Hydrogen Measurement

Craig Lam- Account Manager
John Calame– Market Product Manager – Analyzers
SICK USA

Agenda

Hydrogen Primer

Hydrogen Value Chain

Production, Transformation, Transportation, Storage

Four Hydrogen Measurement Technologies

Q & A

WGMSC
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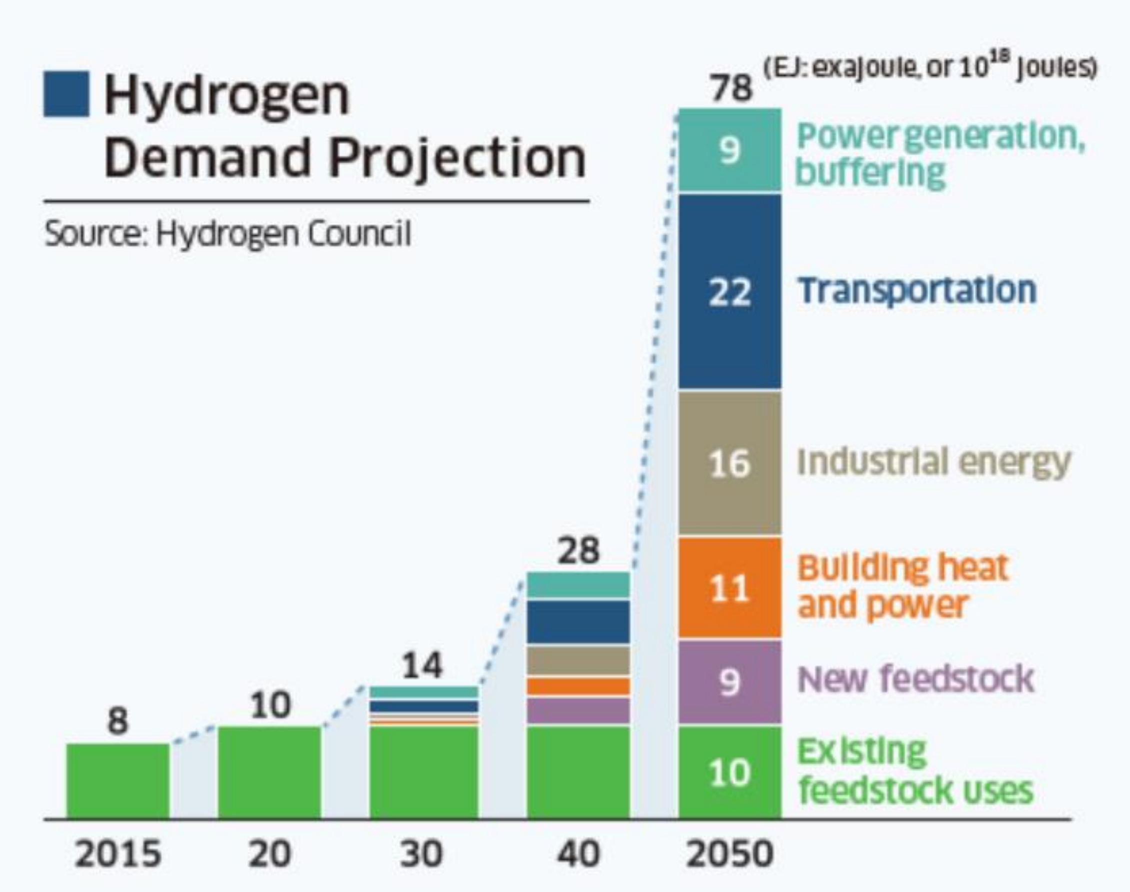
2024

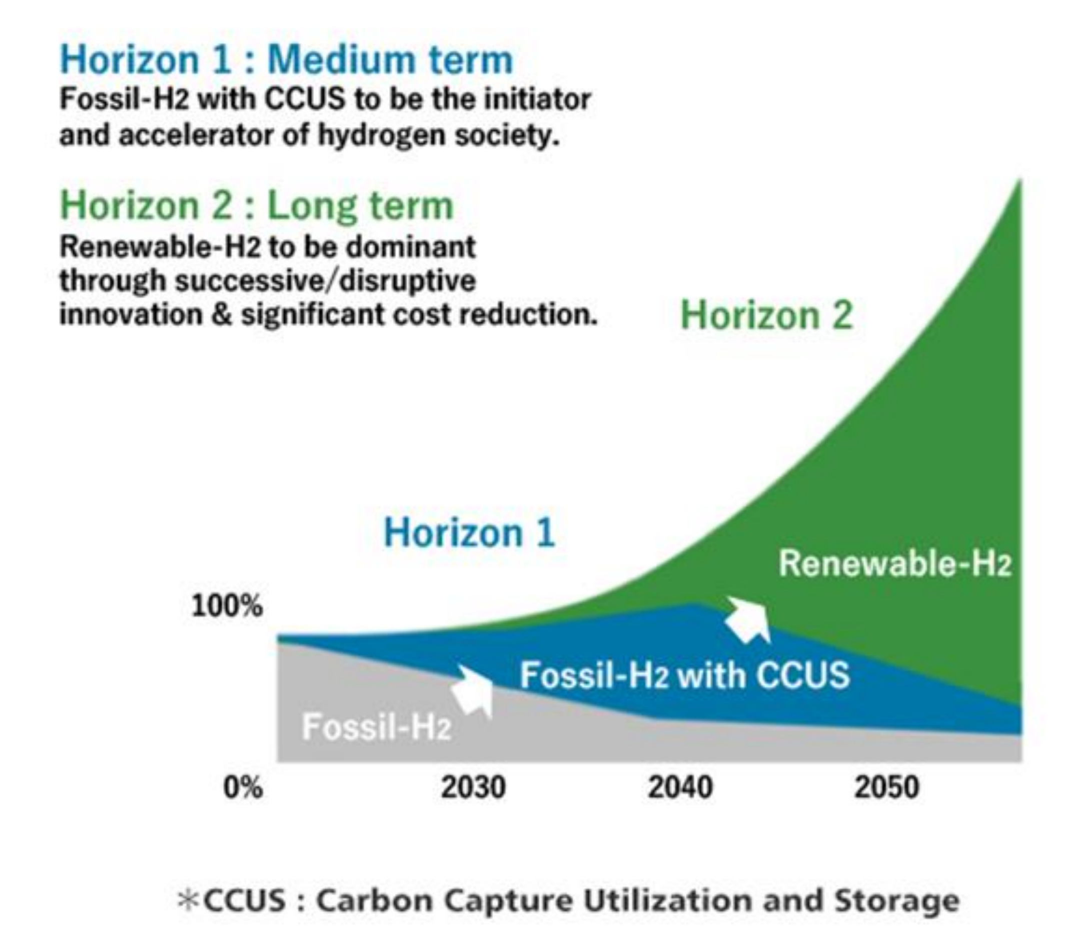
Hydrogen as major contributor to energy transition

Colors of Hydrogen

Green	Water electrolysis process by employing renewable electricity from wind / solar
Blue	Steam Methane Reforming or Auto Thermal Reforming of natural gas. CO_2 is captured and used or stored sequestered (CCUS)
Turquoise	Thermal splitting of methane via methane pyrolysis Experimental process that produces solid carbon
Gray	Steam Methane Reforming of natural gas. CO_2 is produced and eventually released to the atmosphere
Brown/Black	Coal gasification (lignite – Brown, Bitumious – Black). CO_2 and carbon monoxide are produced as by-products and released to the atmosphere.
Purple	Nuclear power and heat through combined chemical/thermal electrolysis splitting of water.
Pink	Electrolysis of water by using electricity from a nuclear power plant.
Red	High-temperature catalytic splitting of water using nuclear power
White	Naturally occurring hydrogen.

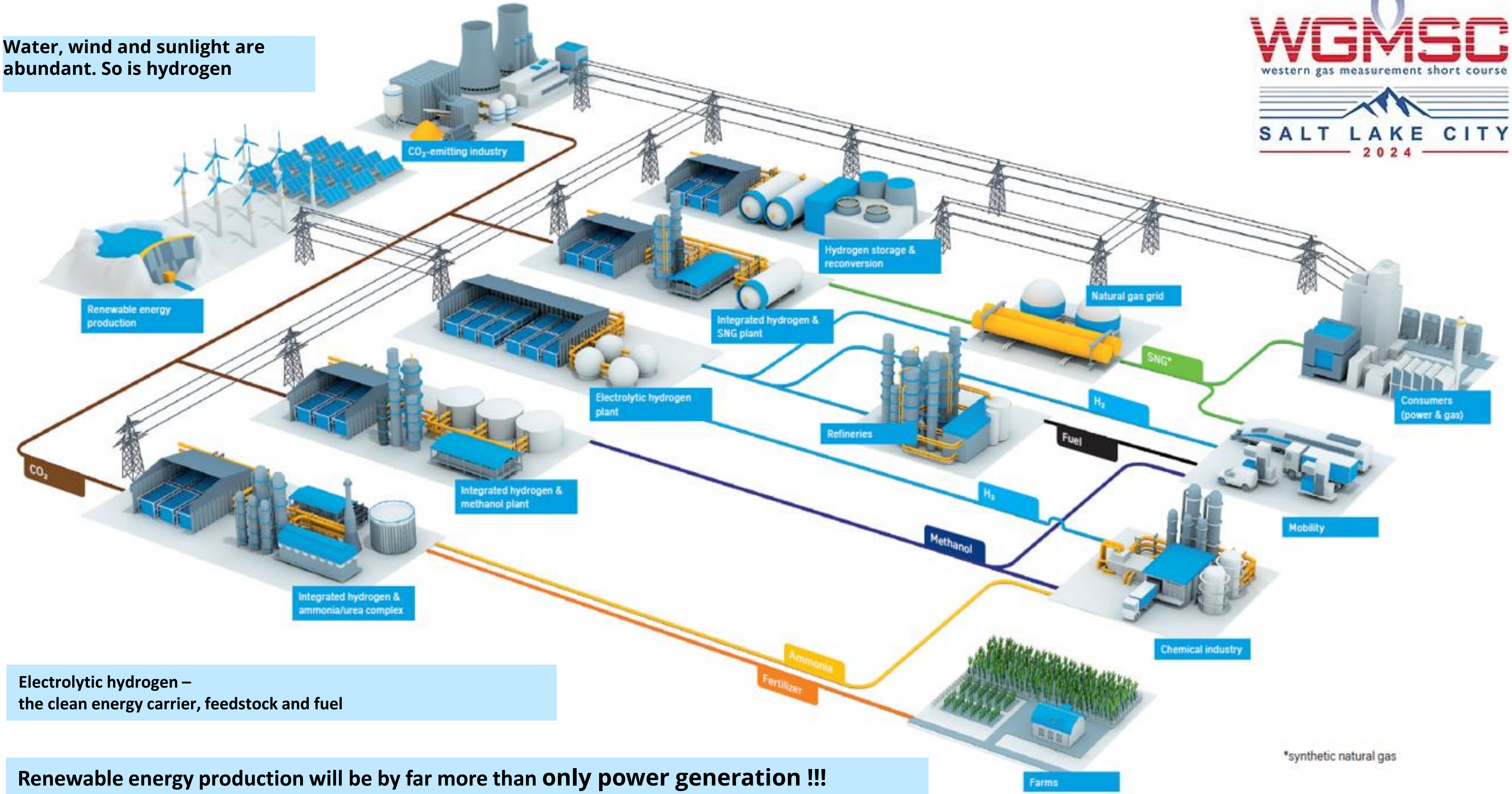
Hydrogen – Origin and Availability





- Actual Prediction: 2050 only 8% of Energy demand out of Hydrogen

Water, wind and sunlight are abundant. So is hydrogen



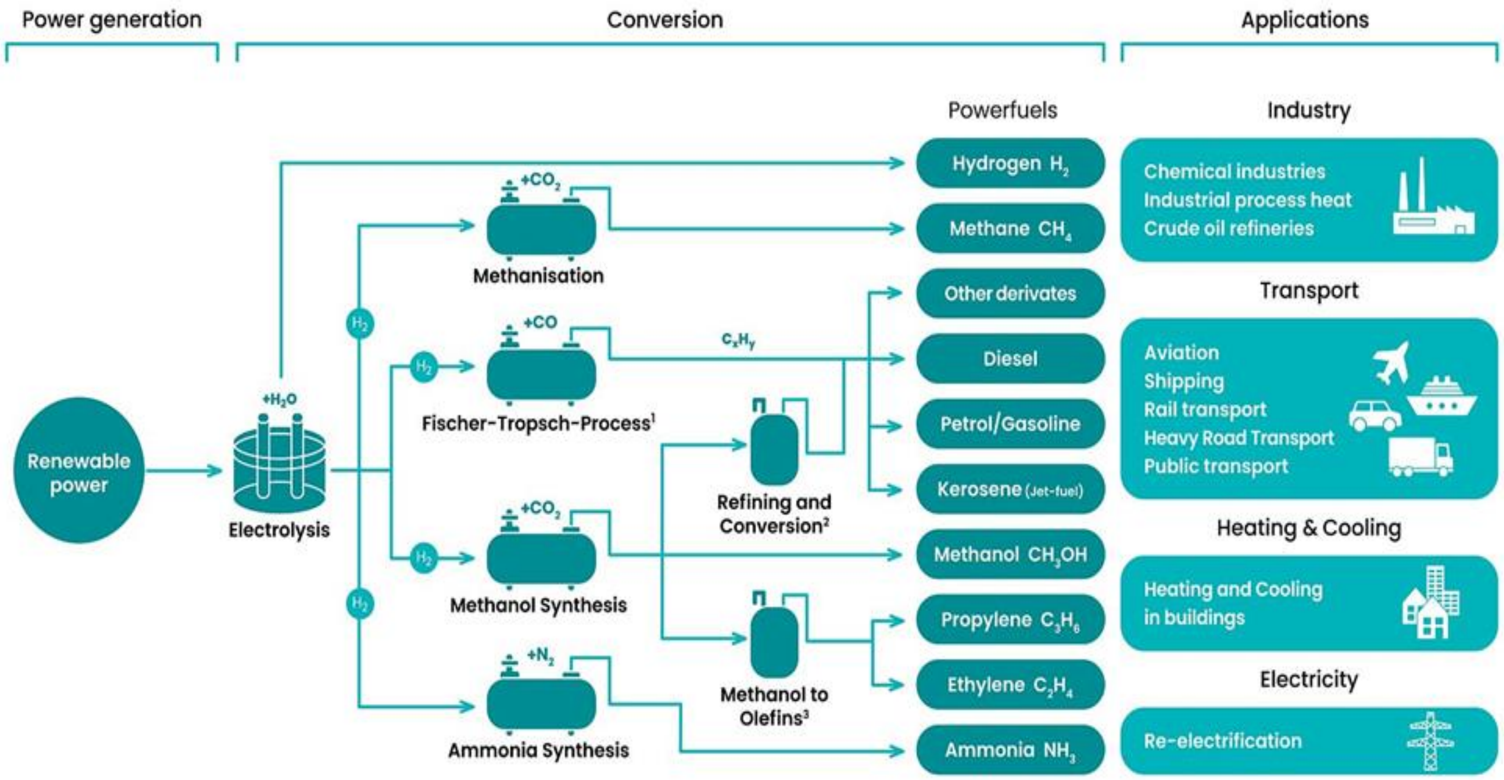
Electrolytic hydrogen –
the clean energy carrier, feedstock and fuel

Renewable energy production will be by far more than only power generation !!!

Source: ThyssenKrupp

Hydrogen

Value Chain



1. Includes: Fischer-Tropsch synthesis, hydrocracking, isomerization and distillation.
2. Includes: DME/OME synthesis, olefin synthesis, oligomerisation and hydrotrating.
3. Methanol-to-olefins process.

Hydrogen

Clean Energy

western gas measurement short course
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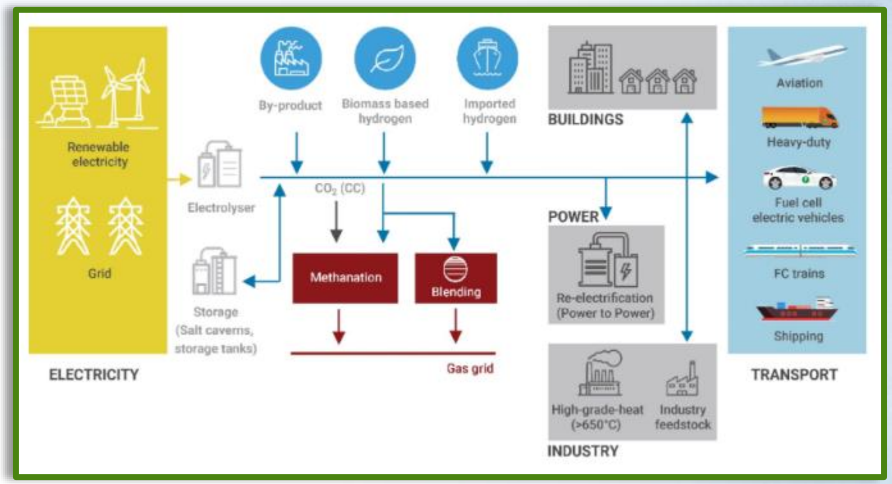
- ***Hydrogen is an energy carrier and can be storage medium***
- Hydrogen can be produced from
  - Fossil fuels
  - Biomass
  - Solar, Wind, Nuclear, Hydroelectric
- Hydrogen use is dominant in industries like oil refining, ammonia production, methanol production and steel production
- Transportation is another market for hydrogen using fuel cells
- It can be transported as gas by pipelines or in liquid (-252 C) form by ships
- There have been many false starts in the past **but this time it *could* be different**

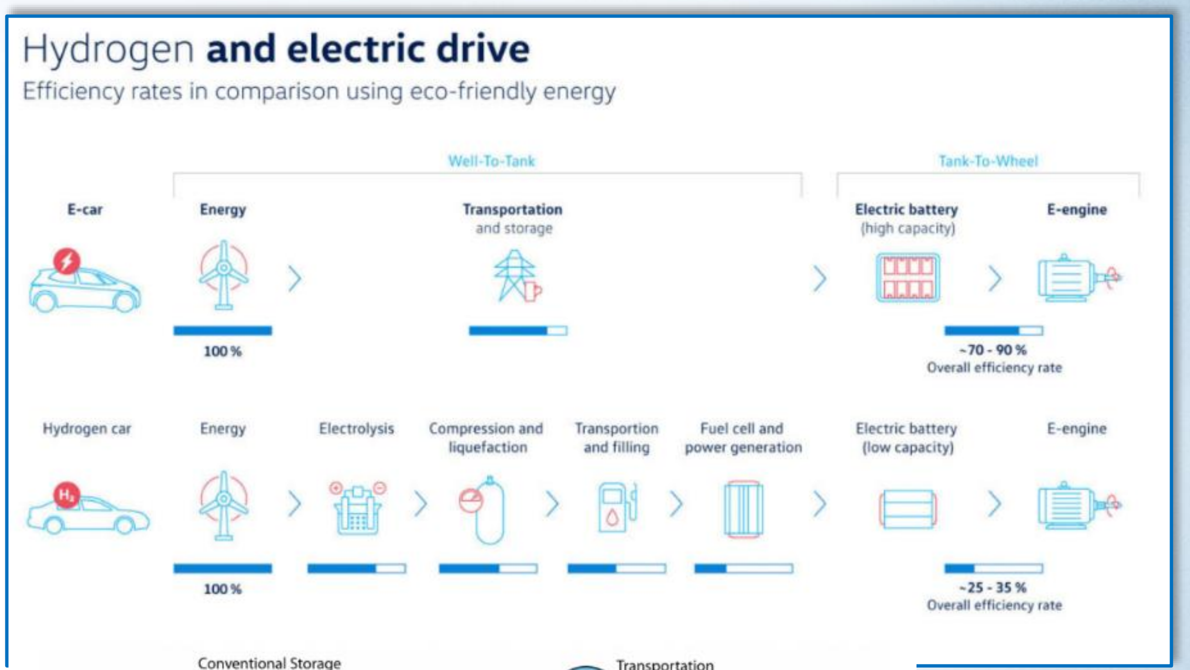


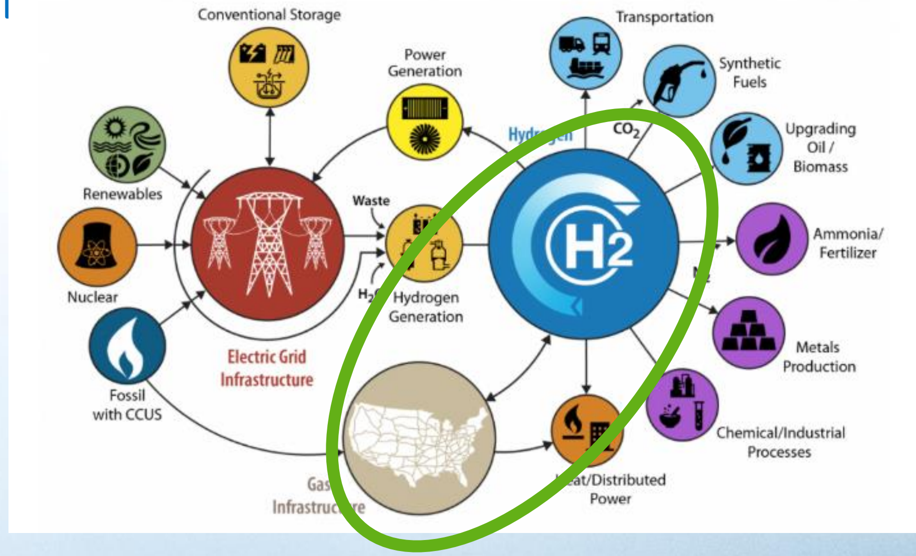
Hydrogen production processes

Clean Energy for transportation

Hydrogen & Fuel Cells

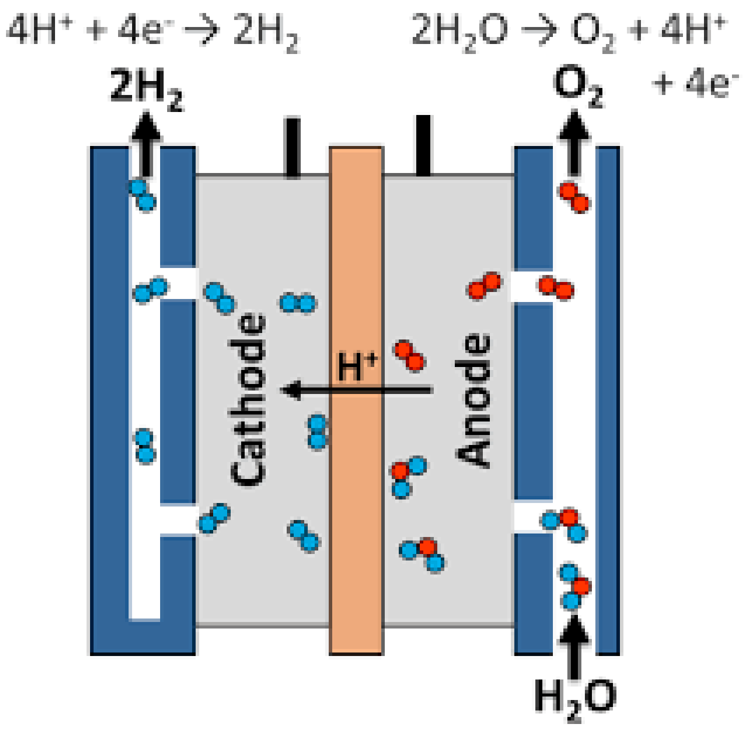
- Fuel cell uses chemical energy of hydrogen (or another fuel) to cleanly and efficiently produce electricity
- Fuel cells work like batteries but do not run down or need recharging
- Renewable sources are source for hydrogen
- Hydrogen has about 3 time more energy content by weight than conventional fuels





Hydrogen

Production-Electrolyzer



Hydrogen Analysis Technology

Thermal Conductivity

Thermal conductivity uses thermally sensitive metals such as tungsten and platinum

When Hydrogen is present it absorbs some of the heat from the active bead

The amount of heat loss is proportional to the concentration

Applications: Hydrogen Purity or a binary Gas mixture

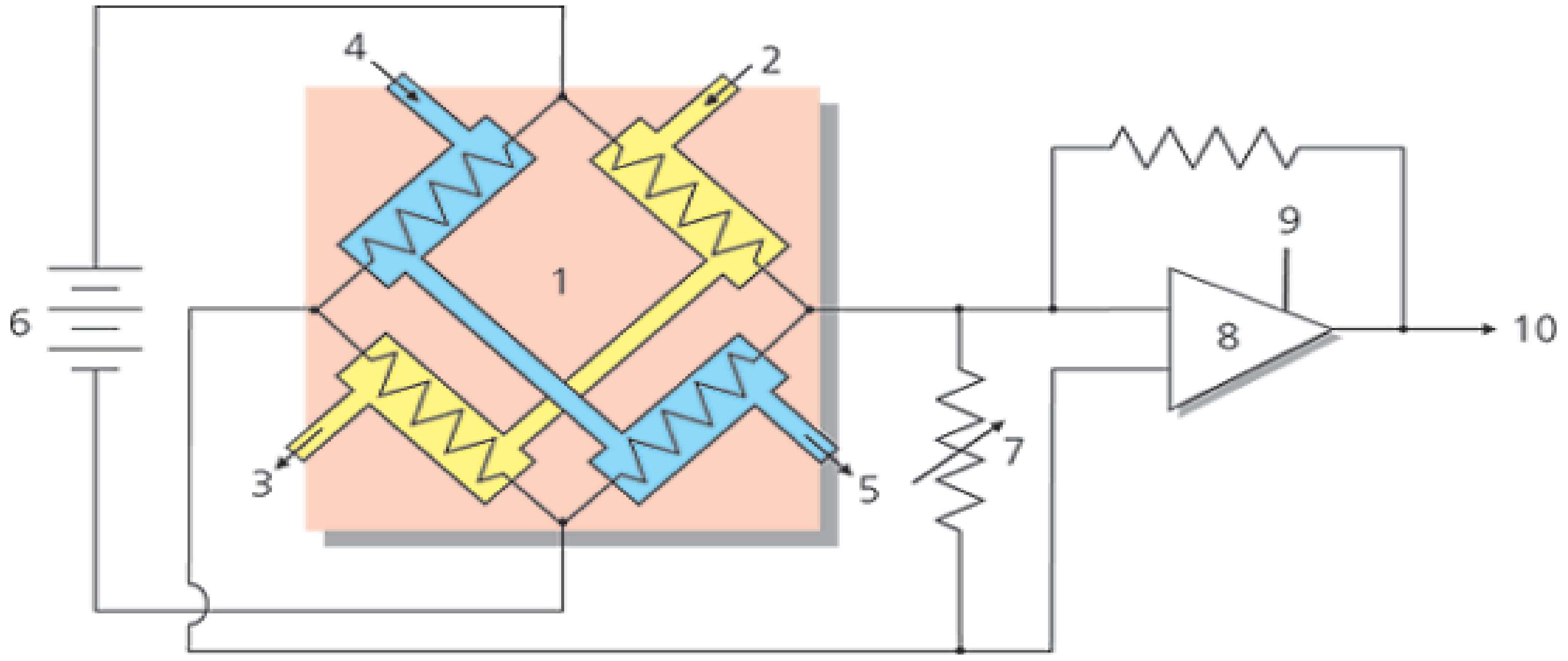
Advantages: No Consumables, sensitive with fast response time

Disadvantages: If more than one other gas is present in a Hydrogen stream other analyzers are required to speciate and compensate for heat loss due to other gases present. This increases the cost and complexity of the system

Hydrogen Analysis Technology

Thermal Conductivity

Figure 2: Schematic diagram of thermal conductivity detector block and electronics.
1 = TCD block, 2 = sample gas inlet from column, 3 = sample gas outlet,
4 = reference gas inlet, 5 = reference gas outlet, 6 = power supply for filaments,
7 = bridge balance adjustment, 8 = amplifier, 9 = amplifier offset adjustment,
10 = output to A/D converter and signal processing.



Hydrogen Analysis

Thermal Conductivity

Hydrogen Analysis Technology

MOS Pd/Ni (Palladium Nickel) & MOS Capacitor

A MOS sensor consists of a heating resistor and a sensitive resistor which is consists of a thin metal oxide layer deposited on a heating element which heats the assembly to its operating temperature.

Hydrogen atoms diffuse into the bulk of the thin film.

Applications: Purity, Leak detection, blending, process, ambient

Advantages: Wide range from ppm to 100% concentration, no consumables, highly selectable to H2, solid- state long life sensor

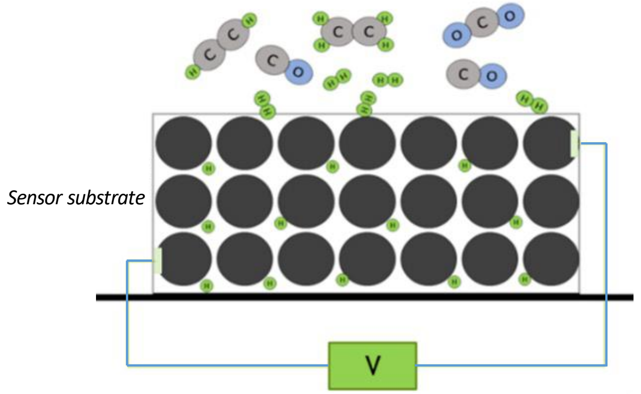
Disadvantages: may require a sample conditioning system for some process and pipeline applications

Hydrogen Analysis Technology

MOS Solid State Sensor

- Continuous, **real-time** measurement
- **Hydrogen specific MEMS sensor**: only affected by hydrogen
- Measures the **partial pressure** of hydrogen at the analyzer
- **Not consumed** and does not wear out
- Easily handles **complex**, **varying** gas streams
- **No preventive maintenance** or reference gases required
- Autocalibration to normalize drift and maintain accuracy

HOW IT WORKS



Sensor bulk thin film resistance changes linearly as a function of H2 concentration as it is continuously adsorbed and desorbed from the proprietary solid-state substrate

MOS Solid State Sensor

Examples

Catalytic Combustion Sensor

Catalytic combustion sensors operate at 450 degrees Centigrade. One bead is passivated (no catalyst applied) so it does not react when it comes into contact with H2 molecules. This bead acts a background reference.

The other bead is coated with a catalyst, so it reacts to gas. The bead is placed on a separate leg of wheat stone bridge electrical circuit.

When H2 is present the active bead’s resistance increases while the passivated bead remains unchanged. This alters the balance of the bridge and changes the output voltage.

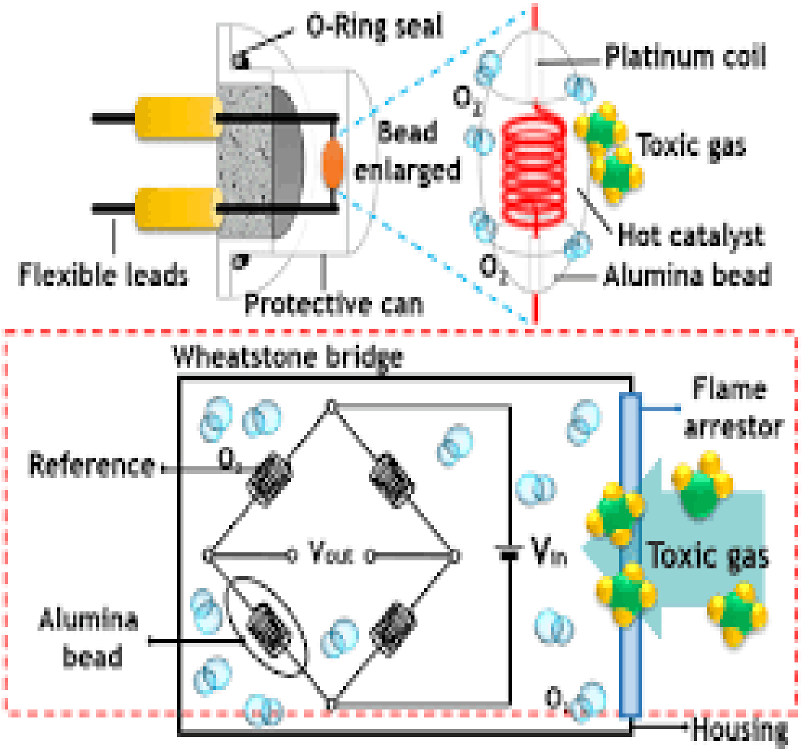
Applications: Area safety monitoring LEL Detection, Fugitive emissions

Advantages: Fast response, no sample system

Disadvantages: Elevated sensor temperature and higher power consumption

Hydrogen Analysis

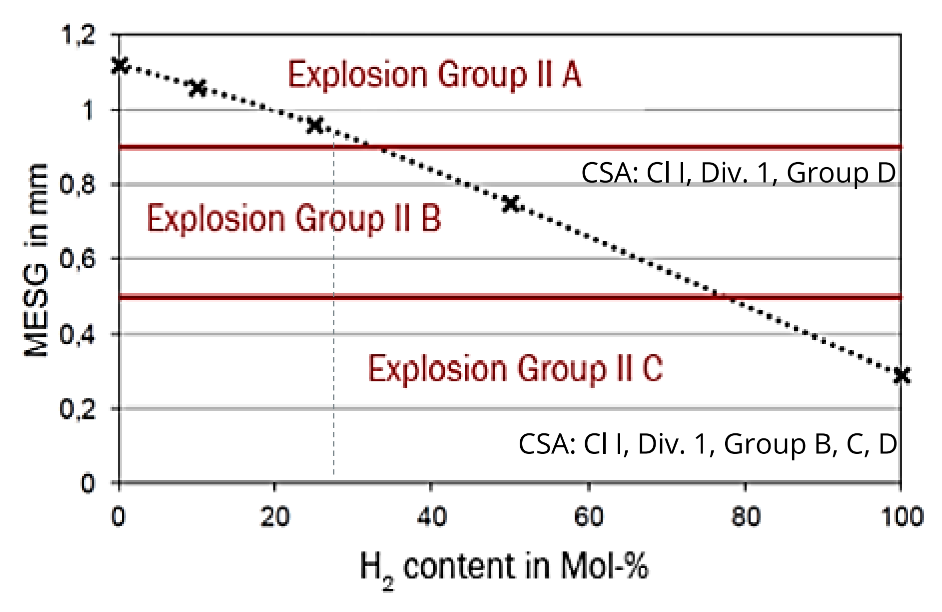
Catalytic Combustion Sensor



H_2 in Natural Gas

Effect of H_2 blending explosion protection

- Explosion pressure changes slightly up to 30% H_2
- >25-30% H_2 explosion group IIB or IIC



Source: BAM: Safety properties of natural gas/hydrogen mixtures, 06/2015

Electrochemical Sensor

Electrochemical hydrogen sensors work on the same principle as fuel cells. They have and anode and cathode separated by thin layer of electrolyte. When hydrogen passes through the electrolyte a reversible chemical reaction takes place that produces and electric current proportional to the concentration hydrogen.

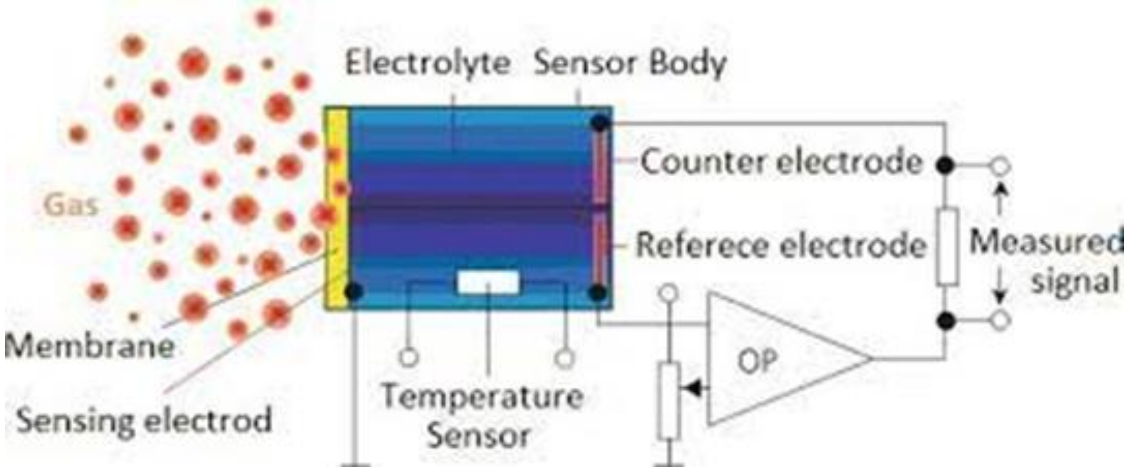
Applications: Hydrogen Concentration in ambient, process or pipelines

Advantages: Relatively low initial cost and power consumption. Sensitive and selective to hydrogen concentration

Disadvantages: Sensor is consumable and requires either replacement or refurbishment at 3–6-month intervals. There is no positive indication of performance. The only way to determine if sensor is working is to challenge it with calibration gas

Hydrogen Analysis Technology

Electrochemical Sensor



Hydrogen Sensor Technologies

Comparison Chart

Feature	Solid State	TCD	Electrochemical	Catalytic
Hydrogen specific	Yes	No	Yes	Yes
Real-time indication	Yes	Yes	Yes	Yes
Cross-Sensitivity	No	Yes	Yes	No
Maintenance Cost	$	$$	$$	$
Installation Cost	$	$	$	$
Field Calibration	No	Yes	Yes	Yes
Gas composition dependence	No	Yes	Yes	Yes
Power Consumption	< 1 W	< 1 W	< 1 W	> 1W

H_2 Blending

Effects on Metering?

Accuracy

Transport

Material

Density

Leakage

Norms & Standards

Explosion Protection

Install Base

H_2 in Natural Gas

H_2 Characteristics

- 8x lighter than natural gas
- 3x higher SOS than natural gas
- 3x lower heating value than natural gas (volume based [kWh/m³])

H_2 in Natural Gas

Effect of H_2 blending explosion protection

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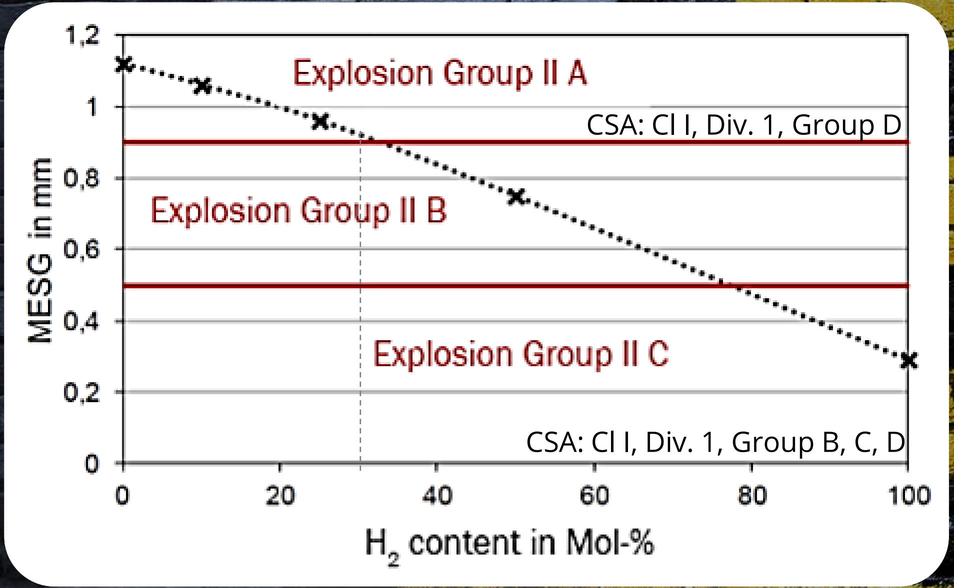


Source: BAM: Safety properties of natural gas/hydrogen mixtures, 06/2015

H_2 in Natural Gas

Effect of H_2 blending on gas meter material

- 30% H_2 blending: no impact on SICK USM used material
  - Meter body: forged and casted material

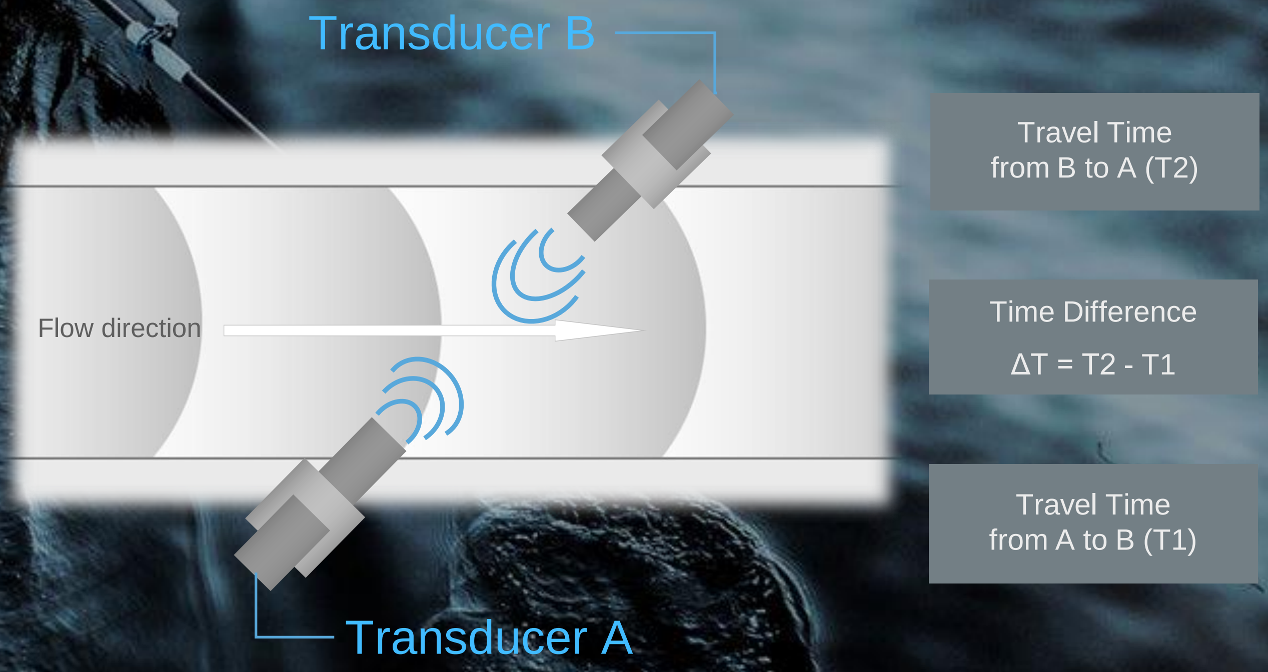
    (e.g., ASTM A350 Gr.LF2, A352 LCC, A182 Gr. F316/316L and Gr. F53)
  - Transducers: titanium
  - Sealings: Viton elastomer
  - Flow conditioner: stainless steel, plastics

Source: BAM: Resilience assessments of metallic container materials and polymeric sealing/coating and lining materials, Berlin, 01/2015

H_2 in Natural Gas

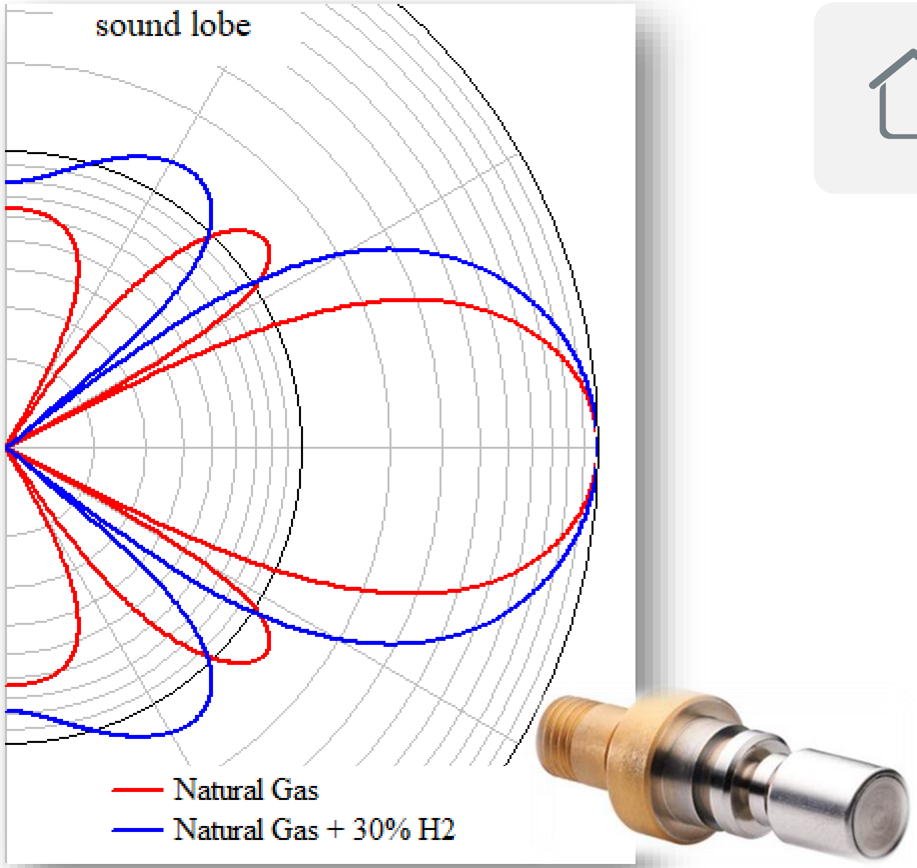
Ultrasonic Measurement Principle

- Transit time base measurement



H_2 in Natural Gas

H_2 Characteristics and USM Influence



- SICK own transducer development
- 30 application optimized transducers

› Acoustics basics

H_2 content ↑	→ Speed of Sound ↑
Speed of Sound ↑	→ Sound lobe ↑
Sound lobe ↑	→ Line size limitation ↑

→ device design accordingly

H_2 in Natural Gas

White Paper - Power To Gas

- Power-To-Gas Whitepaper initially Released in 2019
    - H_2 content in natural gas
    - Fiscal measurement in Mid- and Downstream
    - Based on field experience

SICK AG
WHITE PAPER

FLOWSIC600 / FLOWSIC600-XT
POWER-TO-GAS – Admixture of hydrogen from renewable energies into the natural gas grid and the associated suitability of SICK ultrasonic gas meters

AUTHOR

Daniel Heinig
Strategic Product Manager

SICK Engineering GmbH in Ottendorf-Okrilla/Germany
November 2019

SUMMARY

Gas meters of the FLOWSIC600 and FLOWSIC600-XT families are already suitable today for measuring natural gases containing proportions of hydrogen within the scope transport according to the laws of calibration. The reliability and quality of the measurement results are not ff ected by changes in density, flow velocity or speed of sound.

SICK
Sensor Intelligence.

H_2 in Natural Gas

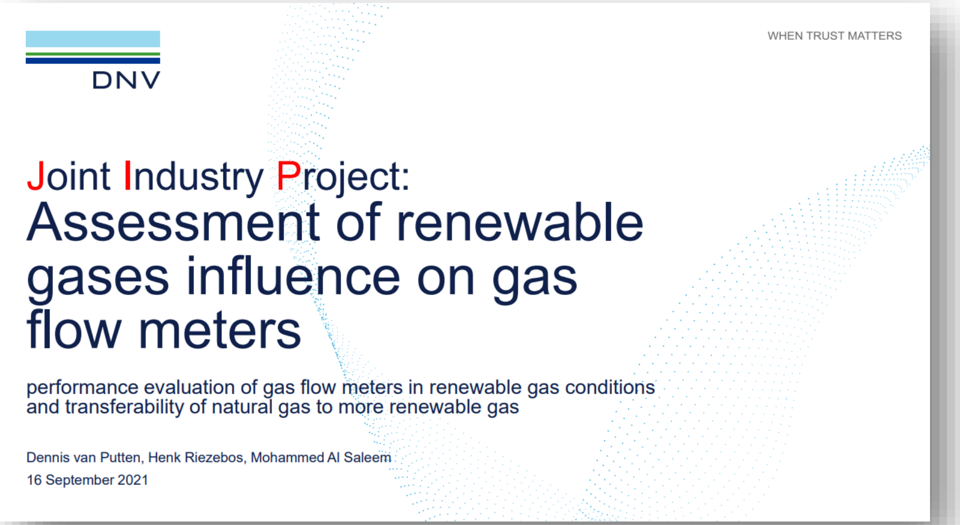
Field Experience

- First installation in 2005
- Pure and mixed gases in process industry

country	product	# of paths	size [mm]	size [inch]	ANSI rating	year of delivery
Germany	FLOWSIC600	4	150	6	900	2005
Netherlands	ALTOSONIC IV	2+2	100	4	900	2007
United States	FLOWSIC600	2	200	8	600	2007
France	FLOWSIC600	1x1	100	4	300	2009
United Kingdom	FLOWSIC600	2	80	3	150	2009
China	FLOWSIC600	2x2	150	6	300	2011
China	FLOWSIC600	2x2	200	8	300	2011
China	FLOWSIC600	2x2	300	12	300	2011
Germany	FLOWSIC600	4	450	18	600	2012
United States	FLOWSIC600	2	200	8	600	2012
Germany	FLOWSIC600	2x2	250	10	300	2013
Germany	FLOWSIC600	2x2	100	4	600	2013
Germany	FLOWSIC600	2	50	2	PN 16	2013
Singapore	FLOWSIC600	1x1	100	4	600	2013
Germany	FLOWSIC600	2x2	100	4	600	2014
Germany	FLOWSIC600	2x2	150	6	PN 40	2014
Germany	FLOWSIC600	2x1	50	2	PN 16	2014
Germany	FLOWSIC600	2x2	100	4	600	2014
Netherlands	FLOWSIC600	1x1	80	3	600	2014
Belgium	FLOWSIC600	1x1	100	4	600	2015
Belgium	FLOWSIC600	2	200	8	600	2015
Germany	FLOWSIC600	1x1	50	2	PN 63	2015
Germany	FLOWSIC600	1x1	50	2	PN 16	2016
France	FLOWSIC600	4	300	12	300	2017
Germany	FLOWSIC600	2x2	150	6	900	2017

H_2 in Natural Gas

Effect of H_2 blending on meter error


DNV

WHEN TRUST MATTERS

Joint Industry Project:
Assessment of renewable gases influence on gas flow meters

performance evaluation of gas flow meters in renewable gas conditions and transferability of natural gas to more renewable gas

Dennis van Putten, Henk Riezebos, Mohammed Al Saleem
16 September 2021

JIP: independent 3rd party project to test renewable gases influence on gas flow meters

- Injection of up to 30% H_2 and CO_2 in natural gas
- 9 meter manufacturers
- 10 end users

H_2 in Natural Gas

SUMMARY MIDSTREAM FLOWSIC600/-XT

SUMMARY

- S6 System: confirmation of installed base: ≤ 0.1% at 10% H_2
- Research H210 system: deviation to base line: ≤ 0.25% at 30% H_2
- Repeatability: ≤ 0.05%
- OIML requirements fulfilled
  (defined in chapter 5.13.5 "different gases")
  - OIML class 1.0 (MID) requirement of MPE ±1.0% fulfilled (Q_t … Q_{max})
  - OIML class 0.5 requirement of MPE ± 0.5% fulfilled (Q_t … Q_{max})
- Market release with MID approval scheduled mid 2022

Source: SICK data evaluation based on DNV JIP, 3rd party test data 05/2021

H_2 in Natural Gas

FLOWSIC500 in pilot application with H_2 blending

FLOWSIC500 - "H_2 injection in gas distribution"

- Installation with excellent comparison data:
  - USM for 100% natural gas measurement
  - Rotary for 100% hydrogen measurement
  - FLOWSIC500 for gas mixture measurement
    - H2 blending from 10…15…20%

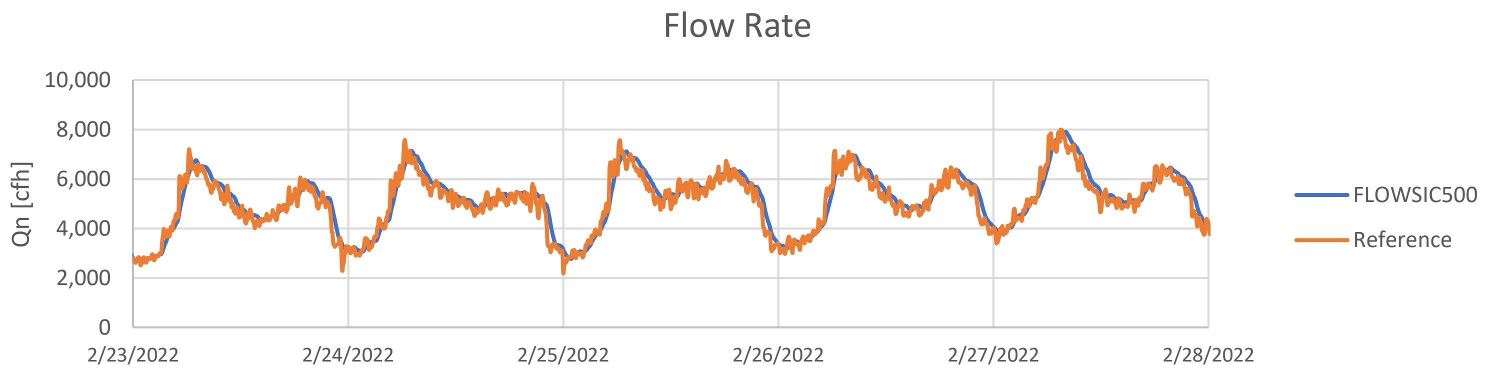
H2READY

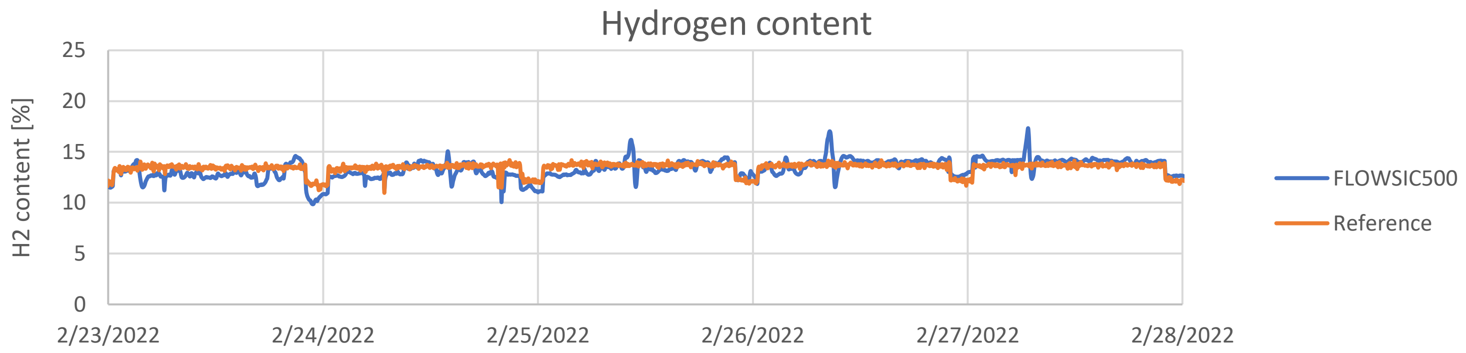
H_2 in Natural Gas

FLOWSIC500 in pilot application with H_2 blending

FLOWSIC500 - “H_2 injection in gas distribution“

› Data Snapshot @ about 15% H2 injection





H_2 in Natural Gas

Test Campaign FLOWSIC500 H2-ready

DVN test facility Netherlands

- 5-day test campaign, ordered by SICK
- Proof of FLOWSIC500 performance, up to 30% H_2
- Generation of data basis for MID approval

- Tests conditions
  - Gas: NG, H_2 (20, 30%)
  - Pressure: 116psi, 232psi

- SICK device: FLOWSIC500 DN100 | 4”

H_2 in Natural Gas

Test Campaign FLOWSIC500 H2-ready

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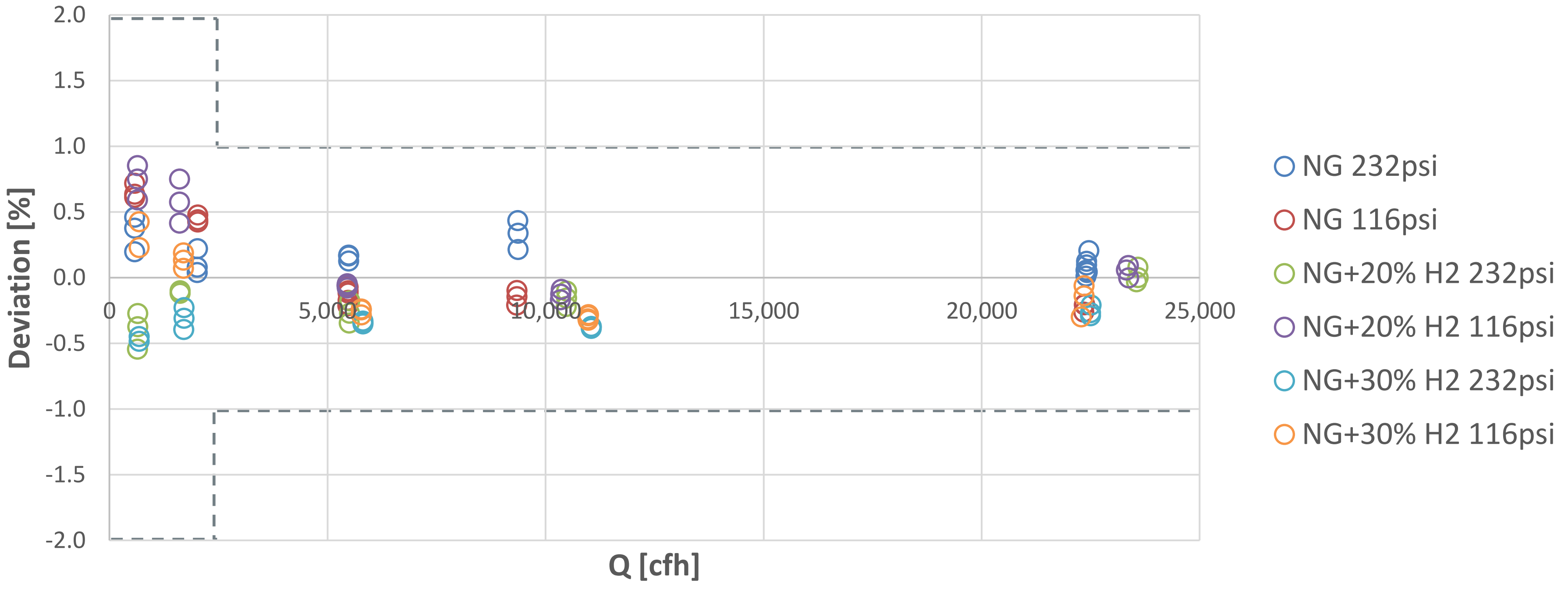
- Performance Evaluation @ DNV Test Facility (NL)
  - Successful test, accuracy limits (class 1) reliably ensured



H_2 in Natural Gas

SUMMARY DOWNSTREAM FLOWSIC500

- 10% H2 blending available today

- Up to 30% H_2 blending
  - Internal testing successful
  - Field installation and testing successful
  - DNV lab testing for 30% H_2 just finished with good results
  - Market release with MID approval scheduled mid 2022

ULTRASONIC METERS HAVE EVERYTHING IT NEEDS TO MEET DEMANDS OF THE FUTURE NETWORK OPERATION

- Proven measurability and accuracy
- IP based communication allows for 24/7 remote access
- Real-time diagnostics support operational control
- And there is even more to name...

H_2 in Natural Gas

How to use USM to check the gas quality?

Real time H_2 content monitoring

Backup for PGC

Detection of H_2 peaks/bubbles

Cost efficient monitoring of customer specs in gas supply

➔ With the help of the NEW Gas Quality Indicator (GQI)!

H_2 in Natural Gas

Gas Quality Indicator (GQI)

What is the Gas Quality Indicator (GQI)?

$$GQI = f(SOS, P_{act}, T_{act}, P_{ref}, T_{ref}, \ldots)$$

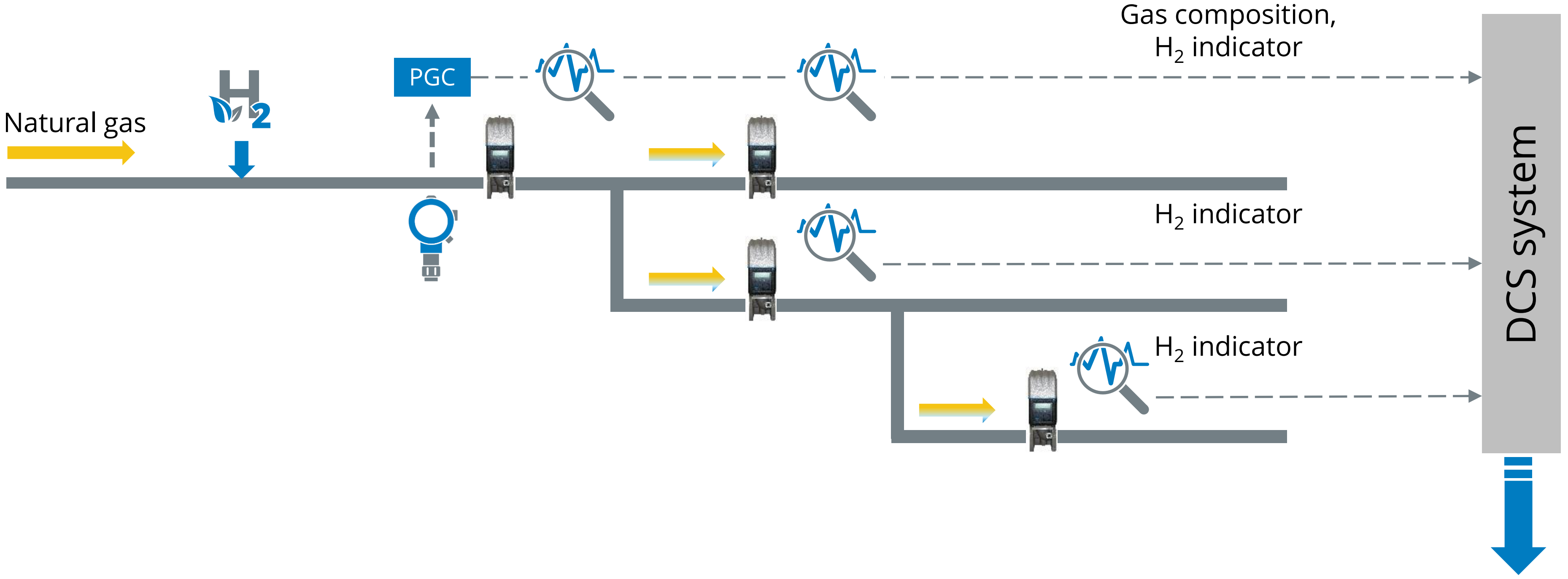
GQI will be implemented as:

- Licensed feature
- Firmware register
- Part of diagnostic values

FLOWSIC Solution for Natural Gas Networks

GQI - Real time Hydrogen content indicator

› Application example: Monitoring of hydrogen **change over time in network**

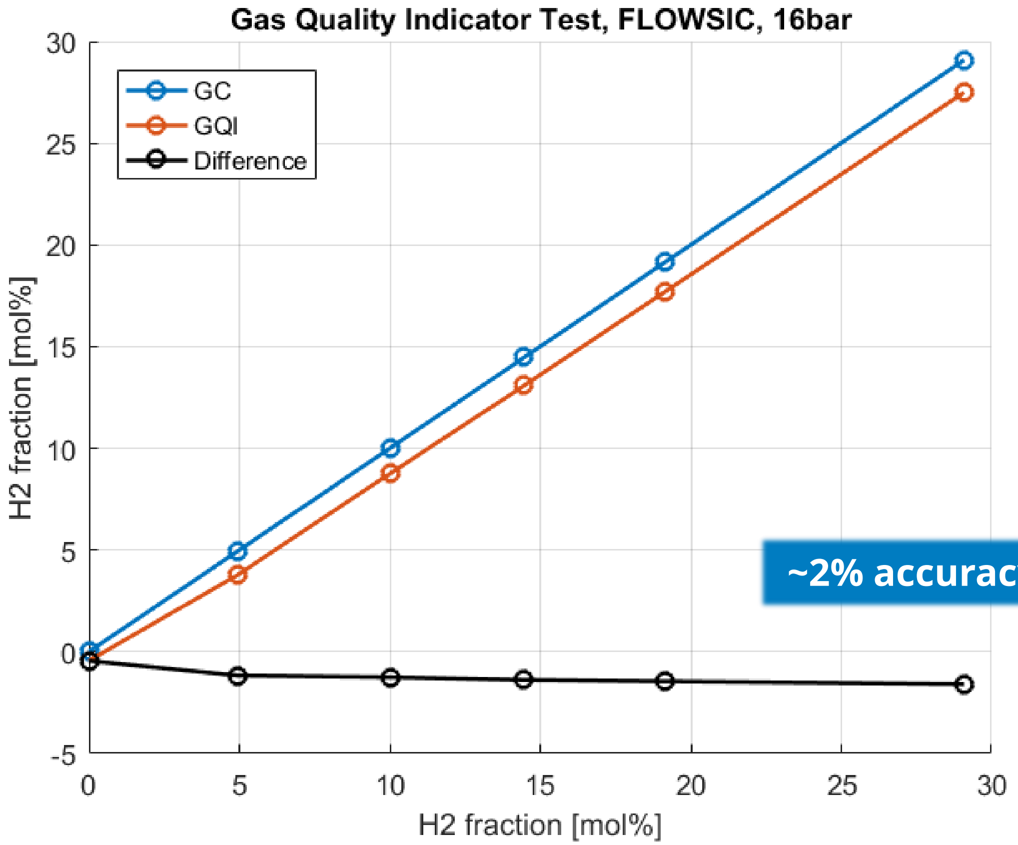


Real-time correlation between PGC analysis and H_2 indicator
Knowledge about network gas quality

FLOWSIC Solution for Natural Gas Networks

Gas Quality Indicator (GQI)

Correlation GQI to H_2 concentration at constant base gas mixture



~2% accuracy of correlation

Source: SICK data evaluation based on DNV JIP, 3rd party test data 05/2021

H_2 in Natural Gas

How to use USM to check the gas quality?

INDUSTRY 4.0 READY

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- **Real time H_2 content monitoring**
- **Backup for GC**
- **Detection of H_2 peaks/bubbles**
- **Cost efficient monitoring of customer specs in gas supply**

➔ With the help of USM diagnostics!

H_2 in Natural Gas

Key take aways

- Investment in H_2 economy is significant
- Gas community prepares for the changes
- First tenders specify H_2-redyness already

- FLOWSIC installed bases is ready up to 10% H_2
- H_2 assessment supports the way to 30% H_2 for installed base
- New devices will support 30% H_2

- Remote connectivity, diagnostics and use of **G**as **Q**uality **I**ndication can help to improve operational excellence
- Partnering is essential to lift full potential

Hydrogen Measurement

Craig Lam – Account Manager
John Calame – Market Product Manager – Analyzers
SICK USA