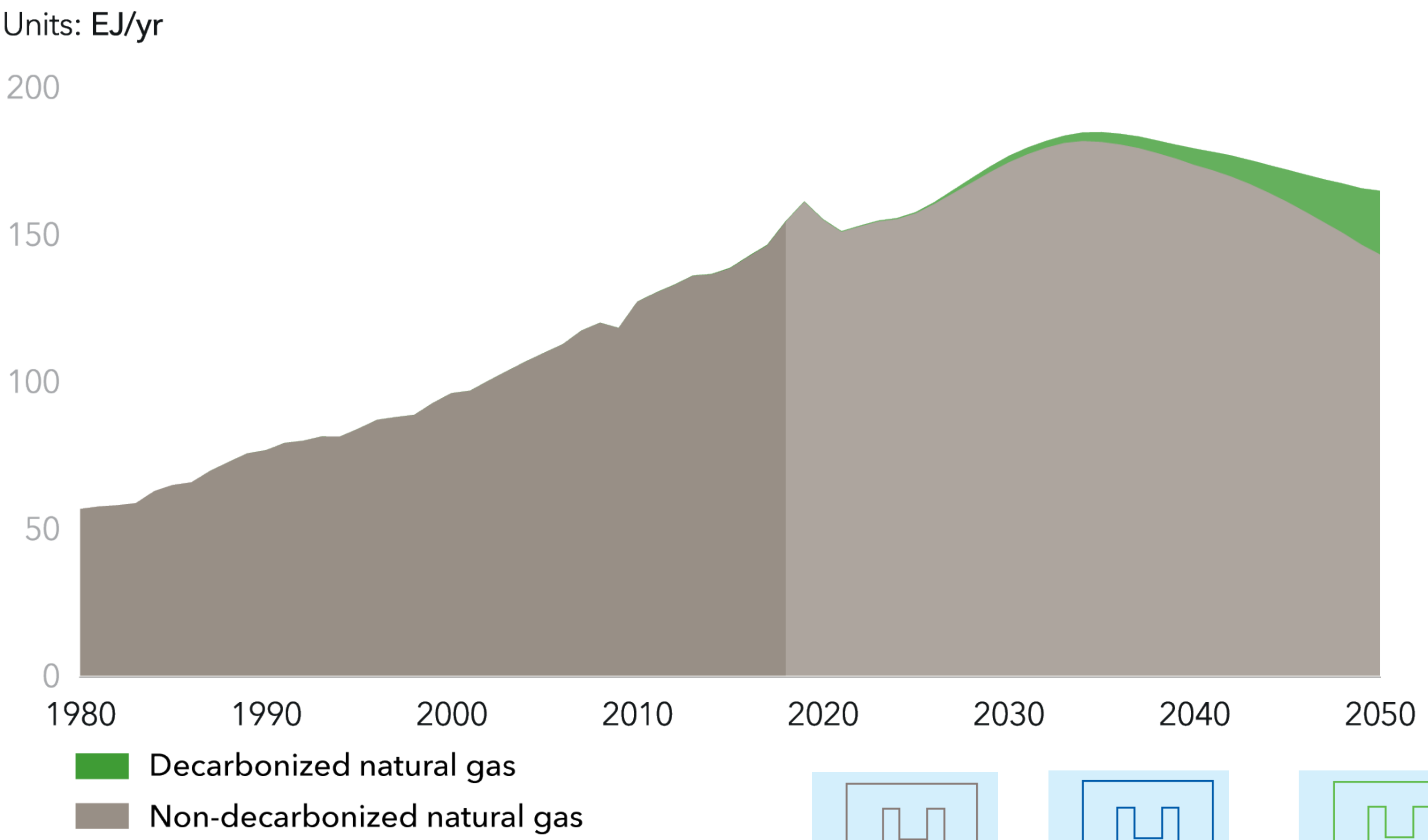
Hoe meet je waterstof?

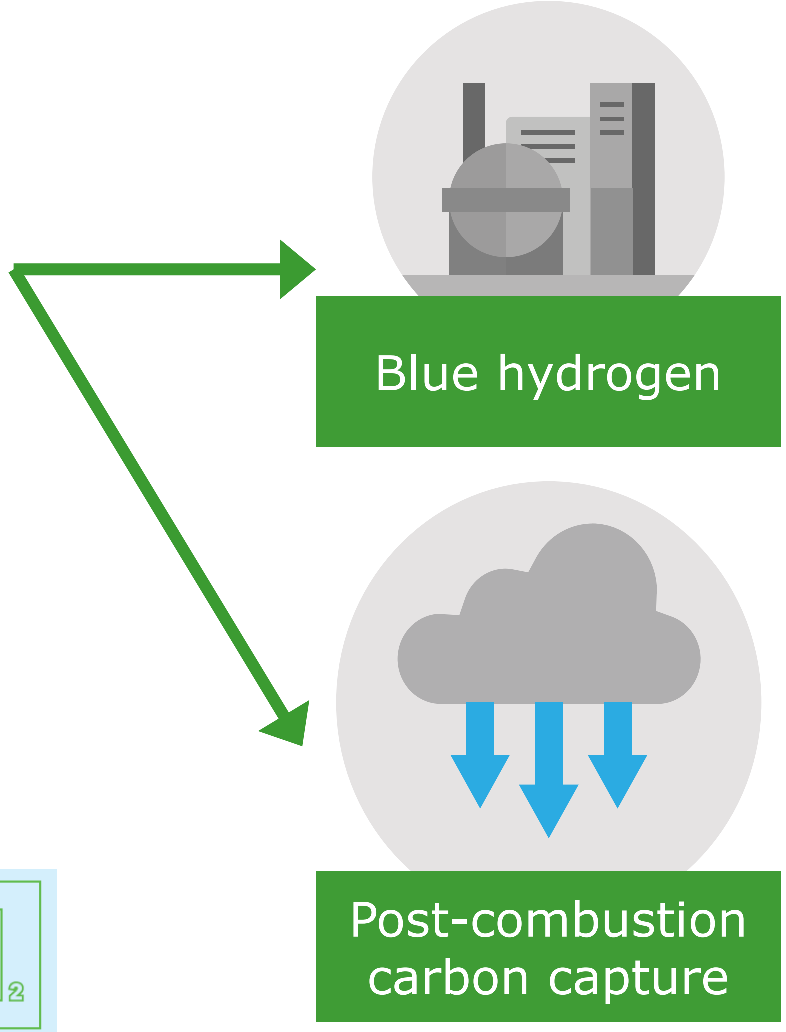
Botlek Studie Groep

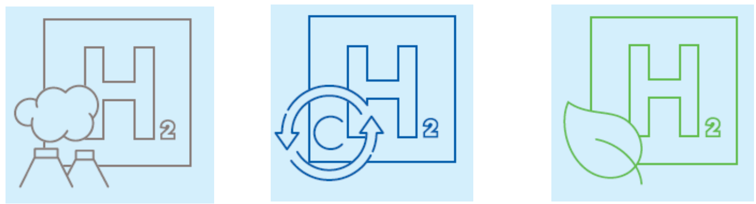
4 February 2021

Content

More needs to be done to decarbonize gas





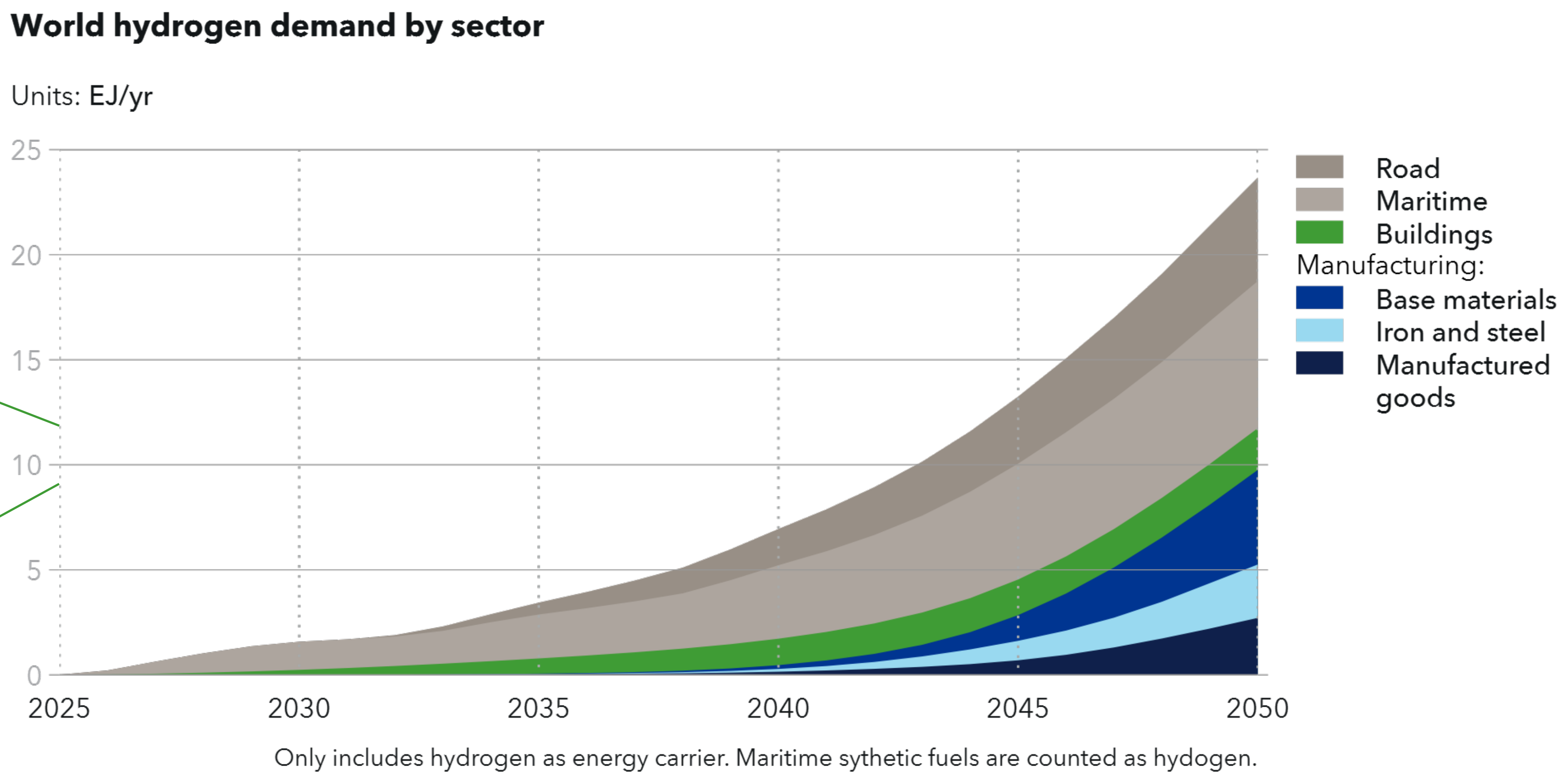


Historical data source: IEA WEB (2019)

Hydrogen could be transformative in the energy transition

12 EJ = 100m tonnes of hydrogen

Today's hydrogen production for feedstock (~72m tonnes)



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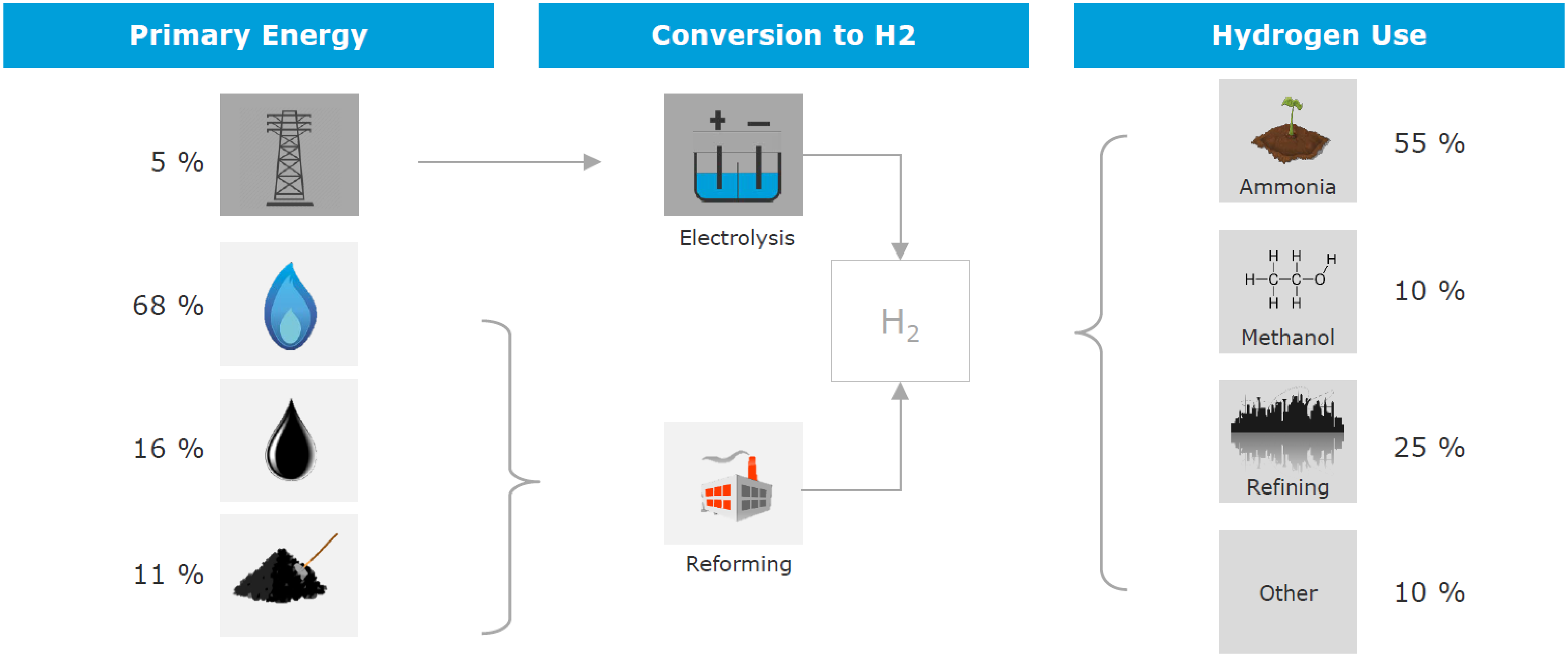
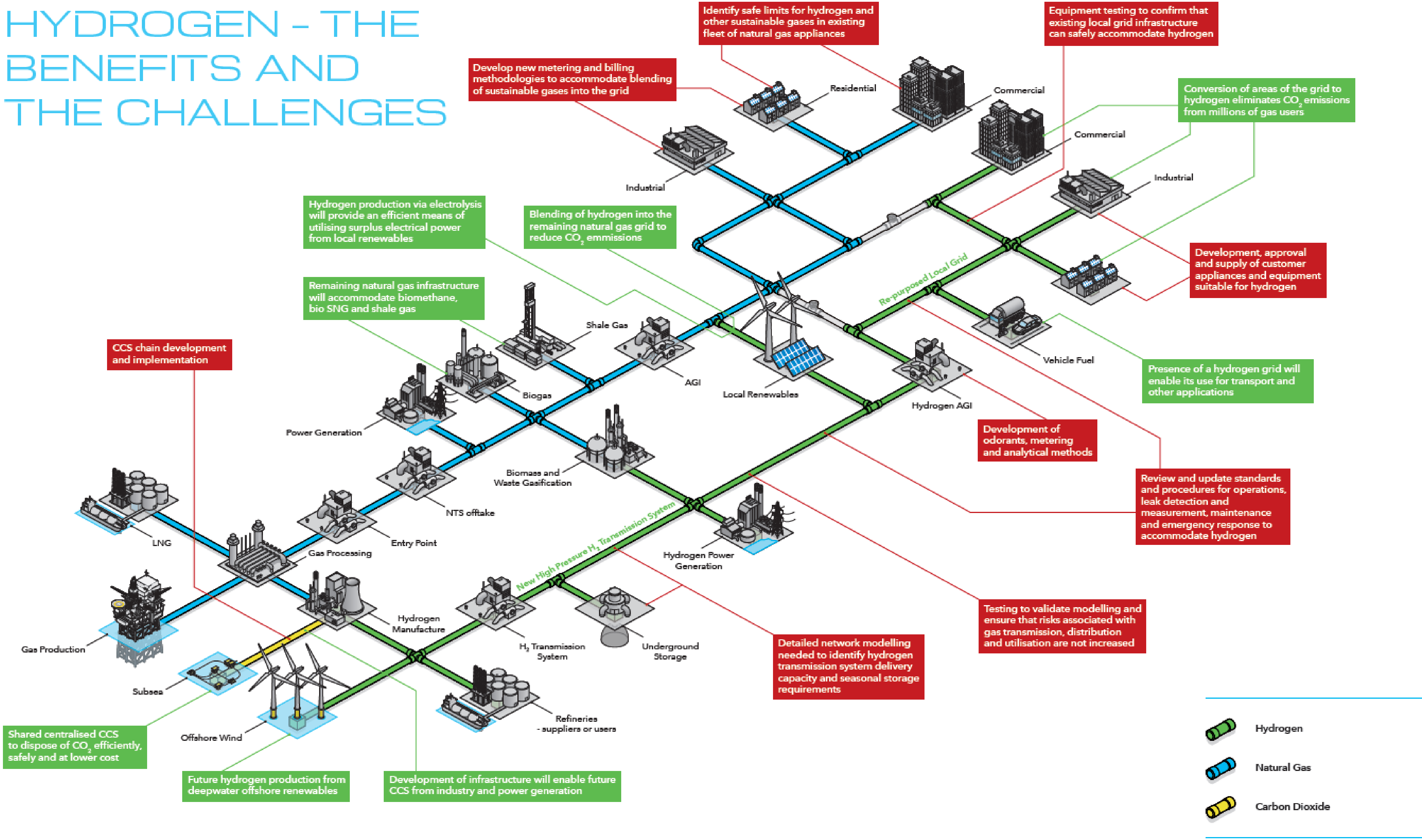
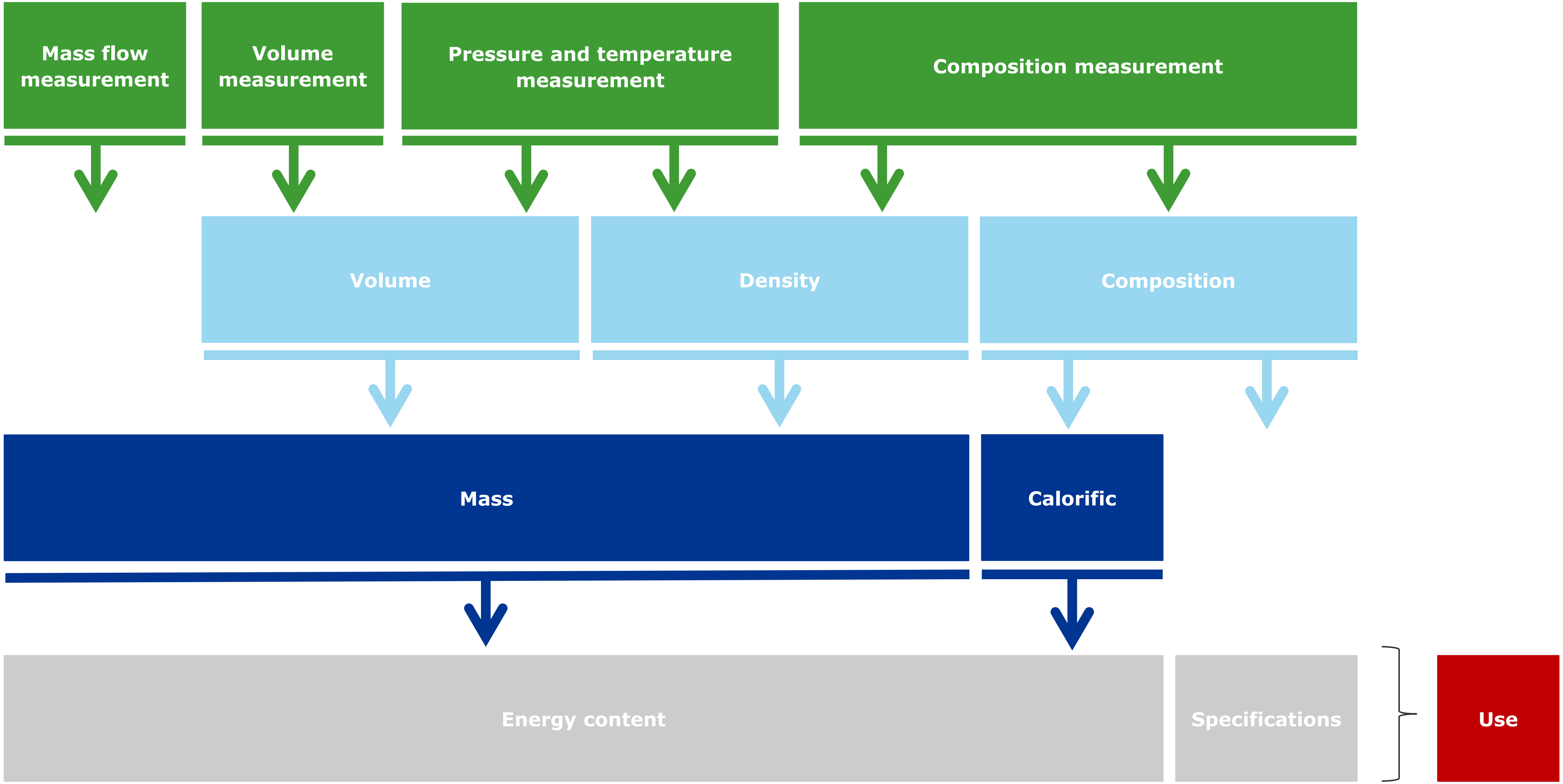
Hydrogen is primarily used as a feedstock



HYDROGEN - THE BENEFITS AND THE CHALLENGES



Determination of the energy content and other specification

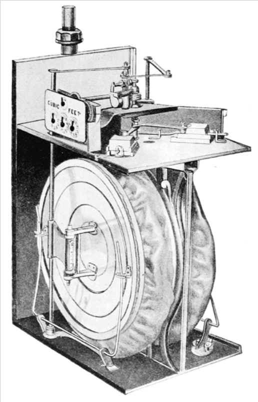


Difference between Natural gas and hydrogen - flow

Characteristic	Natural gas (methane) vs Hydrogen
Nett calorific value (kWh/m³)	≈ 3x HIGHER
Energy density (MJ/m³)	≈ 3x HIGHER
Density (kg/m³)	≈ 9x HIGHER
Explosion limits LEL – UEL (%)	≈ 4X SMALLER range
Speed of sound (m/s)	≈ 3X LOWER
Reynolds (-)	≈ 2x HIGHER
Flow (m/s) at same energy	≈ 3x LOWER

Flow meters – transition to hydrogen from natural gas

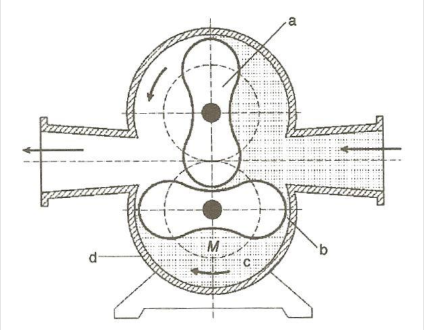
Diaphragm



Source: Wikipedia

- Domestic
- Simple and robust design
- Challenges:
  - internal leakage, ageing effects

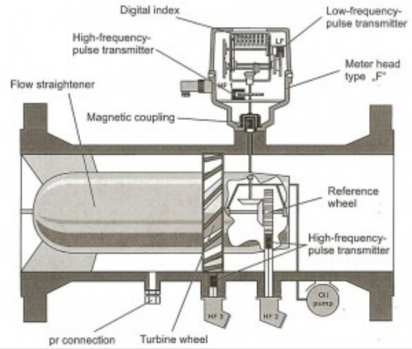
Rotary displacement



Source: www.calibrate.co.uk

- Domestic/industrial
- Challenges:
  - leakage between the impellors

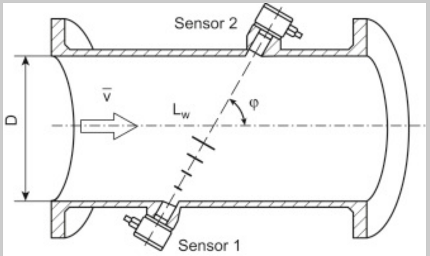
Turbine



Source: www.calibrate.co.uk

- Domestic/industrial
- Challenge:
  - Overspinning
  - Recalibration
  - Straight flow

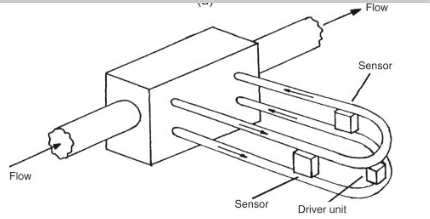
Ultrasonic



Source: Handbook of Natural Gas Transmission and Processing (Fourth Edition)

- Domestic/industrial
- Challenge:
  - Beam blowing
  - Acoustic
  - Flow profile

Coriolis



Source: Measurement and Instrumentation (Second Edition)

- Industrial
- Challenges
  - High pressure drop
  - Pressure effect
  - Density

Understanding the impact of hydrogen on existing flow metering technology

Natural gas will be more and more phased out and replaced by low carbon alternatives. Renewable gases, like hydrogen and biogas have different physical properties. Existing flow meter technology and accuracy has been based on traditional natural gas application; the fitness-for-purpose for use at renewable gases has not been proven yet.

DNV GL launched a joint industry project together with all leading European TSO's and meter manufactures to investigate the effect of natural gas/hydrogen blends on accuracy of existing flow meter technology. Existing technologies and measurement traceability chain are based on traditional natural gas application. The fitness-for-purpose for use at renewable gases has not been proven yet.

The aim of the Joint Industry Project is to evaluate the performance of gas flow metering technologies for renewable gases and develop scaling rules to support the translation of calibration results to other gases.

Lab location	Groningen	Year	2020 – 2021
Client	JIP (European TSO / Global Meter Manufactures)		

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New reference system – sonic nozzle

- sonic nozzles are a constant volumetric flow meter

- Collaboration with PTB for the traceability and transferability (including calibration tests in Braunschweig).

- Setup:
  - 1 sets of 5 sonic nozzles (16, 40, 100, 250, 500 m^3/h)
  - plus a set of two lines Turbine Flow meters and two Coriolis meters
  - DAQ system for up to 16 (Namur pulse) flow inputs and 36 (4-20 mA) P,T inputs

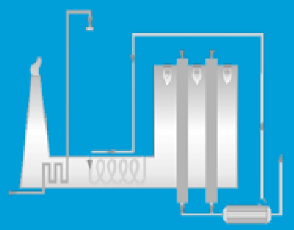
Difference between Natural gas and hydrogen - quality

Characteristic	Natural gas (methane) vs Hydrogen
Thermal conductivity (W/(m·K))	≈ 6x LOWER
Effective diameter (nm)	≈ 2x HIGHER
Molecular weight (g/mol)	≈ 8x HIGHER
Heat capacity (J/K)	≈ 7x LOWER

Hydrogen purity vs. applications

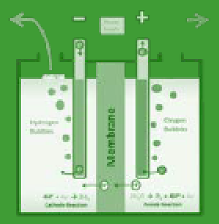
Output hydrogen purity from steam methane reforming

Hydrogen (~97%)



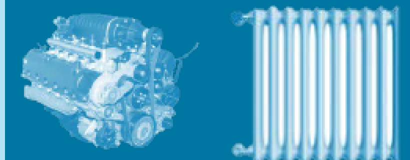
Output hydrogen purity from water electrolysis

Hydrogen (~99,9%)



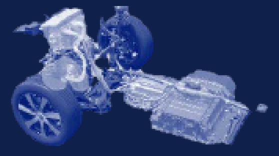
Input hydrogen purity requirement for hydrogen internal combustion engines

Hydrogen (~97%)



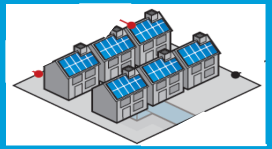
Input hydrogen purity requirement for hydrogen fuel cells

Hydrogen (~99,99%)



Input hydrogen purity requirement for H_2/ natural gas blend used for example in domestic appliances

Hydrogen (0 - ??... %)



Specified maximum impurity concentrations for G-gas (see MR gaskwaliteit), internal combustion, PEM fuel cell applications (see EN-ISO 14867)

		G-gas delivery	Grade A	Types I & II Grade D	Type I Grade E Cat.1, 2 & 3	Type I Grade E Cat. 2	Type I Grade E Cat. 3
Hydrogen	H		98 mol%				
Water	H_2O	≤ -8°C	Non-condensing at ambient conditions	5 µmol/mol	Non-condensing at ambient conditions	Non-condensing at ambient conditions	Non-condensing at ambient conditions
Total hydrocarbons as CH_4	C_xH_y	< 5 mol% PE	100 µmol/mol	2 µmol/mol	10 µmol/mol	2 µmol/mol	2 µmol/mol
Oxygen	O_2	0,5%		5 µmol/mol	200 µmol/mol	200 µmol/mol	5 µmol/mol
Helium	He			300 µmol/mol	400,000 µmol/mol	400,000 µmol/mol	1,000 µmol/mol
Argon	Ar			100 µmol/mol	400,000 µmol/mol	400,000 µmol/mol	1,000 µmol/mol
Nitrogen	N_2			100 µmol/mol	400,000 µmol/mol	400,000 µmol/mol	1,000 µmol/mol
Carbon dioxide	CO_2	10,3% (8-3)	1 µmol/mol	2 µmol/mol			2 µmol/mol
Carbon monoxide	CO	2900 mg/m³		0.2 µmol/mol	10 µmol/mol	10 µmol/mol	0.2 µmol/mol
Total sulphur compounds	S	5.5 mg S/m³(n) (20)	2 µmol/mol	0.004 µmol/mol	0.004 µmol/mol	0.004 µmol/mol	0.004 µmol/mol
Tetrahydrothiophene (THT)	C_4H_8S	10 – 40 mg THT/m³(n)					
Formaldehyde	HCHO	-		0.01 µmol/mol	0.01 µmol/mol	0.01 µmol/mol	0.01 µmol/mol
Formic Acid	HCOOH	-		0.2 µmol/mol	12 µmol/mol	0.2 µmol/mol	0.2 µmol/mol
Ammonia	NH_3	-		0.1 µmol/mol	0.1 µmol/mol	0.1 µmol/mol	0.1 µmol/mol
Total halogenated comp.		-		0.05 µmol/mol	0.05 µmol/mol	0.05 µmol/mol	0.05 µmol/mol
Silicium	Si	0,1 mg Si/m³(n)					
Particulate concentration		100 mg/m³(n)		1 mg/kg	1 mg/kg	1 mg/kg µmol/mol	1 mg/kg

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Measurement techniques Natural Gas vs Hydrogen

		G-gas delivery	Grade D & E
Hydrogen	H	-	GC-TCD
Water	H_2O	TD-LAS	TD-LAS (OPCEAS)
Methane / Total hydrocarbons as CH_4	C_xH_y	GC-TCD (FID)	GC-FID
Oxygen	O_2		GC-TCD
Helium	He	GC-TCD	GC-TCD
Argon	Ar	-	GC-TCD
Nitrogen	N_2	GC-TCD	GC-TCD
Carbon dioxide	CO_2	GC-TCD	GC-TCD
Carbon monoxide	CO		GC-PDD
Total sulphur compounds	S	GC-FPD	GC-MS (SIM)
Tetrahydrothiophene (THT)	C_4H_8S	GC-FPD	GC-MS (SIM)
Formaldehyde	HCHO	-	Wet chemical (CRDS)
Formic Acid	HCOOH	-	To be validated
Ammonia	NH_3	-	Wet chemical (CRDS)
Total halogenated compounds		-	Wet chemical (CRDS)
Silicium	Si	GC-MS (SIM)	
Particulate concentration		Isokinetic	Isokinetic

Difference between Natural gas and hydrogen - output

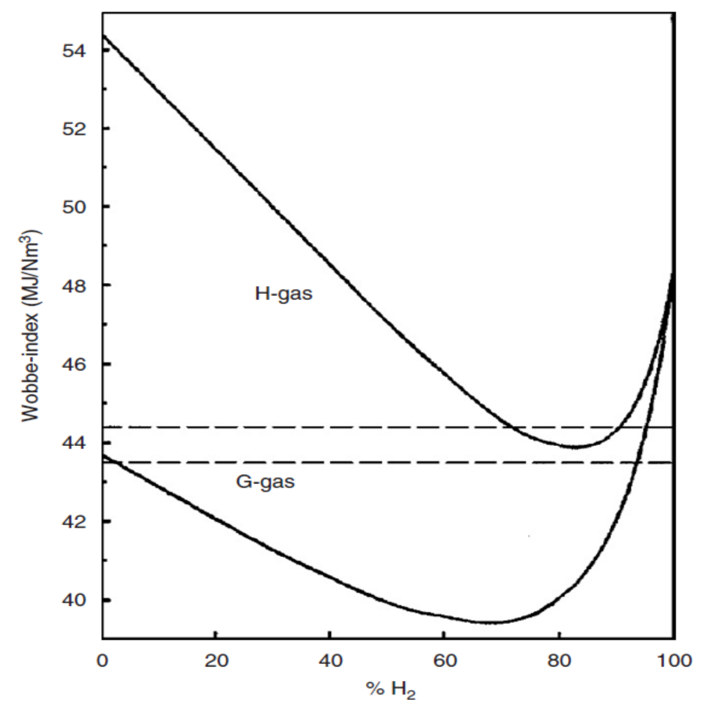
Characteristic	Natural gas (methane) vs Hydrogen
Laminar burning velocity (cm/s)	≈ 5x LOWER
Auto ignition temperature (K)	≈ 45 degree HIGHER
Energy for ignition in air (MJ)	≈ 14.5x HIGHER
Flue gas temperature (m^3/m^3)	≈ 170 degree LOWER
Explosion limits LEL – UEL (%)	≈ 4X SMALLER range
Methane number	≈ 100X Higher
Air to fuel ratio (m^3/m^3)	≈ 4x HIGHER

100% NG

5% hydrogen to NG

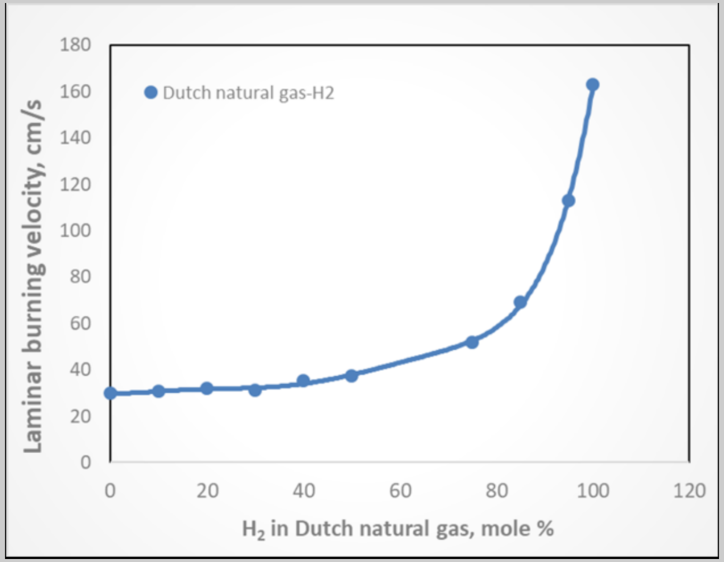
Challenges for appliances when blending hydrogen to gas grid

Wobbe Index



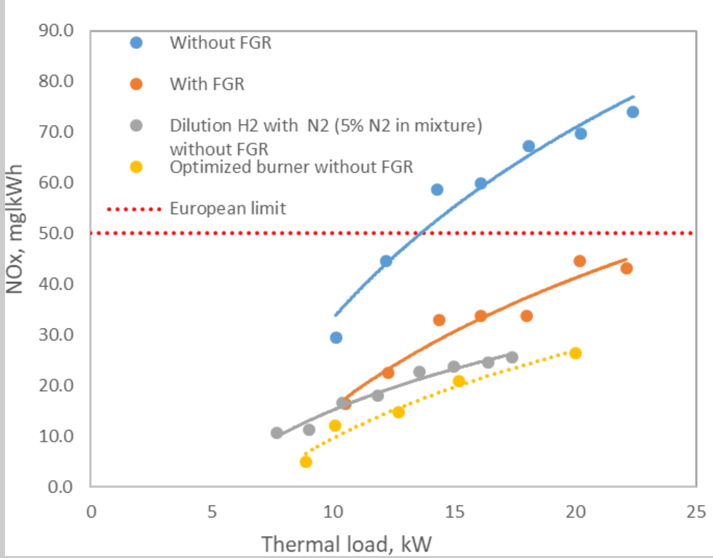
Source: Source: Zachariah JL, et al. Moving towards hydrogen via natural gas: implications for The Netherlands. In: IGRC; 2004.

Burning velocity



Source: DNV GL

NOx



Source: DNV GL

Hydrogen for high temperature industries

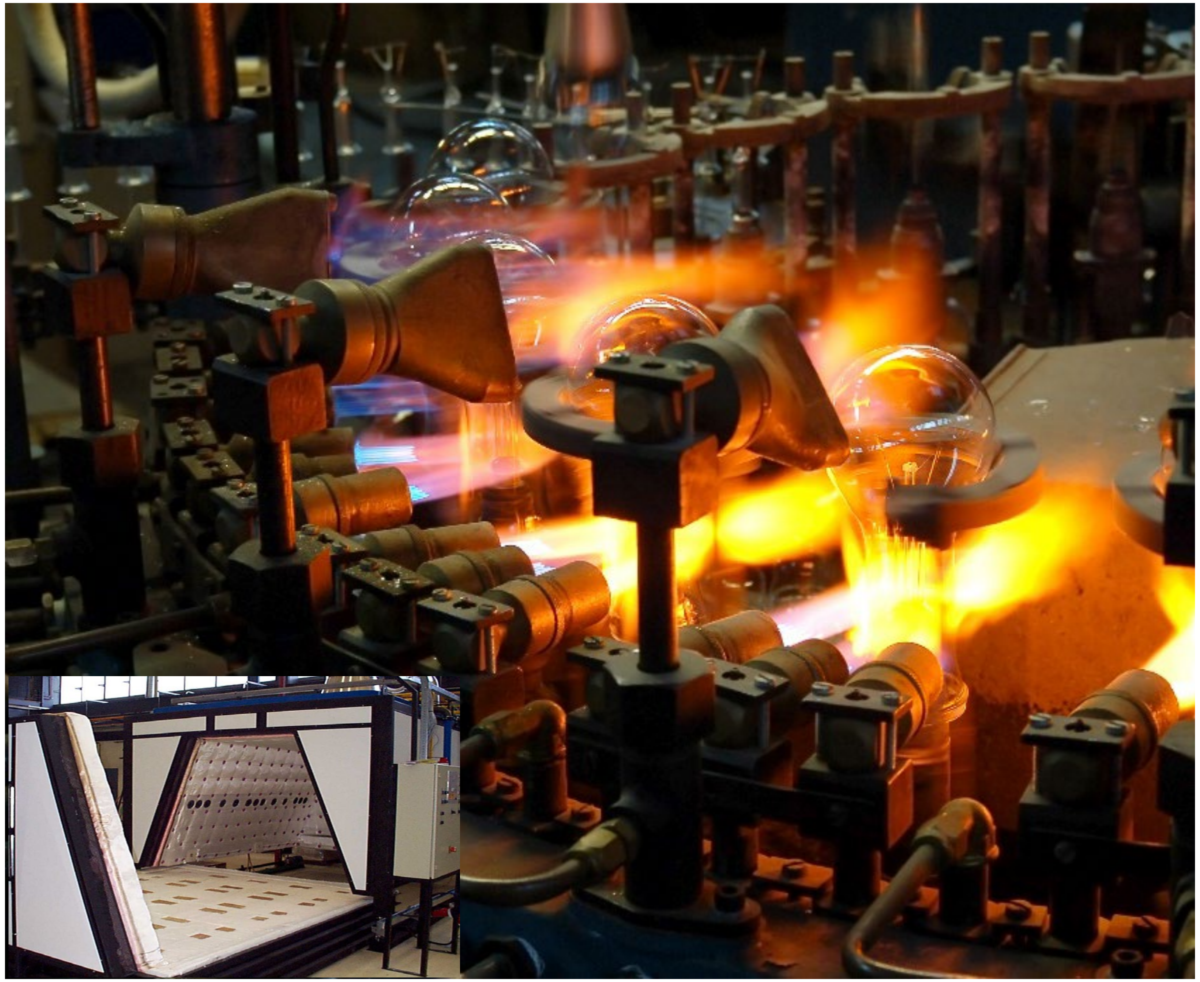
Energy-intensive industrial production processes (e.g. glass, food and ceramic sectors), have a major challenge to decarbonise existing heating processes. A fast and sustainable route to reduce the carbon intensity of these processes is to replace natural gas with hydrogen. However, the technology for this is not yet available.

Under the leadership of Celsian and DNV GL, an international industry consortium has been set up with the aim to develop technology and knowledge for existing industrial heating processes in order to be able to make the gradual transition from natural gas to hydrogen fast and cost-efficiently in the future.

In the first phase of the project experiments are carried out in DNV GL's hydrogen centre. Subsequently, the new technology will be demonstrated in the production process of participating companies.

Lab location	Year
Groningen	2020 - ongoing

Client
Multi Client (35 partners)



De-risking the introduction of alternative fuels for sustainable mobility

Increasing stringent local, national and international environmental legislations demands new solutions for fuels and engine technology for the road and maritime industry.

New, low carbon fuels (biomethane, LNG, Hydrogen , ammonia) reduce global emissions of greenhouse gases, but barriers remain to its widespread adoption. Mismatching fuel quality to a given engine can cause engine knock, reduced performance and even engine shutdown as possible consequences.

DNV GL fuel transition centre is home to a flexible combination of specialized fuel labs and engine test facilities. By combining advanced testing with technical expertise, we support customers in a wide range of areas: characterizing the impact of fuel quality on engine performance (knock, pollutant emissions), defining standards for fuel suppliers and assessing the properties of new lubricants all necessary for the introduction of alternative new fuels for a sustainable mobility

Lab location
Groningen

Year
2015 - ongoing

Client
Multi Client(Fuel Suppliers, TSO’s, Engine Manufacturers)

Hydrogen fired industrial oil furnace

Large scale demo at industrial site in North of the Netherlands

NedMag mines magnesium salt and produces magnesium hydroxide

Demo (starting mid 2020)

- 2 MW burner for oil furnace
- Fuelled by natural gas and hydrogen blends
- Fuel Adaptive Control System for wide range of fuel compositions

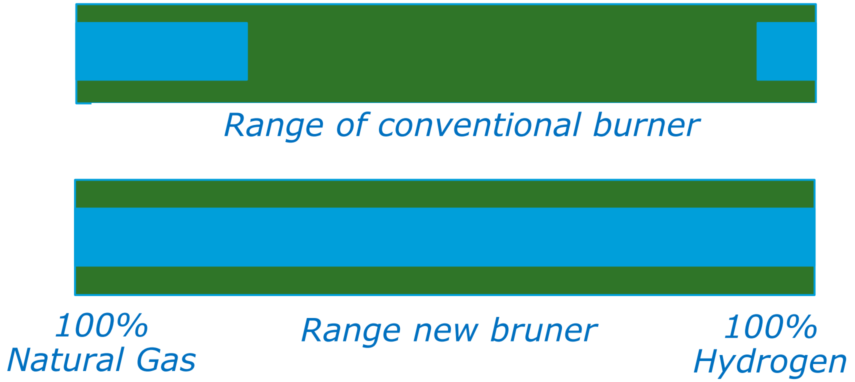
Low cost and fast track solution

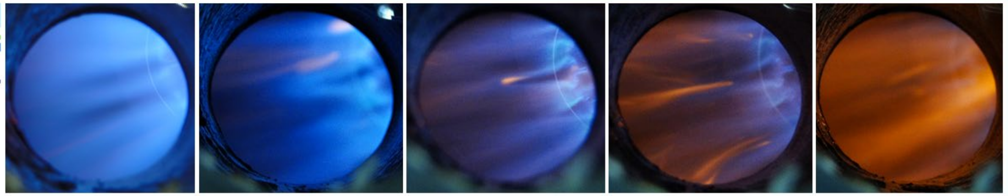
Security of supply

Optimal Combustion:

- High Efficiency
- Low emission
- Constant product quality

Lab location	Veendam	Year	2020 - ongoing
Client	Multi Client(Nedmag, Lamtec)		





Natural Gas	100%	40%	10%	5%	0%
Hydrogen	0%	60%	90%	95%	100%

René Bahlmann
Rene.Bahlmann@dnvgl.com
+316 15 95 97 03

www.dnvgl.com

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