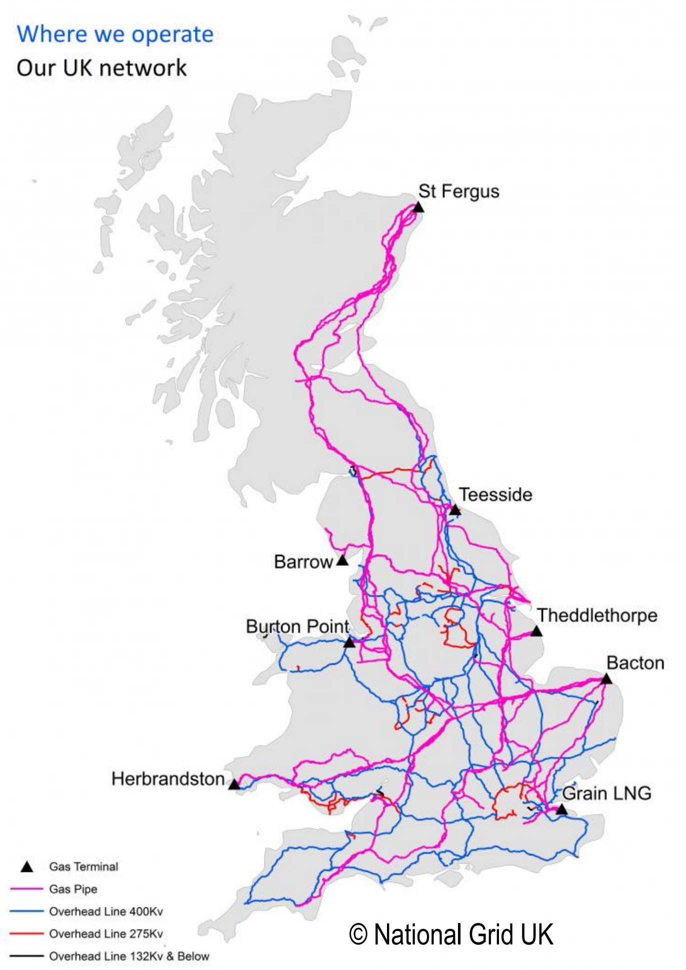
Hydrogen gas networks



UK national gas transmission network
Length more than 300.000 km

- Using pipelines is the ideal way to transport large quantities of hydrogen, e.g. for industrial consumers in the chemical industry or gas turbine power plants, or to serve as a seasonal energy storage facility
- Length of the UK natural gas network **> 300,000 km**
- Conversion of existing pipeline sections to hydrogen makes particular economic sense
- UK has plans to replace natural gas in the gas network with a 20% hydrogen riched blend of hydrogen/natural gas in 2020s

The role of measurement in achieving net zero emissions?

Hydrogen in the gas grid (domestic gas metering):

- Many UK projects investigating hydrogen in heating applications:
  - H21, H100, HyDeploy, Hy4Heat …. and more

- Fluid property implications when replacing natural gas with hydrogen
  - Decreasing calorific value 40 MJ/m^3 vs. 12.7 MJ/m^3
  - Volume flow rates will need to increase 6 → 20 m^3/hr
  - Existing flow meters over-ranged
  - Possible measurement errors
  - Increased wear/failure of mechanical meters

4 Normal operating conditions

4.1 Flow range

The values of maximum flow rates and those corresponding values of the upper limits of the minimum flow rates shall be those given in Table 1.

Table 1 — Flow range

Q_{max} m³/h	Upper limits of Q_{min} m³/h
2,5	0,016
4	0,025
6	0,040
10	0,060

Ref: BS EN 14236:2018 – Ultrasonic domestic gas meters

The role of measurement in achieving net zero emissions?

Hydrogen in the gas grid (domestic gas metering):

- Fluid property implications when replacing natural gas with hydrogen
- Lowest Gas Density, 8X lower than CH_4
  - ρN_2 = 1.2 kg/m^3
  - ρCH_4 = 0.66 kg/m^3
  - ρH_2 = 0.08 kg/m^3
- High speed of sound, 3X higher than CH_4
  - cN_2 = 349 m/s
  - cCH_4 = 445 m/s
  - cH_2 = 1304 m/s
- Low viscosity, 1.25X lower than CH_4
  - μN_2 = 0.018 cP
  - μCH_4 = 0.011 cP
  - μH_2 = 0.009 cP

A.2 Test gas properties

The physical properties of a gas which can change due to variations in gas composition and which are most likely to influence the performance of ultrasonic domestic gas meters are:

Speed of sound range:	min.:	Air
	max.:	100 % CH_4 (with the exception of G 222 as defined in EN 437)
Attenuation:	min.:	Air
	max.:	94 % CH_4, 6 % CO_2 (100 % CH_4 has 3 dB lower attenuation and this level of CO_2 would not be tolerated in a distributed gas)
Viscosity:	min.:	70 % CH_4, 30 % C_2H_6 (100 % CH_4 is within 3 % of the same viscosity and will exercise this parameter sufficiently)
	max.:	Air
Density:	min.:	89 % CH_4, 11 % H_2 (100 % CH_4 is sufficiently close i.e. within 10 % to exercise this parameter)
	max.:	Air

Ref: BS EN 14236:2018 – Ultrasonic domestic gas meters

Hydrogen Domestic Gas Meter Facility

- The facility opened in March 2021
- Flow rates up to 50 m^3/h, 20 – 1500 mbar(g)
- H_2, CH_4, N_2, or mixtures of any two in any ratio
- Measurement uncertainties
  - N_2 : 0.2% (k = 2)
  - H_2 : 0.3% (k = 2)
- Uncertainties will be further reduced, currently building a new hydrogen primary standard

- First job was a test programme to support the UK HyDeploy project, led by Progressive energy and Cadent Your Gas Network
  – 26 flow meters tested with 100% CH_4 and 80% CH_4 - 20% H_2 mixtures
- Now being used for meter manufacturer R&D, and EMPIR research projects NewGasMet MetHyInfra

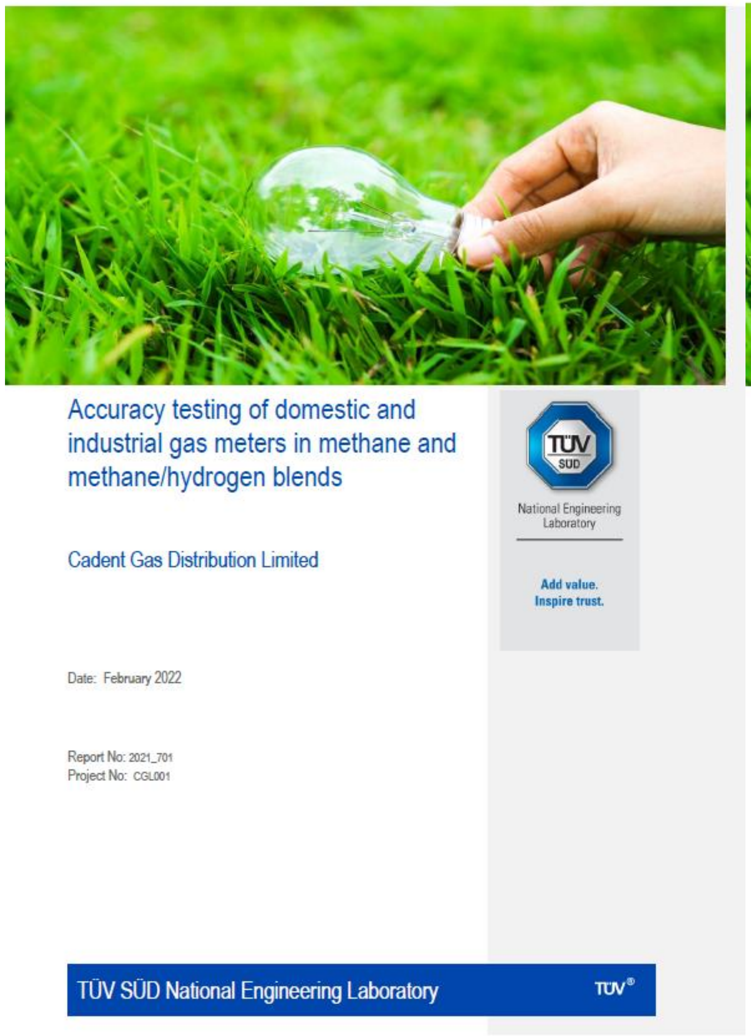
Recent completed projects

HyDeploy Test Programme

- Test programme of 26 domestic and light industrial flow meters
- Thermal mass, ultrasonic, diaphragm, rotary, turbine, Coriolis
- Tested with pure methane and 20% H_2

Fluid properties/measurement uncertainty study

- Effect of 20% H_2 blend on flow measurement uncertainty of orifice plate
- Determination of fluid properties uncertainty from available equations of state
- Propagation through flow measurement uncertainty budget


Accuracy testing of domestic and industrial gas meters in methane and methane/hydrogen blends

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Cadent Gas Distribution Limited

Date: February 2022

Report No: 2021_701
Project No: CGL001

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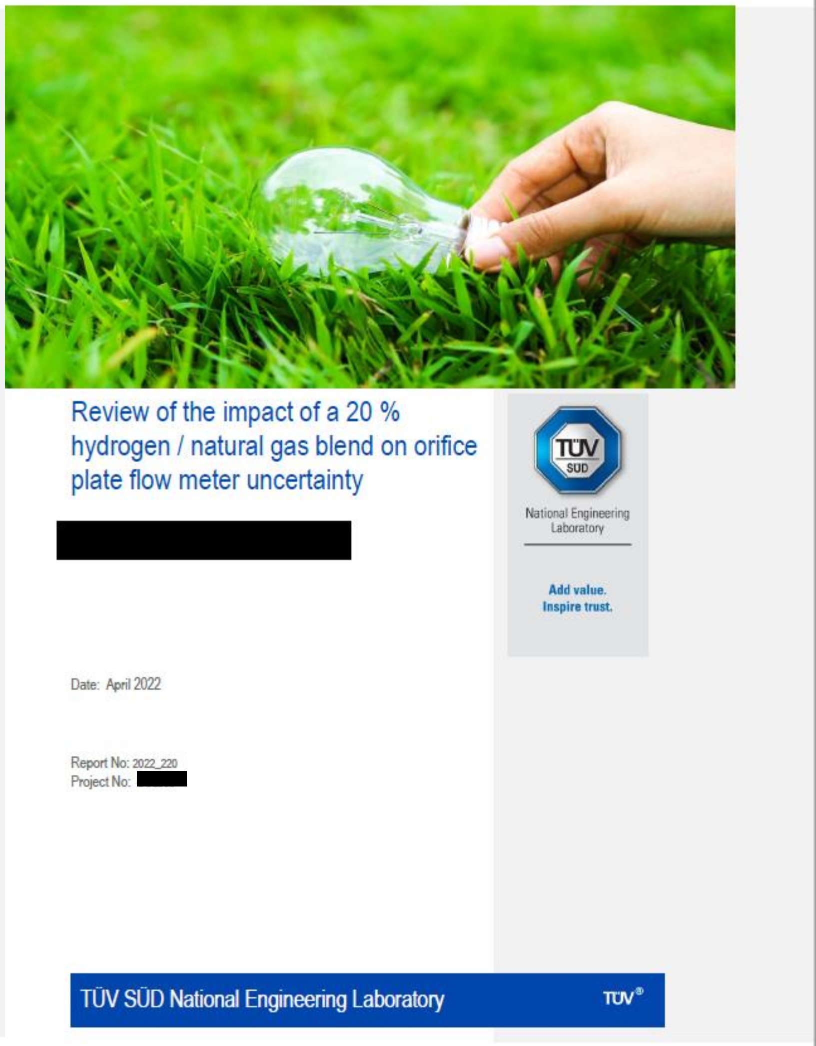
Review of the impact of a 20 % hydrogen / natural gas blend on orifice plate flow meter uncertainty

[redacted]

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Date: April 2022

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Project No: [redacted]

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Large scale hydrogen metering

- **One of the main challenges in addition to what mentioned before:**
  – The lack of large-scale test facilities

No data → no knowledge and confidence in the suitability of the meters

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