Gas Quality and Hydrogen handling
Prime movers’ group

Workshop
25th November 2021

10:00 – 14:00 CET

Welcome address by Gert De Block, Secretary General at CEDEC

01 Welcome and introduction

10:00 – 10:15

02 **Session 1**: Gas system operators

10:15 – 11:20

03 **Session 2:** H_2 users and producers

11:30 – 12:45

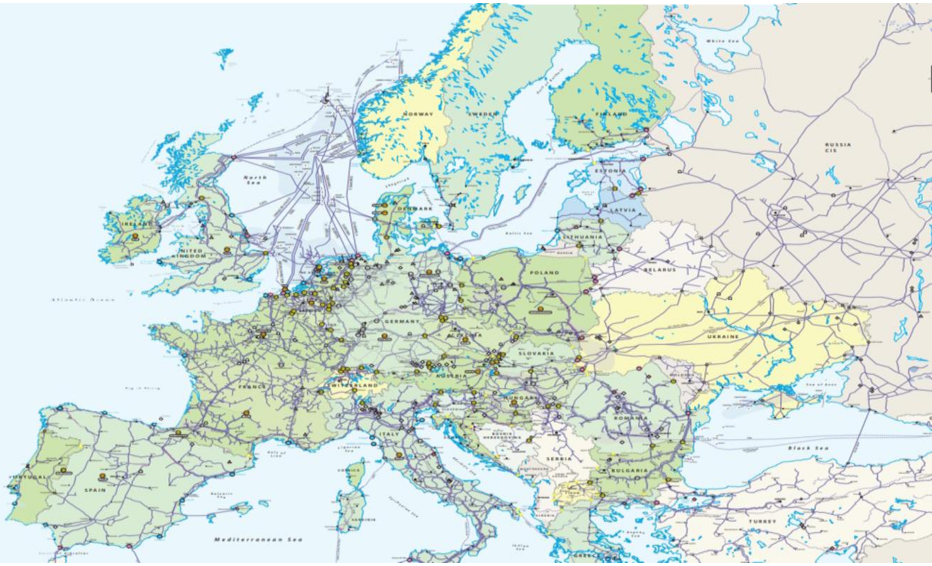
04 **Session 3**: R&D, standards and H_2 integration

12:45 – 13:55

05 Concluding remarks & next steps

13:55 – 14:00

Gas Quality & H2 handling
Prime movers' group



Overview of prime movers' group work during 2021

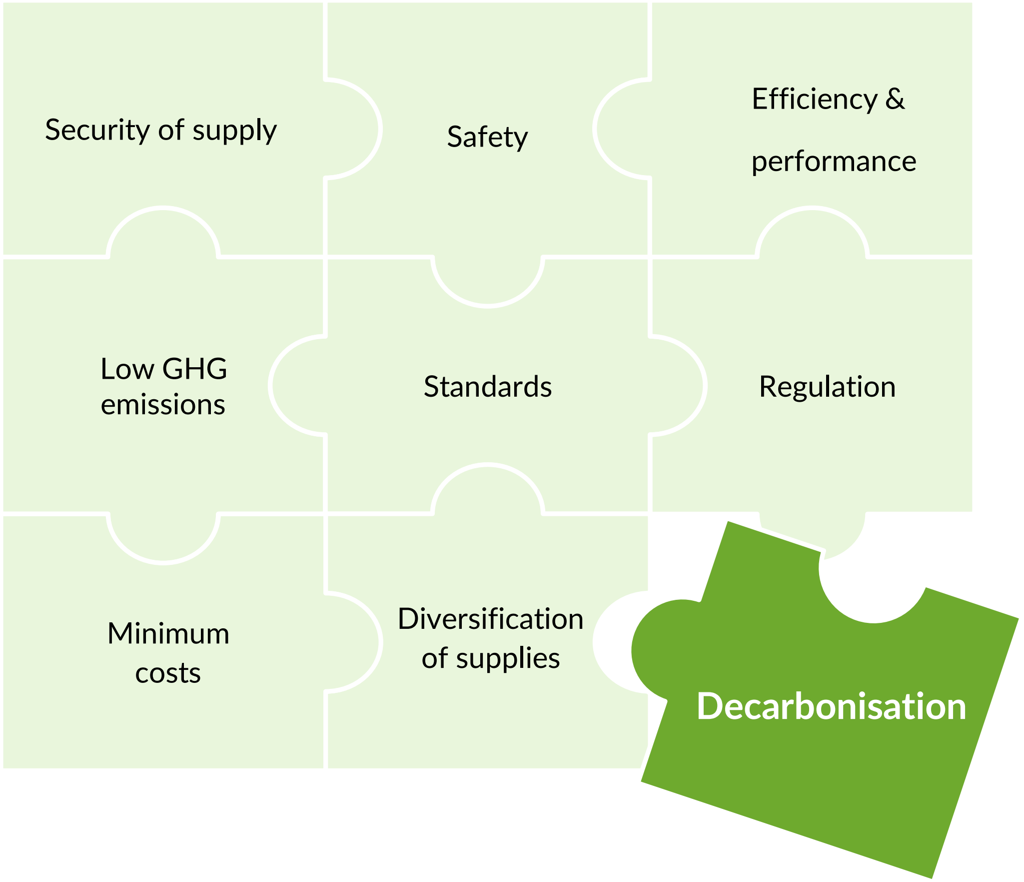
25th November 2021

Rosa Puentes, Interoperability adviser at ENTSOG

The decarbonisation challenge

As the gas industry is gearing up its efforts to rollout increasing levels of **renewable and low-carbon gases**, the European gas system will have to be able to **adapt and deal with diverse gas mixes** which need to be handled technically while…

- Maintaining the same level of security of supply
- Enabling the diversification of supplies
- Striving for the safe, efficient and low emissions use of appliances and applications
- Complying with national and EU standards and regulations
- Keeping the system within reasonable costs
- …



But… which is the most cost-effective way to answer these (sometimes competing) requirements?

Prime movers' group concept

- Promote a fact-based, technology-neutral, and **fair discussion** among stakeholder of the whole gas value chain
- Assess the need for new or upgraded tools to ensure **system interoperability, security of supply and meet end-users' needs** and safety requirements
- Facilitate the development of **innovative and cost-efficient** ways to handle gas quality and **knowledge sharing** on gas quality and H2 handling topics
- Provide the necessary **technical inputs to upcoming Commission proposals** in 'Hydrogen and Gas markets Decarbonisation Package'

Around 40 EU organisations have joined

ETN Global

European Commission

EUTurbines

ERIG
European Research Institute for Gas and Energy Innovation

cefic

ifiec europe
international federation of industrial energy consumers

cen

GEODE

ehi
association of the European Heating Industry

eurogas 30 years

European Engine Power Plants Association EUGINE

Gas Infrastructure Europe

EFET
European Federation of Energy Traders

CENELEC

GERG
THE EUROPEAN GAS RESEARCH GROUP

CEDEC

ACER
European Union Agency for the Cooperation of Energy Regulators

entsog

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

COGEN EUROPE

EASEE-gas
Streamlining the gas business

eurelectric

CECOF

Gas Distributors GD4S For Sustainability

EBA
European Biogas Association

EURAMET

C.E.F.A.C.D

FARECOGAZ

CEER
Council of European Energy Regulators

afecor

ELVHIS

Cerame-Unie
The European Ceramic Industry Association

EUROMOT
The European Association of Internal Combustion Engine Manufacturers

IOGP
International Association of Oil & Gas Producers

marcogaz

Energy Community

NGVA Europe

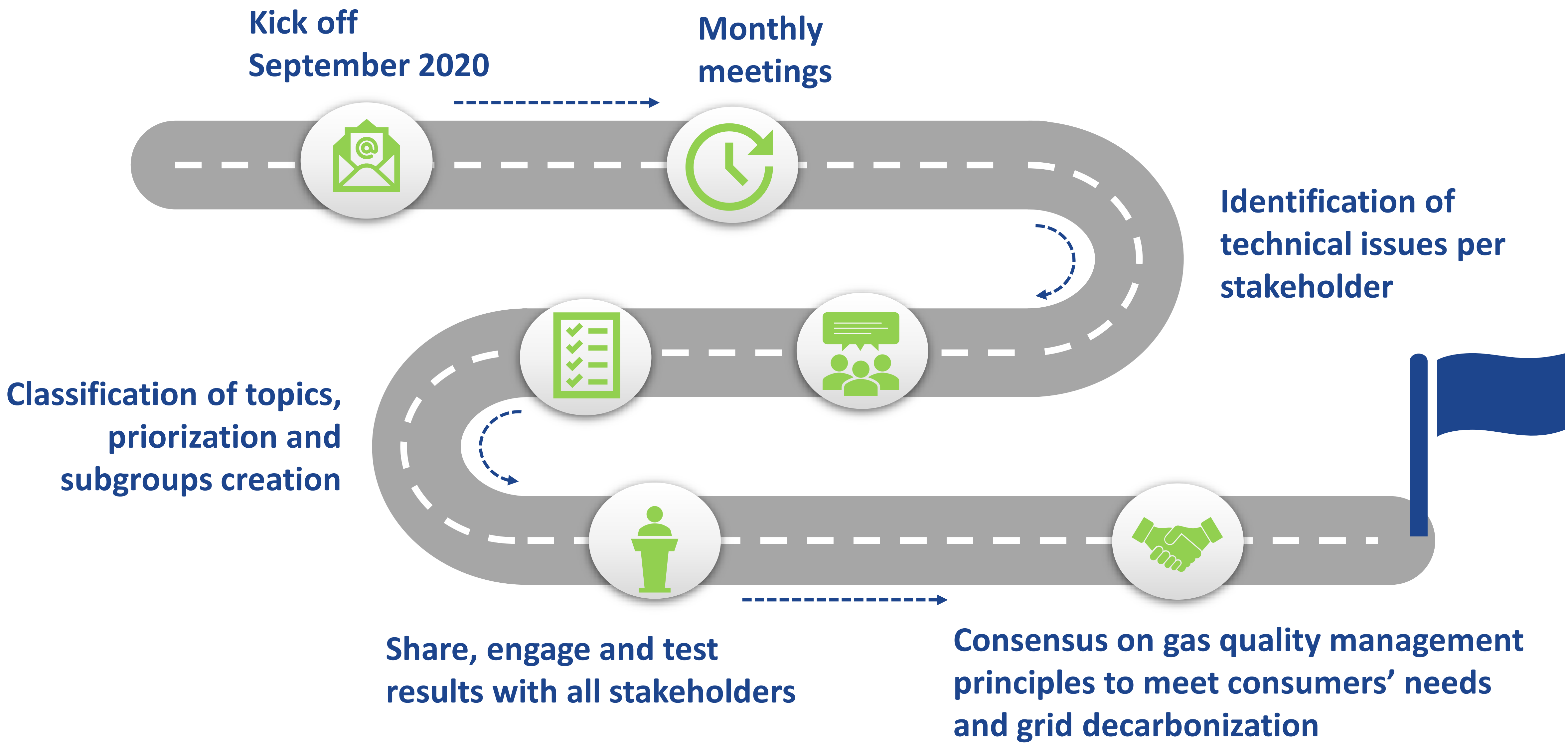
gwi *

Hydrogen Europe

European Commission
Joint Research Centre

* GWI representative is invited to participate due to his experience and involvement in GQ topics, particularly in CEN GQS

Process overview



Subgroups' scope & goal

Subgroup 1: Wobbe Index framework

Members: Prime movers group stakeholders & national standardisation bodies representatives from CEN membership

Chair: A. Vatin (AFNOR) supported by H. Schülken (CEN) and R. Puentes (ENTSOG)

Goal: facilitate the setting of basic rules and procedures (e.g., technical business rules) needed for the implementation of the CEN proposal for a WI classification system at exit points

Deliverable: report including an objective description of the proposed processes, conclusions reached, discussions held and agreements and disagreements between the parties (sent to DG ENER in June 2021)

Subgroup 2: Value chain 'roadmap'

Members: Prime movers group stakeholders' experts in different topics (e.g., deblending, metering, H2 readiness, etc)

Chairs: P. van Wesenbeeck (EASEE-gas) and R. Bimbatti (GD4S)

Goal: deliver concrete principles on gas quality & H2 management

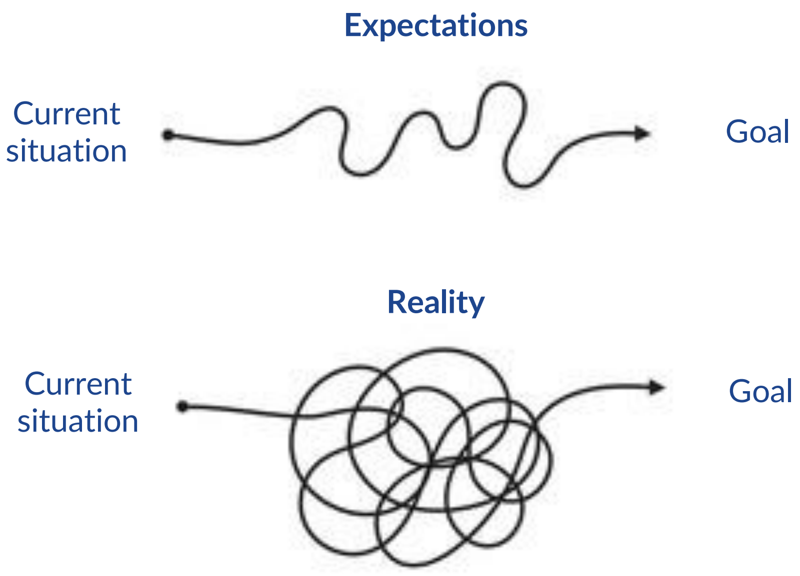
Deliverables:

1. Overview of past, ongoing and future topic-related projects & studies (February 2021)
2. Overview of possibilities of handling H2 blends and associated costs (July 2021)
3. "Decarbonising the gas value chain: 'Roadmap' of challenges & solutions" report (*in progress*)

Highlights from 2021 work

Discussions held had led us to a better understanding of…

- Potential mitigation measures for GQ & H2 handling
- Sector concerns towards GQ variations and H2 blends
- Expected H2 developments in each sector
- Real possibilities for H2 and gas quality management
- Potential ways to decarbonise the gas value chain
- Open questions that need to be further discussed
- Tools that need to be deployed
- Associations' work and efforts towards decarbonization
- How regulation could solve (or mitigate) upcoming challenges posed by decarbonisation
- Key principles needed to implement CEN proposal of a Wobbe Index classification system at exit points



"Not everything that is faced can be changed. But nothing can be changed until it is faced"

(James Baldwin)

Want to know more about…

- Subgroup 1 proposals for a normative framework to implement CEN Wobbe Index proposal of a classification system as exit points? Check it out here
- Subgroup 2 inputs about possibilities of different sectors to manage H2 blends? Check it out here
- Current (and future) mitigation measures for gas quality and Hydrogen handling? Check it out here
- Prime movers' stakeholders work and projects? Check it out here
- The group views on what is needed to use hydrogen (blended and in dedicated systems)? Check it out here
- The group feedback on main difficulties and solutions to deal with H2 blends in the system? Check it out here

What is coming next? Stay tune: Prime movers group GQ&H2 website

Thank you for your attention

Rosa Puentes, Interoperability adviser at ENTSOG

rosa.puentes@entsog.eu

Session 1: Gas system Operators

Session 1: Gas system Operators

Introduction and Q&A moderated by **Eva Hennig** | Head of Brussels Office and department of EU energy policy at Thüga

Reassignment of Natural Gas Pipeline Infrastructure for Hydrogen Transport: Pipeline Integrity Management Roadmap

- **Stefan Klein** | Technical advisor at GASCADE

HyWay 27: repurposing the Dutch natural gas grid

- **René Schutte** | Director HyNorth at GASUNIE

Ready4H2: combining the hydrogen expertise and experiences across European gas distribution companies

- **Peter Kristensen** | Chairman of Ready4H2

Blending of H2 into the natural gas system – Underground Gas Storage point of view

- **Ulrich Duda** | Head of General Affairs at Uniper Energy Storage

Reassignment of Natural Gas Pipeline Infrastructure for Hydrogen Transport

Pipeline Integrity Management Roadmap

S. Klein
GASCADE Gastransport GmbH
2021-11-25

GASCADE

Key facts

- Due to introduction of Hydrogen into a high-pressure gas transmission pipeline system the line pipe material properties can change
- Yield and tensile strength used for stress based pipeline design are reported to be less affected by Hydrogen
- Fracture toughness is reduced depending on line pipe material and Hydrogen partial pressure
- Fatigue crack growth rate (FCGR) is significantly enhanced at relevant partial Hydrogen pressures > approx. 1 bar

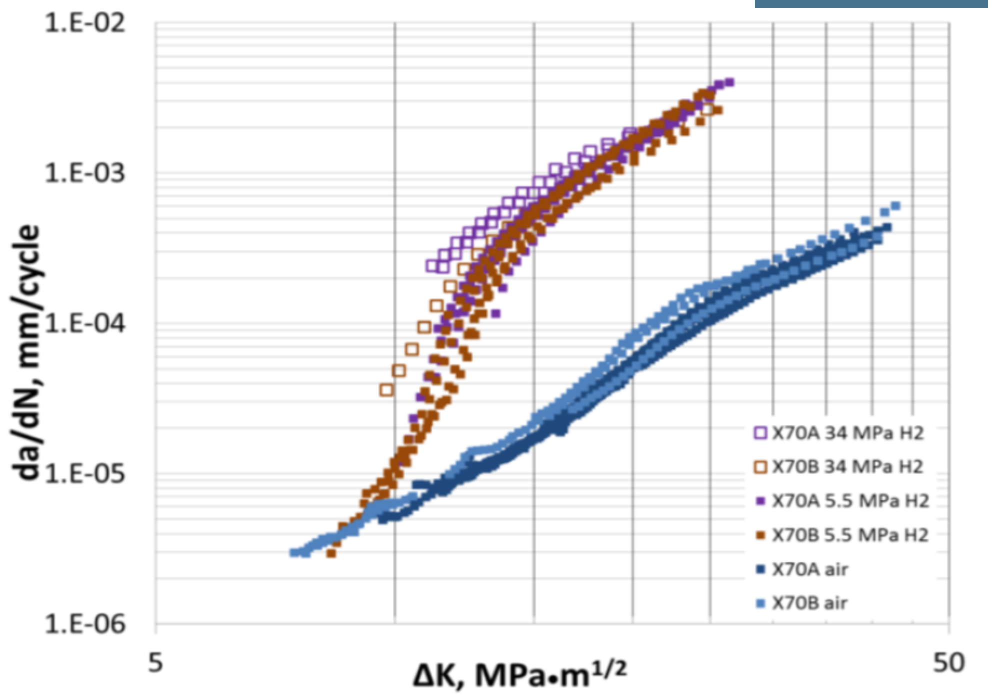


Figure 5. FCGR data on two X70 steels in air (blue), 5.5 MPa hydrogen gas (closed symbols: X70A=purple, X70B=brown), and 34 MPa hydrogen gas (open symbols) at 1 Hz loading rate (R=0.5).

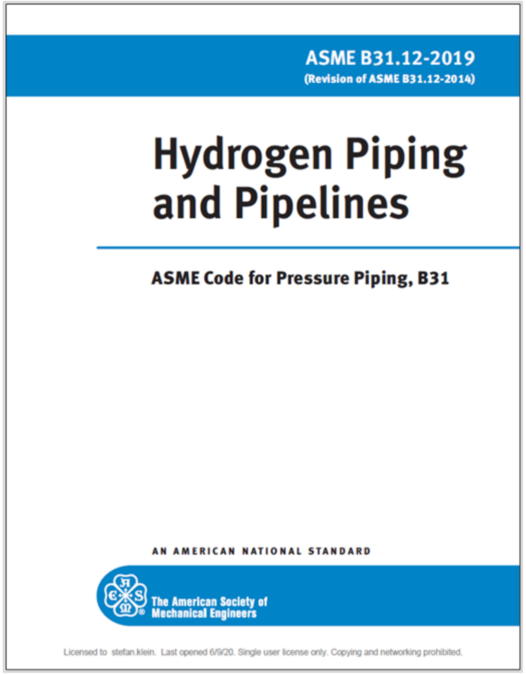
A.J. Slifka et al.: Summary of an ASME/DOT Project on Measurements of FCGR of Pipeline Steels; Proceedings of the ASME Pressure Vessel and Piping Conference 2014, PVP2014-2893

Z. Che: Fatigue crack growth in hydrogen pipeline steels; Ph.D. thesis; Univ. of Illinois, 2018

GASCADE

Challenges

- Changes in the line pipe material properties must consequently lead to a revision of acceptance criteria and assessment models of defects
- Pre-existing stable internal flaws, previously acceptable and of no concern, may under certain conditions become a threat over time
- Under the influence of Hydrogen FCGRs primarily depend on loading conditions
- The driving mechanism for growth are cyclic pressure variations, where low magnitude changes contribute less


ASME B31.12-2019
(Revision of ASME B31.12-2014)

Hydrogen Piping and Pipelines

ASME Code for Pressure Piping, B31

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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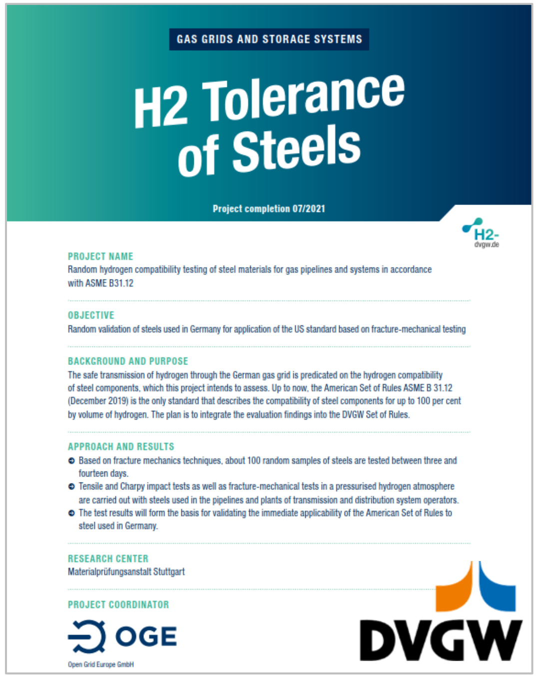
HA-FCG master curve for API 5L steels


GAS GRIDS AND STORAGE SYSTEMS

H2 Tolerance of Steels

Project completion 07/2021

PROJECT NAME
Random hydrogen compatibility testing of steel materials for gas pipelines and systems in accordance with ASME B31.12

OBJECTIVE
Random validation of steels used in Germany for application of the US standard based on fracture-mechanical testing

BACKGROUND AND PURPOSE
The safe transmission of hydrogen through the German gas grid is predicated on the hydrogen compatibility of steel components, which this project intends to assess. Up to now, the American Set of Rules ASME B 31.12 (December 2019) is the only standard that describes the compatibility of steel components for up to 100 per cent by volume of hydrogen. The plan is to integrate the evaluation findings into the DVGW Set of Rules.

APPROACH AND RESULTS
- Based on fracture mechanics techniques, about 100 random samples of steels are tested between three and fourteen days.
- Tensile and Charpy impact tests as well as fracture-mechanical tests in a pressurised hydrogen atmosphere are carried out with steels used in the pipelines and plants of transmission and distribution system operators.
- The test results will form the basis for validating the immediate applicability of the American Set of Rules to steel used in Germany.

RESEARCH CENTER
Materialprüfungsanstalt Stuttgart

PROJECT COORDINATOR
OGE
Open Grid Europe GmbH

DVGW

HA-FCG analysis of vintage and modern European steels

ASME B31.12-2019: Hydrogen Piping and Pipelines

DVGW e.V.: Hydrogen Research Projects – H2 tolerance of steels
https://www.dvgw.de/medien/dvgw/leistungen/publikationen/dvgw-h2-wasserstoff-forschungsprojekte-broschuere-en.pdf
retrieved: 2021-11-24

Key elements

- The German Technical and Scientific Association for Gas and Water (DVGW) initiated revision and expansion of the existing set of technical rules for Hydrogen transport
- Further research and recommendations on fracture mechanical assessment of flaws under influence of Hydrogen are currently being developed
- Existing and future practices might need to be adapted to operational experience for Hydrogen transportation

DVGW G 409 (M)-2020: Conversion of high pressure gas steel pipelines for a design pressure of more than 16 bar for transportation of hydrogen
DVGW G 463 (A)-2021: High pressure gas steel pipelines for a design pressure of more than 16 bar; design and construction

Summary

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- By introducing Hydrogen into a natural gas pipeline system, the line pipe material properties can change. Under certain conditions this change gives rise to Hydrogen-assisted fatigue growth of flaws and might require revision of acceptance criteria of existing defects
- The existing DVGW set of rules is currently being revised and expanded to cover Hydrogen in addition to natural gas
- Research projects have been initiated to close existing gaps
- For pipeline integrity management the set of rules builds a framework, that must be adapted in the future based on operational experience

PRCI™ LEADING PIPELINE RESEARCH

PRCI developed a Hydrogen research project roadmap. Results might contribute and close gaps.

PIPELINE OPERATORS FORUM

POF initiated a working group on In-Line Inspection of Hydrogen pipelines. Results might influence the management of flaws.

Thank you for your attention!

Stefan Klein
Asset Management
GASCADE Gastransport GmbH
stefan.klein@gascade.de

crossing borders in energy

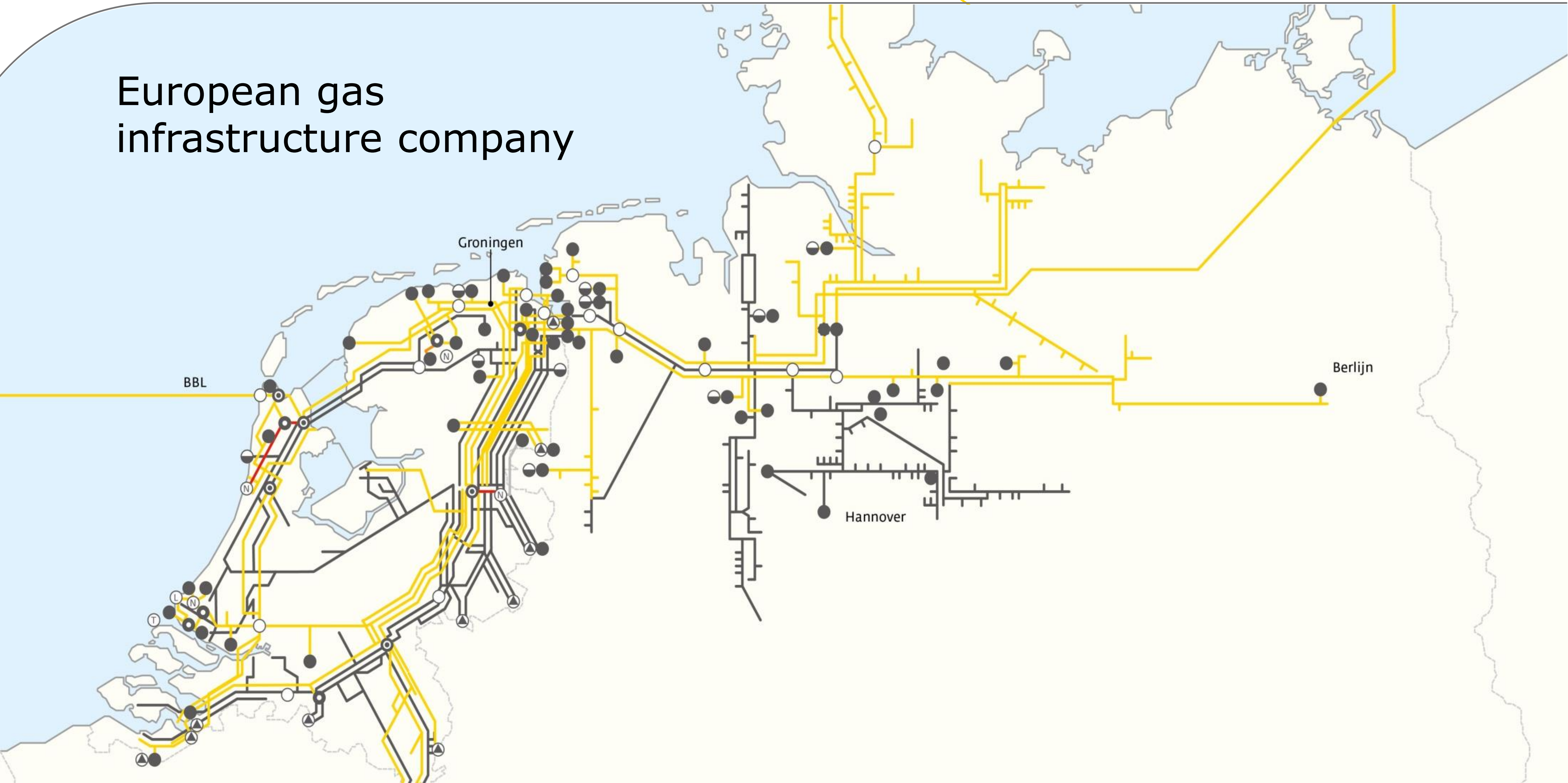
25 november 2021

HyWay27

Repurposing the Dutch grid for hydrogen transport

René Schutte - Project Lead

European gas infrastructure company



The HyWay 27 project explored if and under which conditions, parts of the Dutch natural gas network can be repurposed for transmission of hydrogen

Key research questions

1

Is a transmission network for hydrogen **needed**, and **if so, when**?

2

Is it possible to use the existing natural gas for hydrogen transmission, and **if so**, **would that be desirable**?

3

What **government intervention** will be required to create a transmission network for hydrogen?

Findings

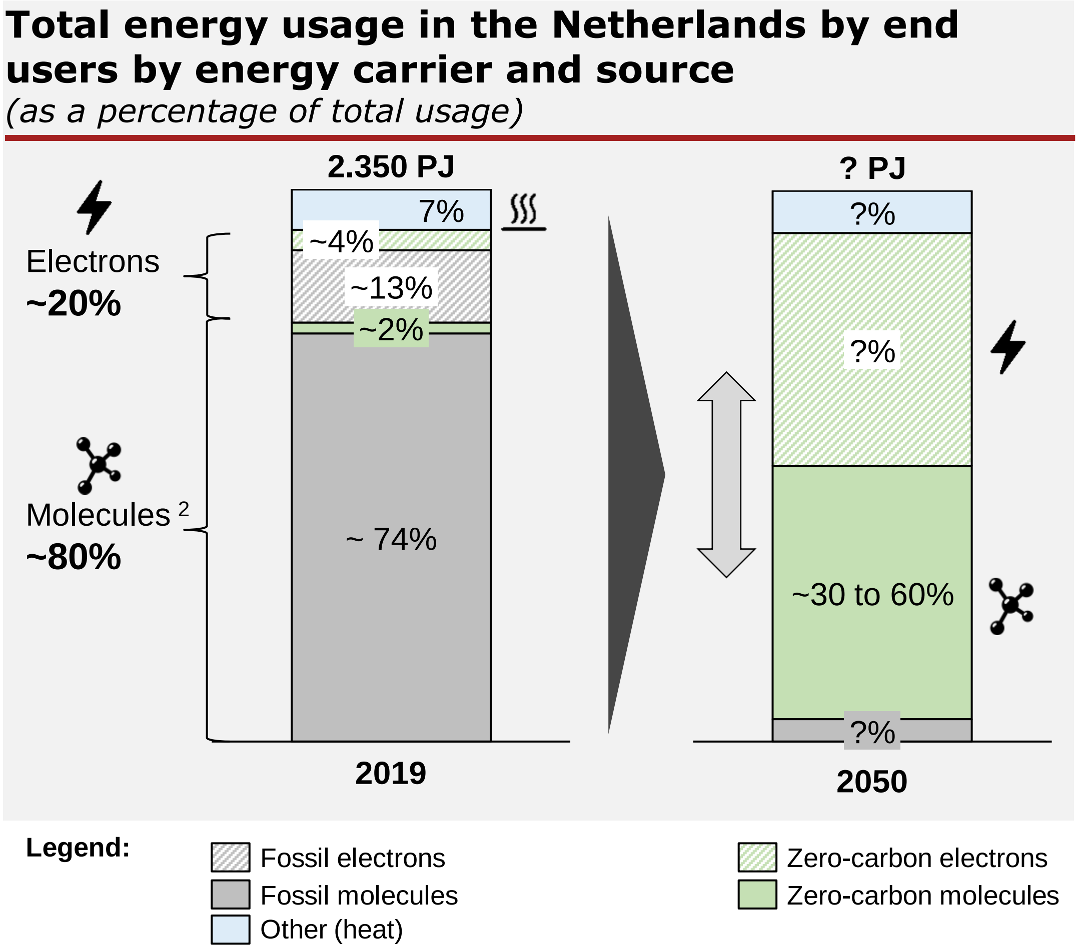
In a climate-neutral economy, pipelines for hydrogen are necessary to connect producers and users of hydrogen cost effectively. **Towards 2030** a transport network is needed to meet ambition of 3-4GW electrolysis

Existing natural gas infrastructure offers enough capacity for future hydrogen volumes and **can technically be modified**/repurposed. The **cost** per km investment is **4 times lower than new-build**

Government intervention should be aimed at financially supporting both **transport and production/usage** of hydrogen **in parallel**. Advice is to **initiate next steps** in repurposing existing natural gas grid

Source: HyWay 27. Strategy& - PwC

Hydrogen is an essential building block for a climate-neutral economy in 2050



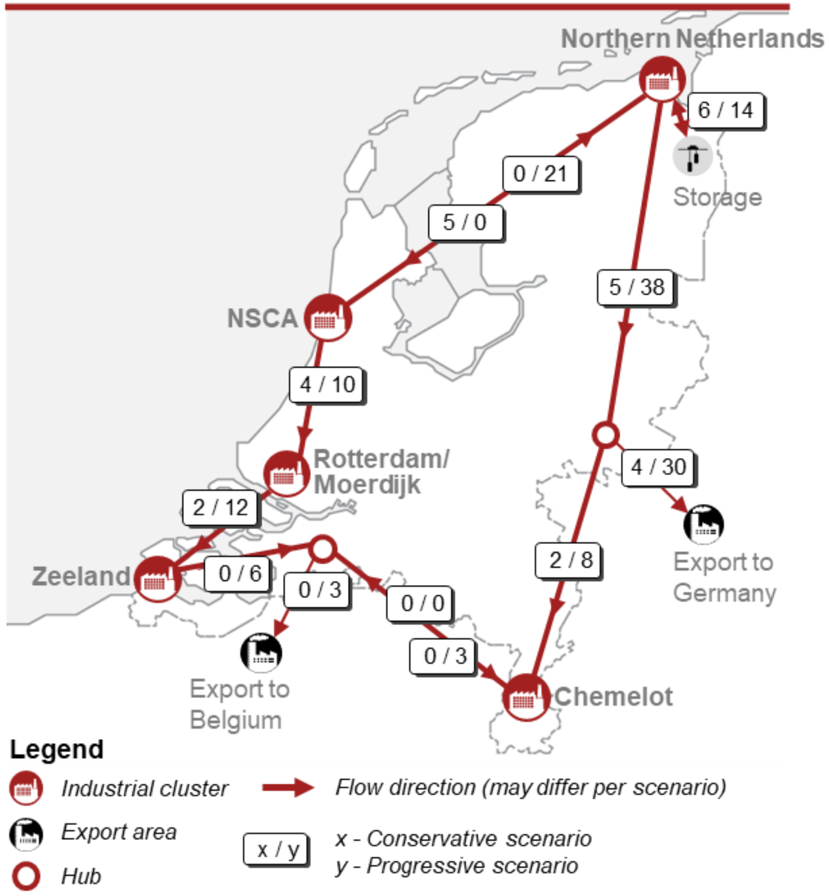
- **Molecules** currently **make up ~80%** of the energy usage and are largely fossil based
- In a climate-neutral economy, **molecules will still be needed** (estimated ~30-60% of energy usage):
  - As a fuel
  - As feedstock
  - For storage
- However, such molecules need to be carbon-free: due to its scalability **clean hydrogen is essential building bock** in addition to biofuels

Source: HyWay 27. Strategy& - PwC

Large scale hydrogen production requires transport and storage

- Transport develops from regional to interregional
- Storage needed to balance supply & demand
- Green hydrogen drives storage need
  - Highly variable supply from solar and wind

Illustrative analysis of transport flows in 2030 based on the Dutch government's hydrogen ambitions *(Cumulative annual volume in PJ [on an hourly basis]). Source: Strategy&*



The Netherlands can become a European hub for climate-neutral energy and feedstock

The contours of a possible hydrogen transmission network in 2030 *Source: Gasunie, Strategy&*

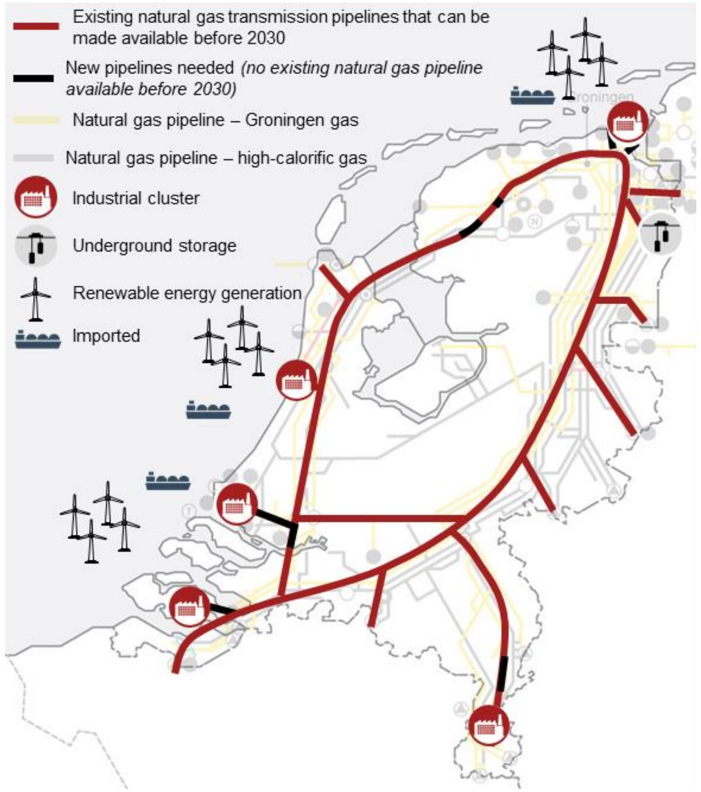
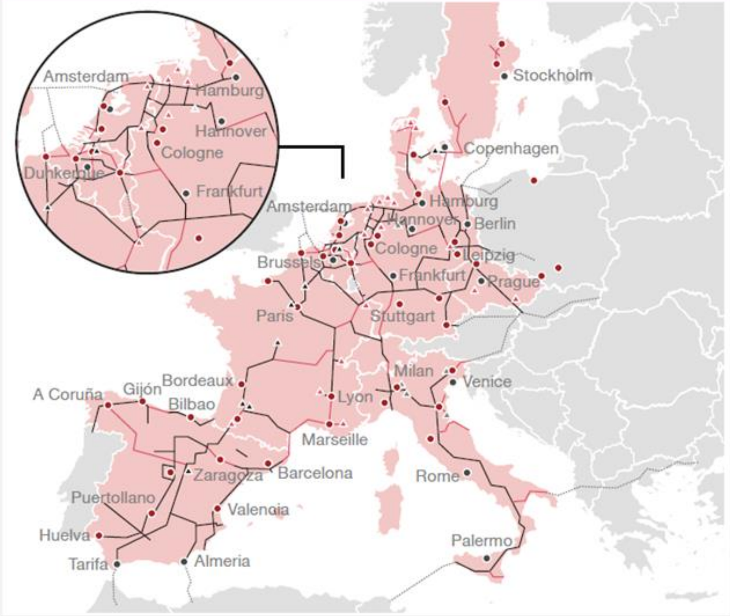


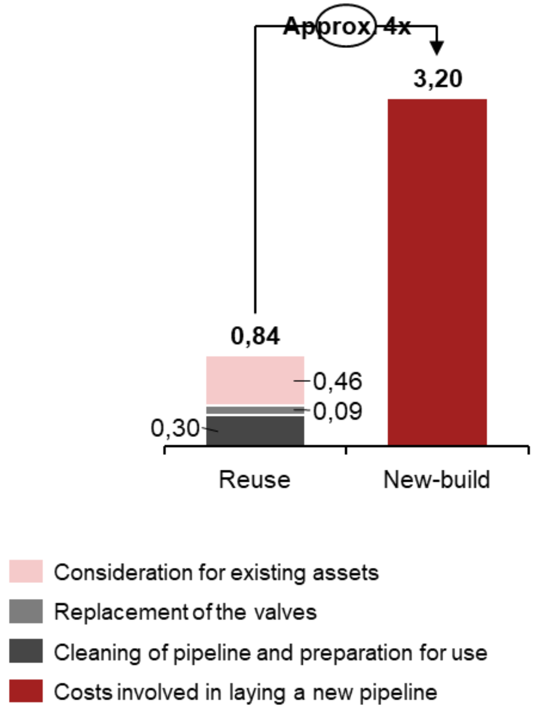
Illustration of the possible European hydrogen backbone in 2040
Source: Guidehouse (2020)



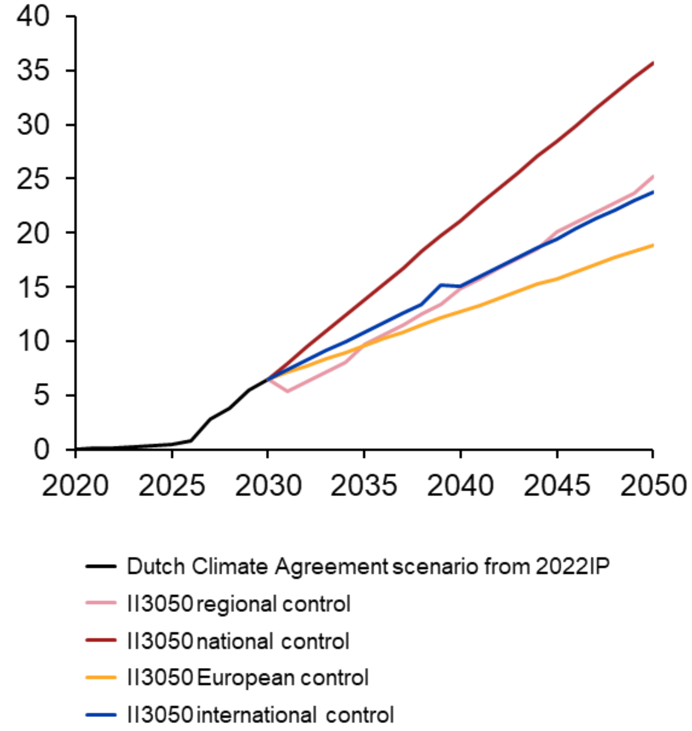
▲ Potential H_2 storage: existing/new salt cavern
▲ Potential H_2 storage: aquifer
▲ Potential H_2 storage: empty gas field
● Industrial cluster
● City, for orientation (if not already specified for industrial cluster)

Repurposing natural gas grids is more cost-effective and government support required to develop value chain and mitigate higher risk

Comparison of per-km investment required for reuse and new-build
(millions of € per km).
Source: Strategy& based on figures provided by Gasunie



Zero-carbon and low-carbon hydrogen capacity development forecasts for the Netherlands (GW per year).
Source: II3050



gasunie
crossing borders in energy

25 november 2021

HyWay 27 recommendations:
Realisation of a national hydrogen network;cost efficient and safe

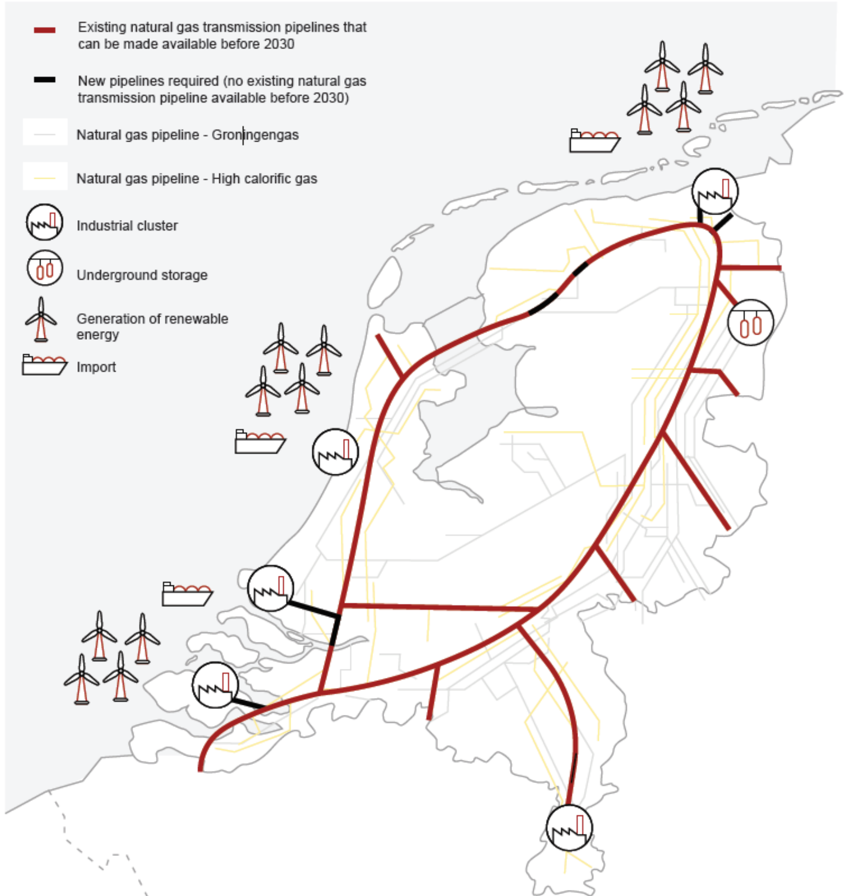


Image: PwC

1. Take a decision in principle
Zero-carbon hydrogen requires new transmission supply chains, both in 2030 and in the intervening years as well. In order to achieve this in good time, a decision in principle must be taken in the short term to repurpose a part of the existing natural gas transmission networks for the transmission of hydrogen. Existing pipelines will be ready sooner for the transmission of hydrogen and repurposing them is cheaper than building new pipelines.

2. Draw up a rollout plan
Where will the transmission network be located and what actions have to be taken? Draw up a rollout plan containing the envisioned contours of the transmission network in 2030. Describe the actions that will be needed in the coming years. Striking the right balance is key. On the one hand, the rollout plan must provide potential hydrogen consumers with clarity on when the infrastructure will be available and, on the other hand, a step-by-step rollout must ensure that there is room to adapt to developments as these emerge.

3. Determine how the market will be regulated
The further the hydrogen market grows, the more the infrastructure developed will need to be regulated. Who is to be allowed to operate in the market and under what conditions? Only with clarity on how to regulate the hydrogen market can it be decided in the short term who is to be responsible for repurposing the natural gas networks and ultimately for the operation of the newly created hydrogen transmission network.

4. Draw up a plan to kick-start the supply chain
Investing in a hydrogen transmission network is not a sound decision if there is too little supply and demand. That is why government intervention and clarity on financial resources is necessary if we are to develop the supply chain and, this way, achieve the ambitions for 2030. Furthermore, it must be determined how the public money can best be distributed among the different parts of the chain.

https://www.hyway27.nl/en/hyway-27-is-completed

thanks for your attention

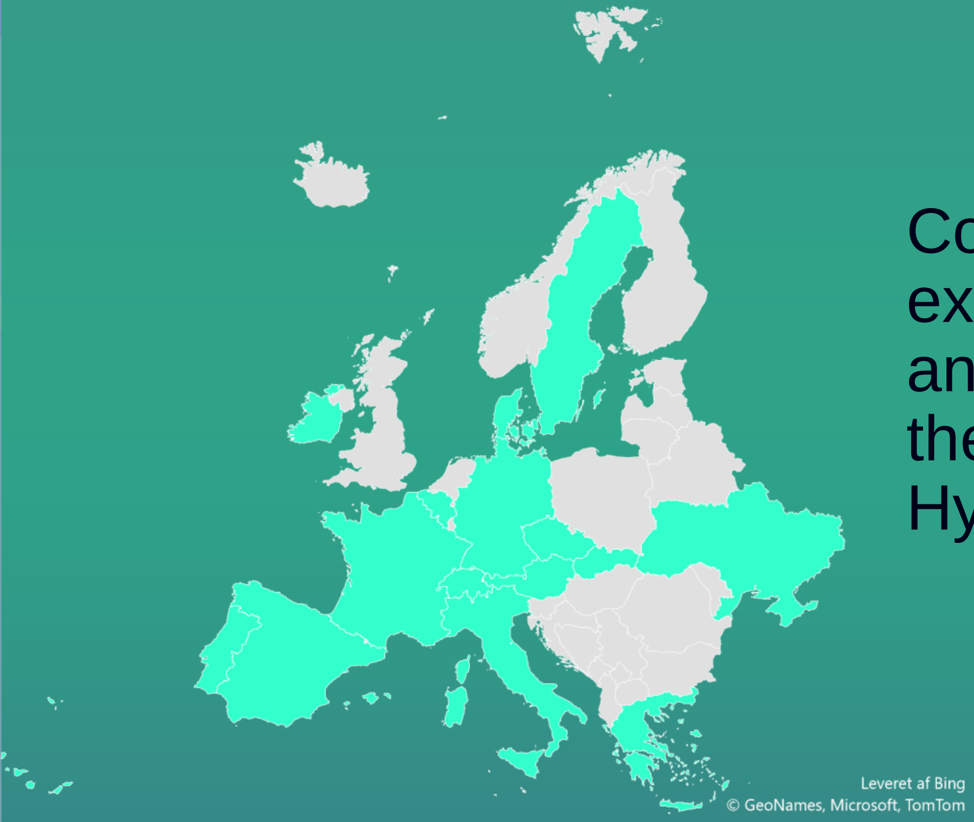
questions?

ready4H2

Europe's Local Hydrogen Networks

Peter Kristensen, Chief Strategy Officer, Evida – Chair of the Ready4H2 project – pkr@evida.dk

European DSO study Ready4H2



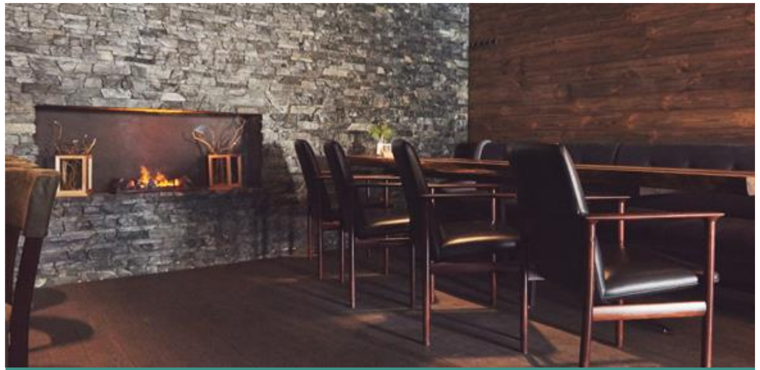
Combining the hydrogen expertise and experiences across the European gas DSOs and creating a common understanding of how the distribution networks can help realize the Hydrogen Ecosystem and support Fit For 55.

90 DSOs from 15 Member countries: Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Ireland, Italy, Portugal, Slovakia, Spain, Sweden, Switzerland, Ukraine
8 Member associations: CEDEC, Eurogas, Energy Community, GEODE, GERG, Marcogaz, ERIG, GD4S

ready4H2

European local gas networks deliver cost-effective and safe energy to consumers

The networks in our alliance keep 64 million households warm in winter and supply a further 12 000 CHP plants to run district heating systems.



We supply 3 million commercial businesses, including the restaurant kitchens that prepare the meals we all enjoy.

We serve 150 000 industrial premises, including industries such as glass and ceramics that need a gaseous flame to produce their products.

Our networks are extremely reliable, with very few interruptions to gas supply, which is important for families to stay warm and businesses to function.

We have supported green gas grid injection, with around 550 biomethane plants connected to gas networks across Europe.

We are providing the critical evidence and have gained fundamental and practical experience from many hydrogen research and pilot projects.

Purpose

Creating a consolidated European understanding of the DSOs role in the hydrogen community

Toolbox for facilitating discussions with EU and national regulators

Highlighting the gas DSOs role in supporting the development of the hydrogen economy in Europe

ready4H2

Focus of the content in Ready4H2

Task I
Knowledge

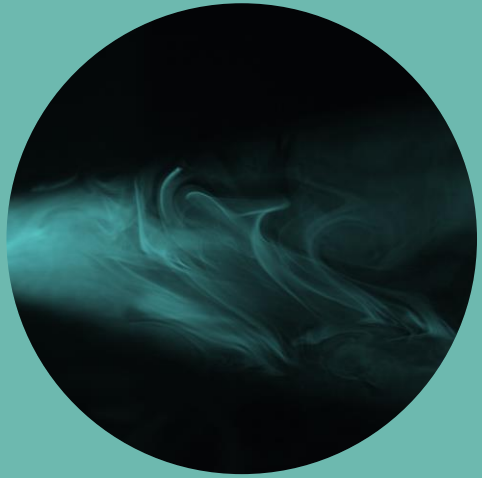
- Gathering hydrogen knowledge from DSOs
  - Technical knowledge
  - PtX projects
  - Background information of the DSOs

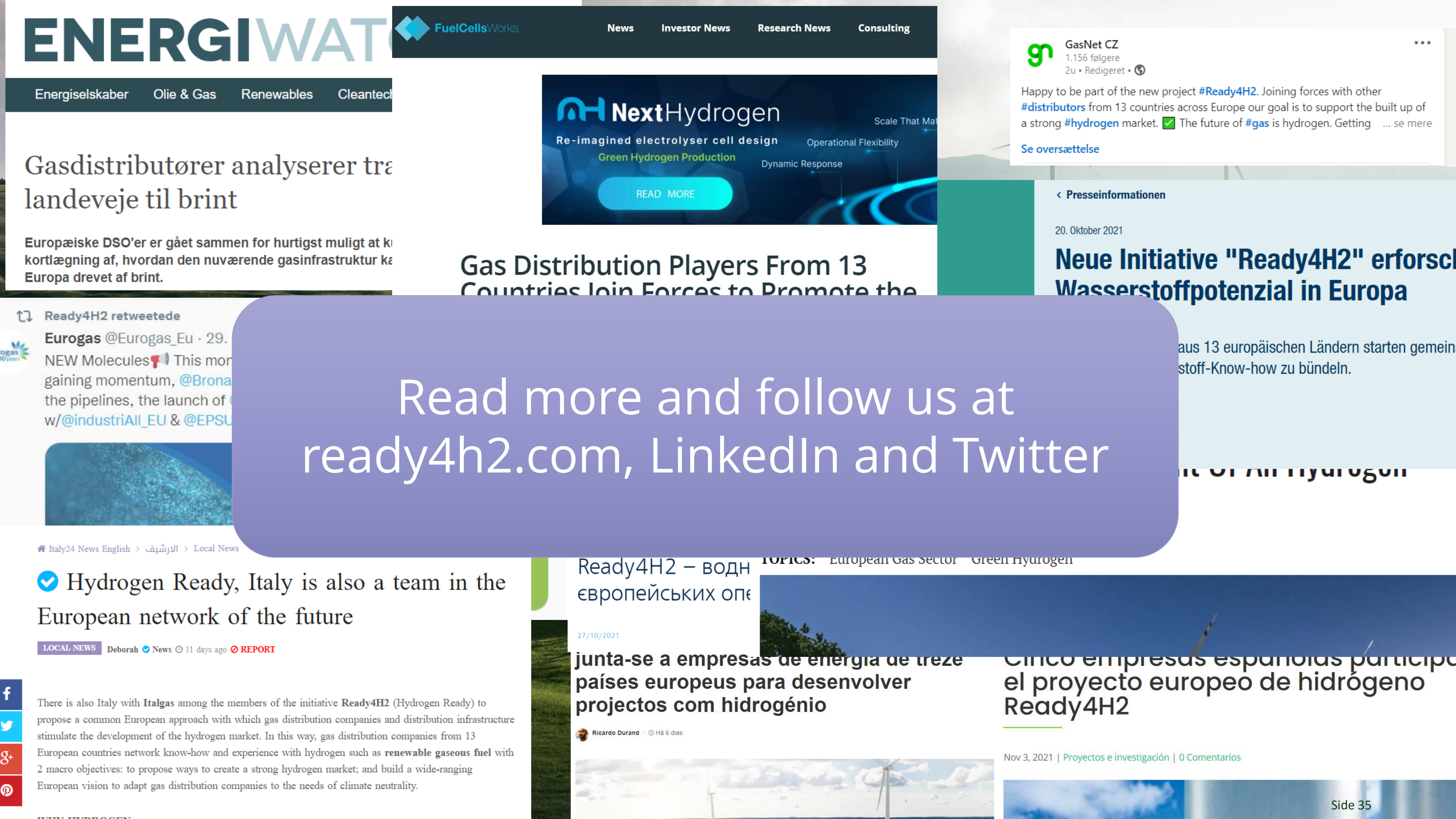
Task II
Value proposition

- Understanding the DSOs role in the hydrogen value chain
- Coupling DSOs and growth related to the PtX sectors

Task III
Roadmap

- Identifying barriers and how to tackle them in order to unlock the DSOs role in PtX
- Showing how climate neutrality can be reached faster and more efficiently with the support of the DSOs





Read more and follow us at ready4h2.com, LinkedIn and Twitter

Empower Energy Evolution

Blending of Hydrogen into the natural gas system – from Underground Gas Storage point of view

25.11.2021

Blending of hydrogen in Underground Gas Storage (UGS)

1. **Blending of hydrogen** in the gas infrastructure is one possible pathway to decarbonize the gas sector
2. The **challenge** consists in handling and storing mixtures of hydrogen and natural gas in existing UGS facilities under **high pressure conditions** and with increasing hydrogen rates
3. Analyses of UST storage assets show both **technical and commercial impacts** on surface and subsurface storage equipment caused by the injection and storage of hydrogen/natural gas admixtures > 2% for all types of UGS
4. **Huge differences depending on storage type**: **Salt caverns** are by nature more compatible with hydrogen compared to **Porous rock facilities**

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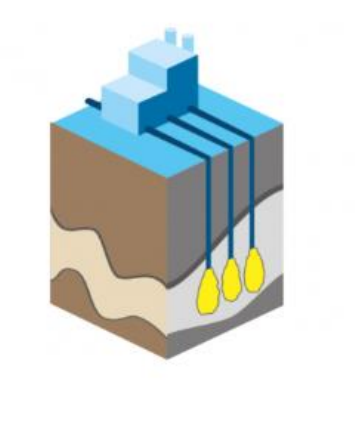
Technical aspects in blending of hydrogen into UGS (1)

- **Subsurface installations:** The influence of hydrogen on the materials of existing well completions creates integrity defaults: corrosion of steel, fractures in the elastomer of sealing elements, reaction with the well cementation.

- **Salt cavern:** Confinement in salt layer is not considered as problematic.

- **On surface facilities:**
  - **Impact on compression power** due to a less calorific fuel gas
  - **Gas turbines needs to be checked** to avoid damage to the turbine blades
  - **Modifications on gas measurements** and process gas chromatographs are required
  - **Impact on desulfurization and dehydration units**, especially with air injection or dehydration
  - For many existing components, **no certification for hydrogen is in place**



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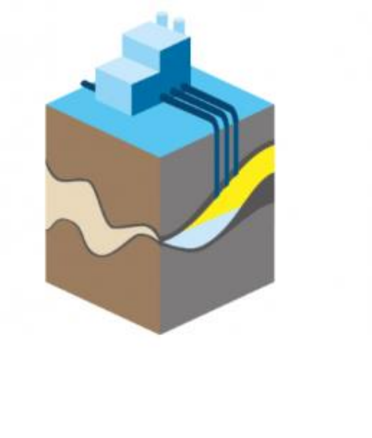
Technical aspects in blending of hydrogen into UGS (2)

- In **porous rock**, such as aquifers or former gas or oil fields, phenomena of dissolution in water, fingering and confinement under caprock need additional and individual research and testing in pilot projects.

- **Chemical/biological reaction** in porous reservoirs very likely.

- Risks are linked to the **consumption of Hydrogen by microorganisms**, implying H2S generation, development of biofilms in the vicinity of wells and even pore clogging in the worst case.

- **Hydrogen acceptance diversifies** from one storage site to another, depending on the lithology of the reservoir, water chemistry, pressure, temperature, microorganisms' population, and gas quality (presence of CO and CO2 for example).



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Commercial and legal aspects

- **Certification** of facilities/components for hydrogen blending in existing storage sites
- **Regulatory risks** due to the fact that no admixture rates of H2 are set in the Technical Standards (DVGW G260 on gas quality in Germany) which are legally binding between SSO and TSO via Grid Access Ordinance “Netzzugangsverordnung”.
- Additional Capex (new sub-/surface installations) for repurposing of storage sites, reduced marketable capacities (H2 three times lower energy content) and higher Opex (e.g., compressor costs) to be born by SSO ? (different from regulated TSOs)
- TSO´s responsibility for **system integrity**: might SSO refuse injection of H2 admixture due to technical restriction and how to handle varying blending rates on existing contracts and marketing of capacities?

Conclusions on H2 blending in gas storage assets

1. Blending of more than 2% hydrogen to the natural gas system leads to high costs for the technical upgrading of the storage facilities (i.a. for individual certification)
2. Additional costs (Capex) for the retrofitting of the systems as well as commercial losses that serve to create a higher hydrogen compatibility of up to 10% need to be subsidized or compensated (regulatory framework).
3. More than 10% hydrogen to the natural gas system would lead to nearly new investment costs of a storage site (surface installations)
4. For porous rock, such as aquifers or former gas or oil fields individual additional research and testing in pilot projects is necessary

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A pure hydrogen infrastructure and the necessary retrofitting of individual cavern storage facilities is economically more advantageous with increasing hydrogen blending rates and should be prioritized in the decarbonization of the gas market

Session 2: Hydrogen users & producers

Session 2: Hydrogen users & producers

Introduction and Q&A moderated by Sonia Clarena Barón | Deputy Secretary General at EUTurbines

Getting ready for the use of hydrogen: the roadmap of the European heating industry

– Harald Petermann | Technical Affairs Director at EHI

How can industry handle gas quality variations caused by hydrogen

– Jochen Wagner | Procurement & Regulatory Affairs at BASF

Hydrogen-readiness of gas power plants – what next?

– Annette Jantzen | Manager Policy and Public Affairs at EUGINE

CHP Hydrogen applications, projects and vision

– Alexandra Tudoroiu-Lakavice | Head of Policy at COGEN Europe

– Klaus Payrhuber| Strategic Product Development Manager at INNIO Group

IOGP perspective on the role of hydrogen

– Kees Bouwens | Regulatory Advisor at ExxonMobil, representing IOGP

Getting ready for the use of hydrogen: the roadmap of the European heating industry

Harald Petermann | EHI Technical Affairs Director

ehi
association of the
European Heating Industry

EHI brings together manufacturers of heating systems in Europe

SPACE HEATING

WATER HEATING

CONTROLS

EMITTERS
- UNDERFLOOR HEATING
- RADIATORS

125 000
people employed directly by the industry

1 billion €
yearly investments in RDI*

28.5 billion €
turnover / year

* Research, Development and Innovation

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APTT · attb · Assotermica · BDH Bundesverband der Deutschen Heizungsindustrie · EUA energy&utilities alliance · fegeca · GebäudeKlima Schweiz · De Nederlandse Verwarmingsindustrie · Stowarzyszenie Producentów i Importerów Urządzeń Grzewczych · TALTEKA · Uniclima

Our members represent 90% of EU market for heat & hot water generation, covering a wide range of technologies

1. Buildings is a hard-to-decarbonise sector

- The single largest source of energy consumption in the EU, representing 40% of final energy consumption and 36% of CO_2 emissions.
- 61 million heating systems installed in Europe are inefficient.
- 71% district heating in Europe still based on fossil fuels (27% coal and peat) with old infrastructure.
- The replacement rate is slow - 4% a year.
- **Heating is a regional issue** depending on climate zones, local energy infrastructure, building types, consumer preferences, and financial capability.

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2. A multi-technology, multi-carrier approach is key to deliver decarbonisation

- We need:
  - A mix of renewable and decarbonised energy sources;
  - A mix of efficient heating technologies;
  - Increased system efficiency, including digitalisation.
- Electrification with heat pumps (electric and hybrid) will play a much bigger role than today.
- Long term scenario of the EU Commission for decarbonisation of buildings in 2050 anticipates 34% direct electrification*. **What about the rest of buildings?**

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*In depth analysis in support of Commission Communication COM (2018) 773 and Impact Assessment for the 2030 climate target plan.

3. Hydrogen is necessary from the energy system perspective

- Storage:
  - Hydrogen provides daily, weekly, seasonal storage of renewables to produce heat and electricity on demand (i.e. Energy system integration).
- Buildings can help create a H2 market:
  - Provide a stable and reliable demand for hydrogen…
  - … Will lead to economies of scale and security of investments and reduce costs for all use sectors.
- Use existing infrastructure:
  - Gas infrastructure is available (with adaptations) to store, transport, distribute H2.

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4. Hydrogen technologies for heating are ready

- Today
  - Gas end use products installed in field (>1995) can work with bio methane and bio-LPG and up to 10% H2 blend[1].
  - Many modern condensing boilers can work with up to 20 vol-% H2 blend with CE approval.
- From 2026:
  - Optional pictogram on the energy label for the purpose of raising awareness, indicating the capability of appliances to use green gases
  - Introduce an ecodesign requirement for gas fired appliances[2] to work with a variable share of hydrogen of up to 20 % by volume
- In 2029:
  - Introduce an ecodesign requirement for hydrogen readiness, i.e. make sure gas fired appliances* are capable of operating safely and efficiently with 100 % hydrogen, either after a conversion or without.

1 The maintenance situation and appliance settings need to be appropriate
2 For the scope, see the EHI position paper on the Consultation Forum meeting for the review of the ecodesign and energy labelling regulations for space and water heating

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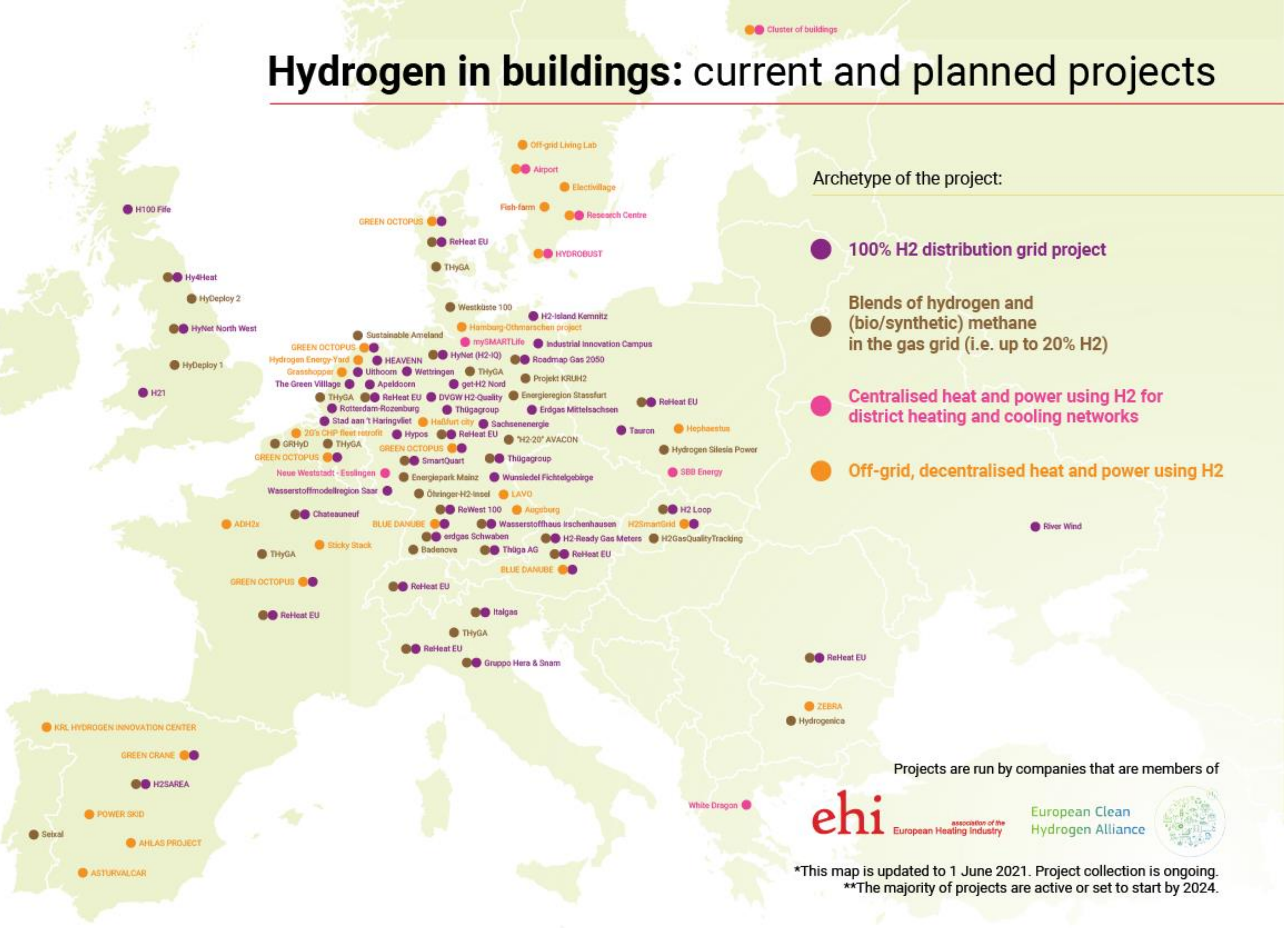
5. Hydrogen is safe and cost-efficient for consumers

- All hydrogen appliances must meet the safety requirements of the Gas Appliances Regulation (EU) 2016/426;
- Third party conformity assessment required on the appliances;
- Standards are being updated for use of appliances with hydrogen.

- 100% H2-ready technology: minor cost effect to the end user; no regret solution toward CO2-neutrality:
- Domestic H2-ready boiler ~+17%, compared to condensing natural gas boiler; conversion kit to 100% H2 ~13% of H2-ready boiler price
- H2-ready thermally-driven and hybrid heat pumps: total cost increase for consumer – well below 10%.

6. Hydrogen in buildings is already a reality

83 projects across Europe… and counting.



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CONTACT

+32 (0)2 880 30 70

ehi@ehi.eu

www.ehi.eu

@EHIassociation

PRIME MOVERS' GROUP ON GAS QUALITY AND HYDROGEN HANDLING

How can industry handle gas quality variations caused by Hydrogen?

CEFIC-IFIEC

How can Hydrogen cause gas quality variations?

- In natural gas grids
  - Hydrogen normally not present (maybe in traces)
  - Gas quality variations can occur due to blending of Hydrogen with natural gas in the grid
  - In some countries a legally binding maximum Hydrogen content is defined in the national natural gas standard (max. 10%), but in many national natural gas standards Hydrogen is missing

- In dedicated Hydrogen grids
  - Initial Hydrogen content that can be achieved and type of by-products depends on the production process
  - Without defining a minimum quality standard for Hydrogen to be injected into the grid, gas quality variations will be more significant → different upgrading/separation technologies are required to achieve such a defined minimum quality standard for Hydrogen
  - Depending on the grid infrastructure (new or repurposed) Hydrogen quality may vary across the grid (especially at the beginning of such a dedicated grid)
  - Storages can significantly impact the Hydrogen quality as the operating mode of storages does not fit to the optimal operating mode of upgrading/separation technologies

How can industry handle gas quality variations caused by Hydrogen?

- No general answer, as it depends on the application/process itself, the installed equipment and the expected Hydrogen or by-product content
  - Steady fluctuations (e.g. of Hydrogen content) are the most critical, lead to higher cost and can cause unexpected outages
- In natural gas grids
  - Applications/processes are optimized for the typical (historical) natural gas quality at exit point
  - In heating/burning processes at least a Wobbe Index detection and a Hydrogen detection will be required to control & possibly adapt the process in case of changing gas quality
    - Worst case: heating/burning equipment must be changed
  - In chemical processes using natural gas as feedstock, separation technologies might be required depending on absolute level of Hydrogen
  - The possible rate of change of Hydrogen content must be considered when designing the separation process
- In dedicated Hydrogen grids
  - If processes require higher gas quality than the defined minimum Hydrogen quality standard, upgrading technologies must be used

How can industry handle gas quality variations caused by Hydrogen?

- Specification of a typical premix burner (existing asset base)

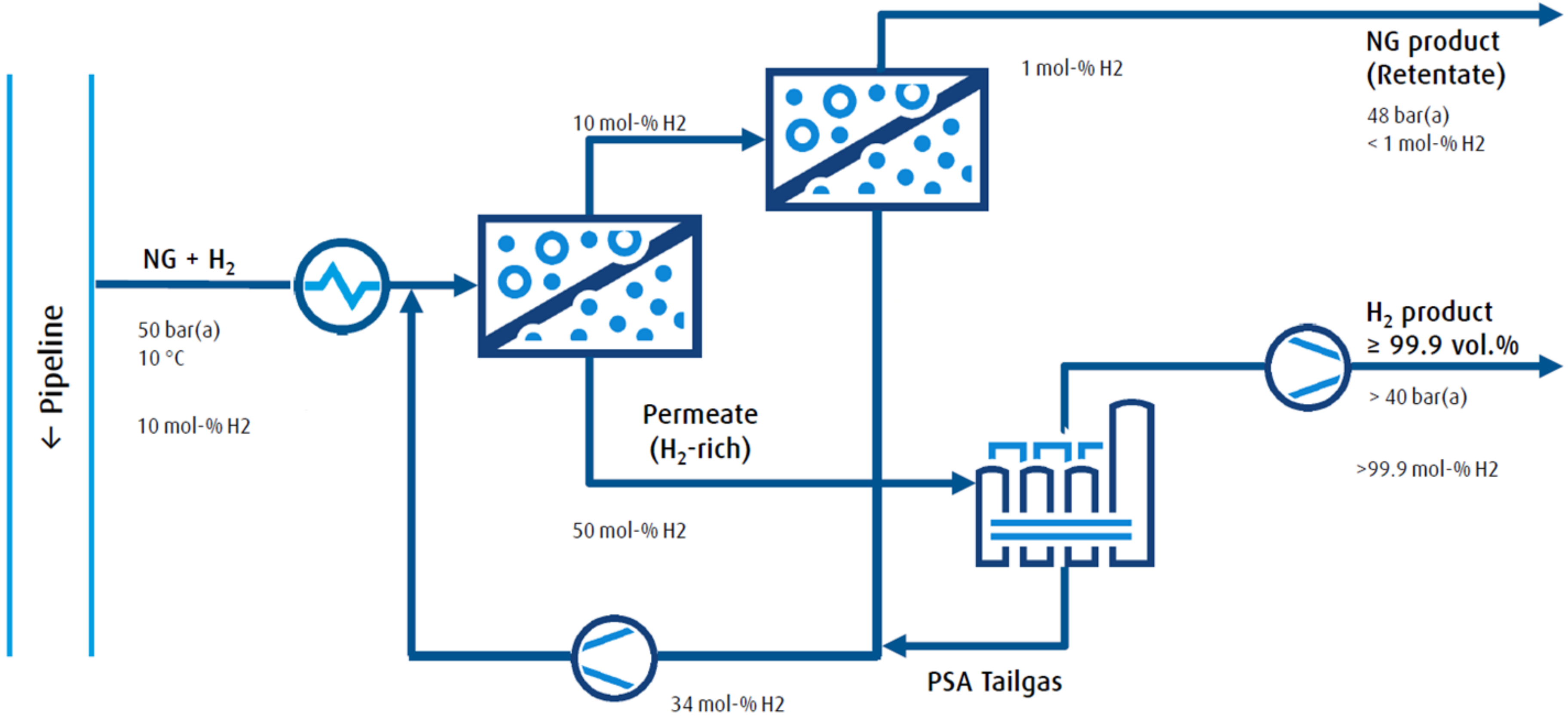
Property		Requirement
Wobbe Index (WI_{net})	Range	36 - 52 MJ/m^3
Fluctuations	Max	± 10 % with max. gradient 0.5 %/s
Lower Heating Value (LHV)	Approx. Range	35 - 50 MJ/kg
Fluctuations	Max	± 10 %
Gas condition		
Gas pressure	Max	37 bar abs
	Max	1.1 * Min
	Min	Project specific
Fluctuations	Max	± 0.3 bar
Gradients	Max	± 0.1 bar/s
	Max	± 0.2bar/s for max. 10s
Gas temperature	Min	0 °C or 20 K above dew point of hydrocarbons or water
	Max	150 °C
Composition		
Higher Hydrocarbons + Hydrogen (C_{2+} + H_2)	Max	22 % vol
Hydrogen (H_2)	Max	5 % vol
Carbon Monoxide (CO)	Max	30 ppmv
Sulphur (S)	1st limit	Standard Equipment < 72 mg/Nm^3 (<50 ppmv as H_2S)
		>72 mg/Nm^3 (>50 ppmv as H_2S)
	2nd limit	>200 mg/Nm^3 (>140 ppmv as H_2S)
	Max	7'200mg/Nm^3= 7.2g/Nm^3 (5'000 ppmv = 0.5% H_2S)
Contamination / Trace elements		
Lube oil content	Max	0.5 ppm wt
Dust content		free of dust
Sodium + Potassium (Na + K)	Max	0.5 ppm wt
Magnesium (Mg)+Calcium (Ca)	Max	2.0 ppm wt
Vanadium (V)	Max	0.5 ppm wt
Lead + Zinc (Pb + Zn)	Max	0.5 ppm wt
Nickel (Ni)	Max	1.0 ppm wt
Total heavy metals (V + Pb + Zn + Ni)	Max	2.0 ppm wt

Wobbe Index (WI_{net})	Range	36 - 52 MJ/m^3
Fluctuations	Max	± 10 % with max. gradient 0.5 %/s

Hydrogen (H_2)	Max	5 % vol

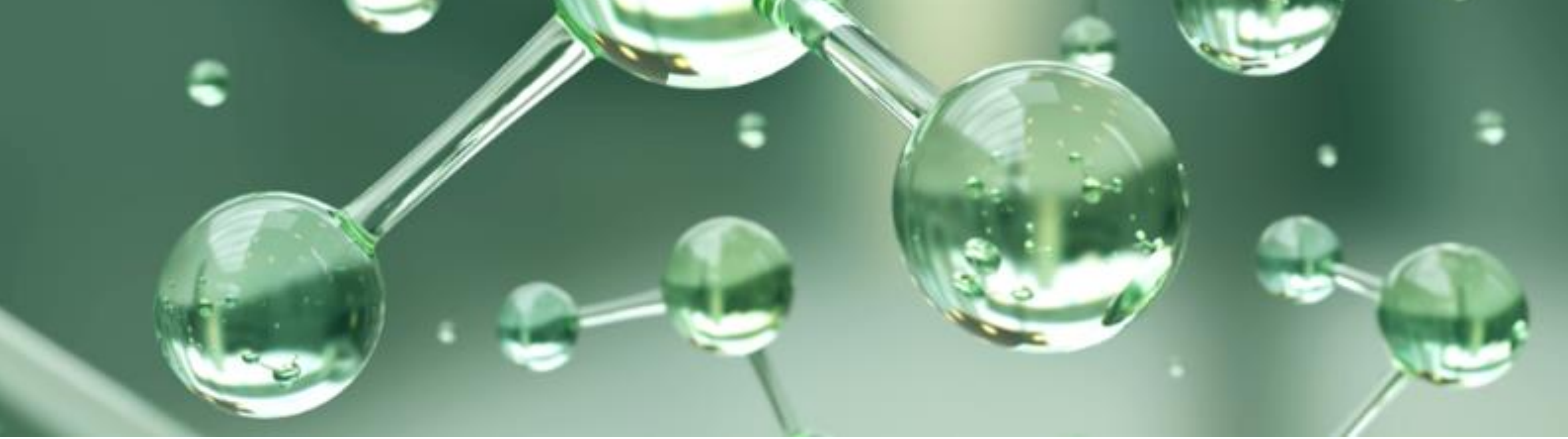
How can industry handle gas quality variations caused by Hydrogen?

- Possible design for separation of Hydrogen blended natural gas



Conclusion

- From a technical point of view, gas quality variations caused by Hydrogen can be handled
  - More challenges expected in case of Hydrogen blended natural gas than in dedicated Hydrogen grids
- No “one size fits all” solution
- Complexity of solution depends on which gas quality can be expected in the future
- Upgrading/separation technologies lead to a higher energy demand which interferes with other dossiers promoting energy efficiency (e.g. state aid, EED or ETS)
- Costs will be significant, especially OPEX → who bears these additional costs?
- Installation of stranded assets must be avoided



H2 READY Power Plant

Hydrogen-readiness of gas power plants – what next?

Prime Movers' Group on Gas Quality and Hydrogen Handling, 25-11-2021

EUGINE

EUTurbines

About

H2 READY Power Plant

European Engine Power Plants Association (EUGINE)

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Baker Hughes

DOOSAN

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MAN Energy Solutions

MITSUBISHI POWER

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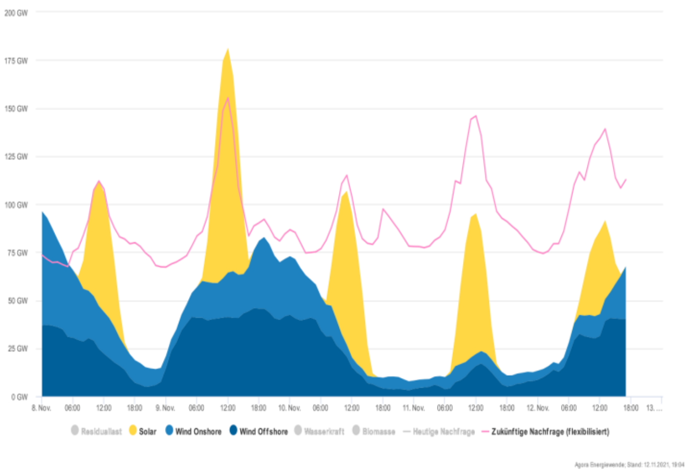
A Caterpillar Company

Why H2-Readiness for Gas Power Plants?

Defining technology requirements today for tomorrow's needs



REPLACING NATURAL GAS

Fossil gas needs to be replaced – hydrogen is one of the main alternatives

CLIMATE-NEUTRAL ELECTRICITY & HEAT

With hydrogen, gas power plants can generate carbon-neutral electricity and heat

FUTURE-PROOF POWER PLANTS

Due to a lack of other options, gas power plants today operate with natural gas, but will be technically ready to switch to hydrogen once it becomes available

Understanding H2-Readiness

H2 READY Power Plant

- **Target:** One definition for all types of new gas power & cogeneration plants – turbine & engine-based – indicating capability and conversion costs

- **A two-step approach:**

Step 1:
Building new future-proof "H2-ready" plants now
Operation starts with natural gas but technically prepared for a later switch to hydrogen

→

Step 2:
Upgrading the plant from natural gas to H2 when needed
Depending on adequate supply with H2 and economic feasibility for the operator

H2-Ready Definition for NEW Gas Power Plants

H2 READY Power Plant

EUTurbines

Level A	Level B	Level C
100% H2	**25% H2**	**10% H2**
A1: no substantial modifications	B1: no substantial modifications	C1: no substantial modifications
A2: minor upgrading	B2: minor upgrading	C2: minor upgrading
A3: upgrading possible	B3: upgrading possible	C3: upgrading possible

Categories:

No substantial modifications: Limited modifications may be needed, with costs **up to 5%** of overall plant building costs.

Minor upgrading required: Upgrade costs estimated to be **up to 10%** of overall plant building costs.

Upgrading technically and economically possible: Technology suppliers estimate the costs for this upgrade **up to 20%** (turbine-based) **– up to 30%** (engine-based) of the overall cost of building this power plant.

Hydrogen-readiness of gas power plants

- **New power plants** can operate with hydrogen and are ready for a climate neutral energy system
- **Existing power plants** can also operate with hydrogen, but need individual analysis

EUGINE H2-Ready Checklist for EXISTING plants

H2 READY Power Plant

EUGINE

Gas / Fuel System (from the handover point of the gas grid to the injection into the engine)

Component	To be evaluated	25% H2-blend	~100% H2
Gas metering	Does the metering concept need to be reviewed? (depending on the gas supplier)		
Piping & sealings	Is the security and tightness of components in gas flow regulating handling components sufficient? Are diameter and material of piping adequate?		
Purging	Is the purging of the system possible?		
Valves & sealings	Is the security and tightness of components in gas flow regulating handling components sufficient?		
	Are diameter and material of piping adequate?		
	Are additional pressure relieve valves necessary?		

Engine-related

Component	To be evaluated	25% H2-blend	~100% H2
Fuel-mixing	Do changes of density, pressure and transient load make adaptations necessary?		
Dosing system	Materials used		
Core engine unit	Pre-ignition & ignition system, cylinder heads, pistons, crankcase ventilation and on engine gas pipes		
Combustion monitoring	Are adaptations of the software necessary?		
Intercooler system	Materials, sizing, flame arrestors		
Turbo charger	Suitability for rated power and transient load		

Cooling System

Component	To be evaluated	25% H2-blend	~100% H2
High temperature & low temperature water cooling	Are adaptations due to changes in heat balance and different water temperature necessary?		

Oil System

Component	To be evaluated	25% H2-blend	~100% H2
Lube oil system	Suitability of the oil used		

Exhaust Gas System

Component	To be evaluated	25% H2-blend	~100% H2
Exhaust system	Are adaptations caused by different dewpoint necessary?		
	Is the pressure resistance appropriate?		
Exhaust duct	Ventilation concept and need for additional safety valve/dilution		
Aftertreatment system / SCR	Functionality with regard to temperature change		

Safety System of the Plant

Component	To be evaluated	25% H2-blend	~100% H2
Gas safety concept	Is a review and adaptation necessary?		
Plant ventilation system	Does the ventilation design need to be adapted (additional sensors & different components)?		
Fire, gas & heat alarm systems	Review and adaptation regarding potential H2 leakages necessary		
H2 concentration detection	Is the measurement of critical H2 concentration in atmosphere & detection of H2 for lower explosion limits ensured?		
Access control	Foresee additional access restrictions to machine room caused by potential leakages		
Civil works	Are adaptations necessary?		

Other Components of the Plant

Component	To be evaluated	25% H2-blend	~100% H2
Electric systems / low voltage & medium voltage	Are additional security measures in case of H2 leakages for the operation of the LV and MV panels necessary?		
Controls	Are changes in plant operation necessary?		
Documentation of installation & maintenance Operational guidelines & manuals	Rework installation, maintenance and operation guidelines to include H2-related operation & safety aspects		
Hand tools, electric & mechanical tools, gas measuring & analysis devices	Suitability of all tools to changed ATEX conditions		

- **probably no adaptation required**
- **probably minor adaptations required**
- **probably adaptation required**
- **adaptations required**

Responsibility of the gas supplier

Adaptation of the gas reduction / compressor station to the volume increase caused by hydrogen

European Engine Power Plants Association EUGINE

EUGINE is the voice of Europe's engine power plant industry. Our members are the leading European manufacturers of engine power plants and their key components. Engine power plants are a flexible, efficient, reliable and sustainable technology, helping to ensure security of electricity supply and providing (renewable) electricity and heat.

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H2-Ready Power Plants – What else is needed?

Hydrogen supply to power plants

- Ensuring hydrogen grid access for power plants
- Integrated planning of gas/hydrogen, electricity (and heat) grids involving the power plant sector

Supportive market design

- General EU-wide GHG intensity target & renewable gas target
- Equal rules for all sectors regarding access to hydrogen
- Bridging the cost gap with Contracts for Difference

Contact

Ralf Wezel
EUGINE & EUTurbines
Secretary General
ralf.wezel@eugine.eu
ralf.wezel@euturbines.eu

Annette Jantzen
EUGINE
Manager Policy and Public Affairs
annette.jantzen@eugine.eu

Sònia Clarena Barón
EUTurbines
Deputy Secretary General
sonia.clarenabaron@euturbines.eu

Head Office
Lyoner Str. 18
60528 Frankfurt
Germany
Phone +49 69 66 03 – 1936

Brussels Office
Boulevard A. Reyers 80
1030 Brussels
Belgium
Phone +32 2 706 82 97

www.eugine.eu

www.euturbines.eu

COGEN EUROPE

Towards an efficient, integrated and cost-effective net-zero energy system in 2050

COGEN EUROPE

PRIME MOVERS GROUP ON GAS QUALITY AND HYDROGEN HANDLING

25 November 2021

Our Mission

Cross-sectoral voice of the cogeneration industry

Work with EU Institutions and stakeholders to shape better policies by:

- Building a robust evidence-base demonstrating the benefits of cogeneration.
- Using the expertise of our membership.
- Establishing strong coalitions and partnerships.

Members

National Associations

Corporate Members

Our Vision

Resilient, decentralised and carbon neutral European energy system with cogeneration as its backbone

2050

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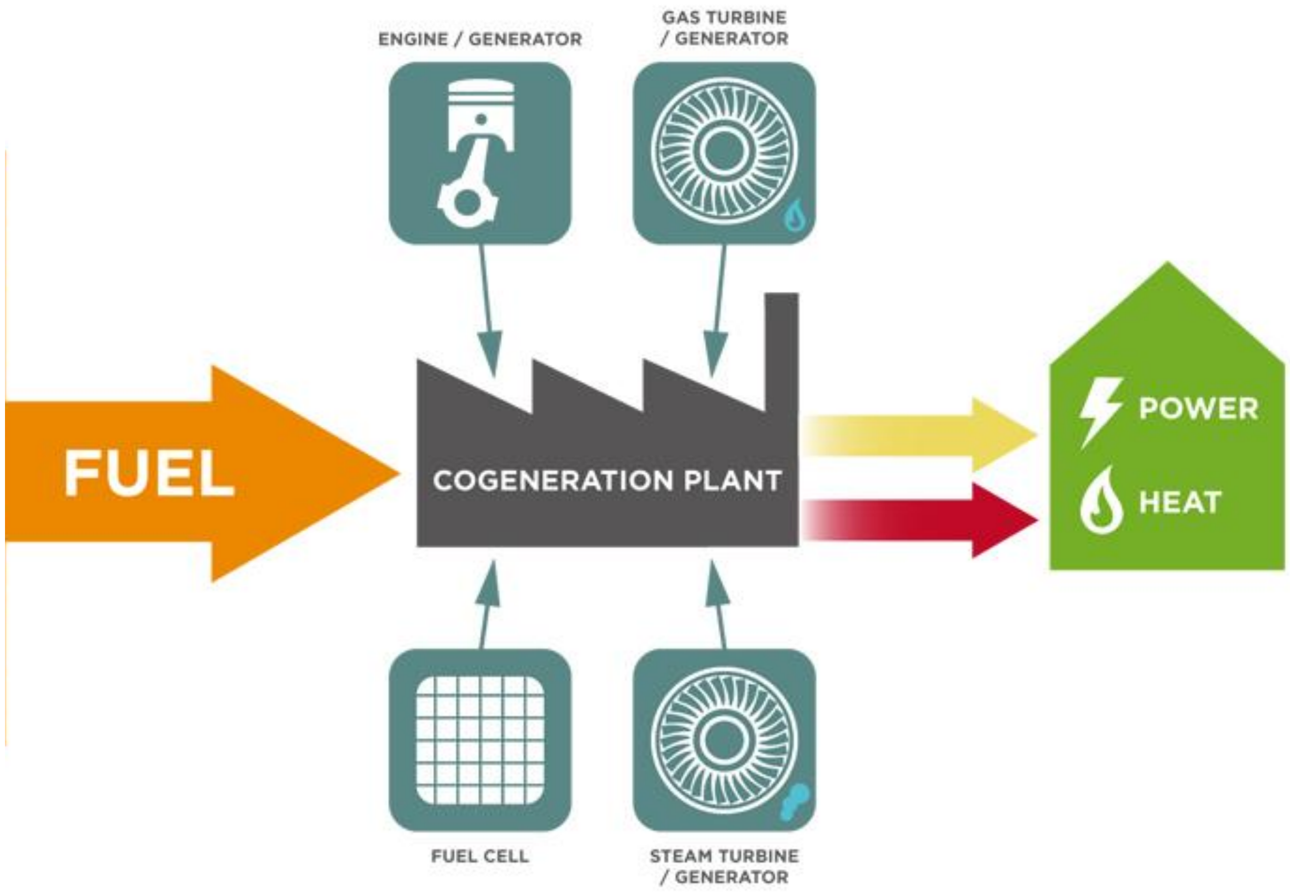
The Cogeneration Principle



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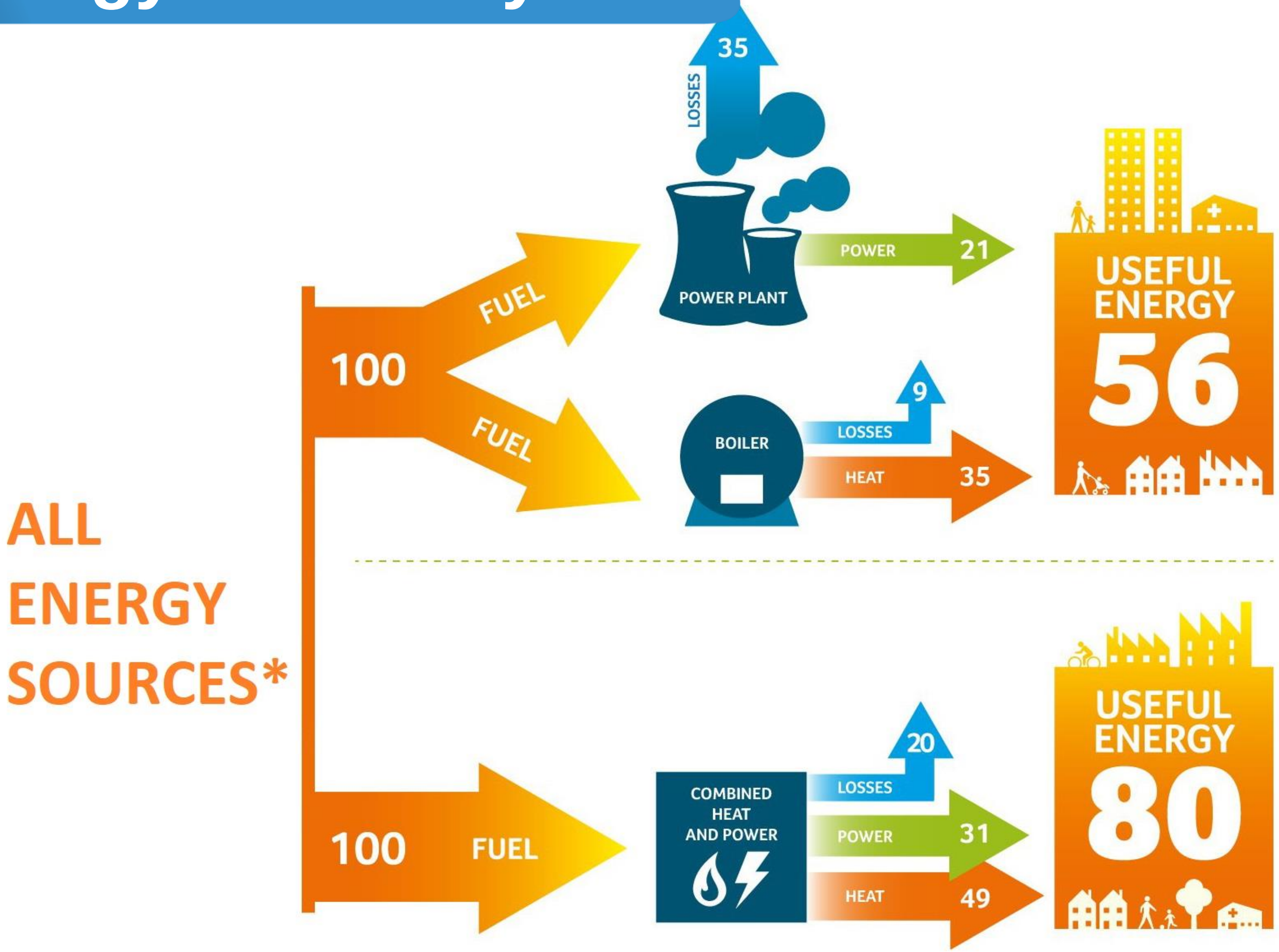
Putting Energy Efficiency 1st



* Including, but not limited to, biomass, biogas, coal, geothermal, hydrogen, (bio-)LPG, natural gas, residual waste and solar thermal

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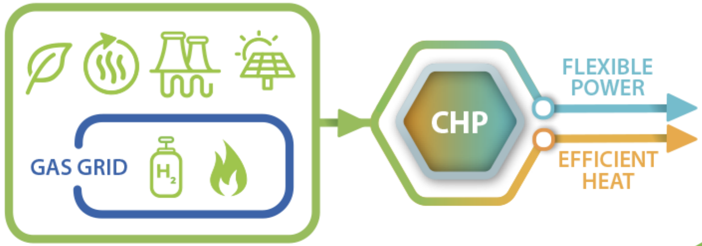
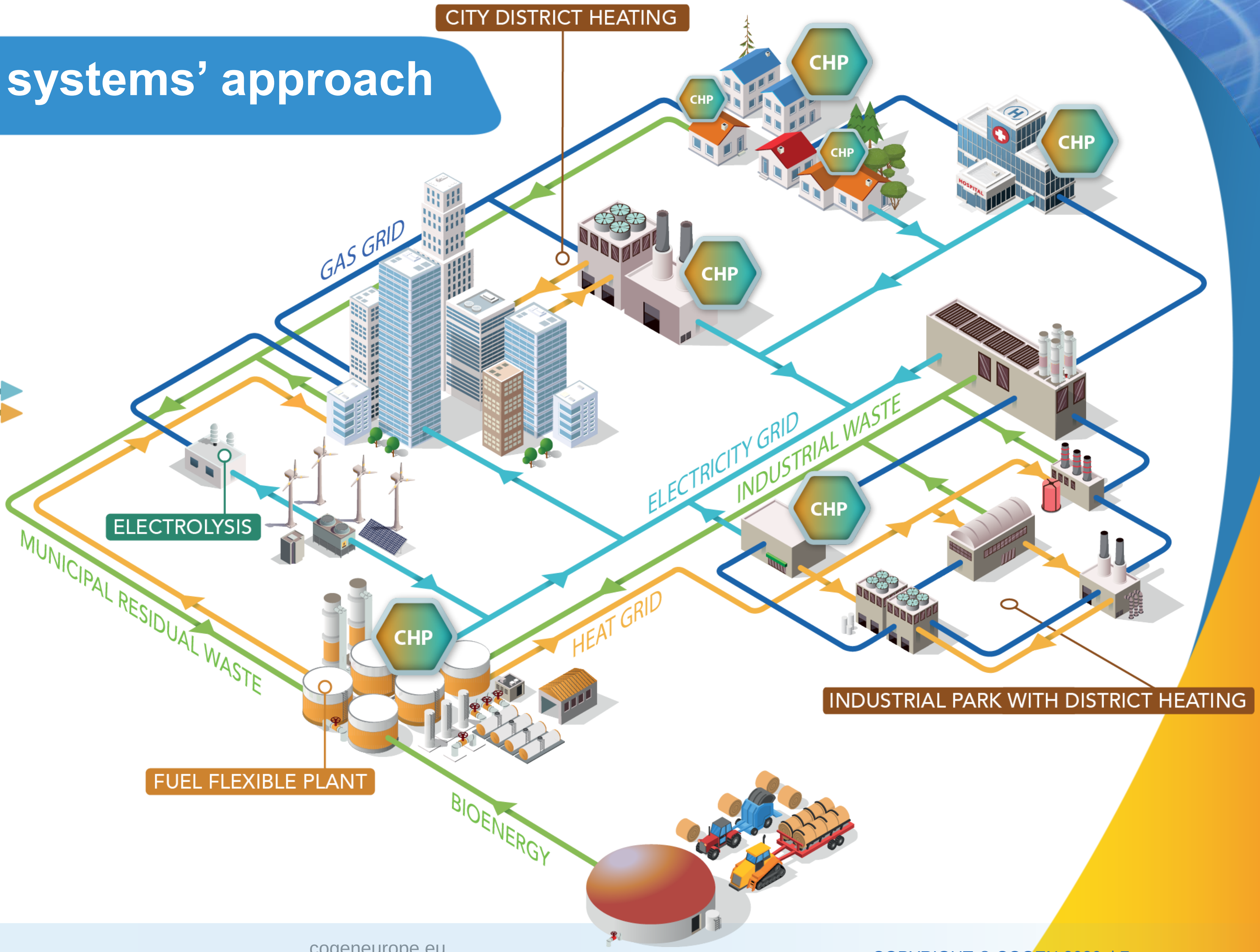
Taking an integrated systems' approach

Cogeneration:

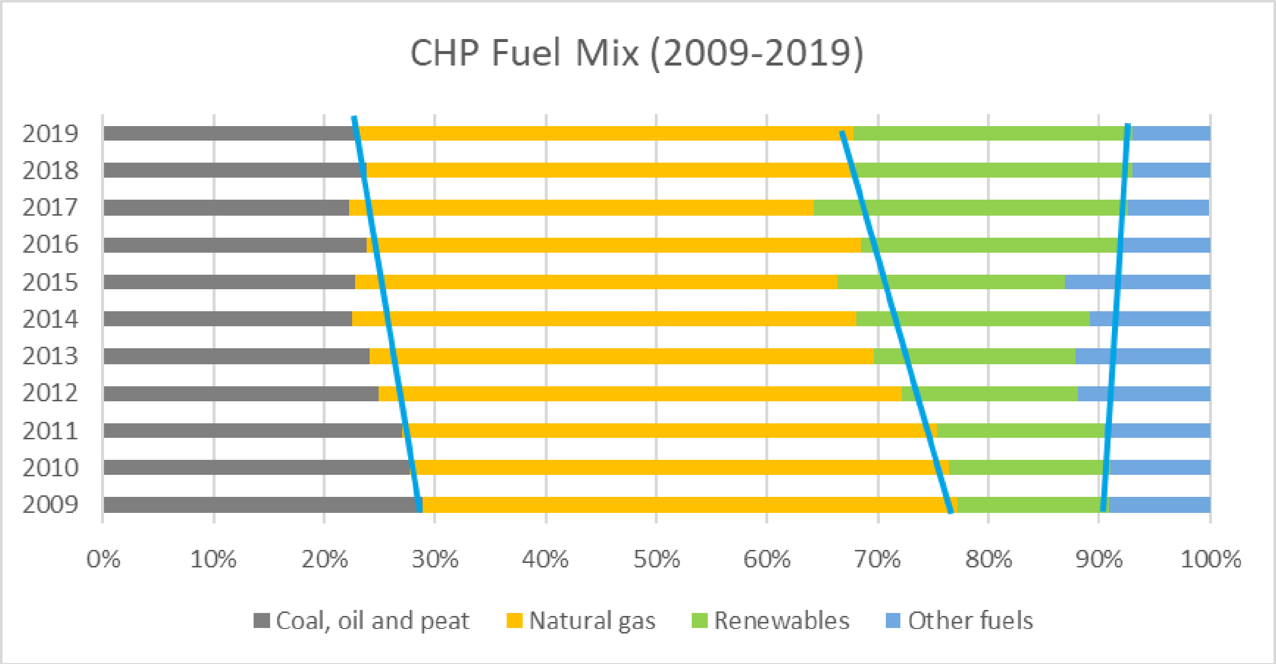
backbone of local and integrated energy





CHP enables the **integration of the energy system** by efficiently linking electricity, heat and gas at the local level and **providing energy when and where needed.**

CHP sector today



- Stable CHP capacity (**~115 GWe**)
- Delivering **12% of power** & **~14% of heat** in EU27
- In all sectors: **buildings**, **industry** & **district heating**
- Across a range of **increasingly low carbon & RES** fuels: **~40% natural gas** & **~30% renewables** (incl. green gases)
- Reducing emissions via efficiency gains & a fuel switch

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CHP's Multiple Benefits in 2050

Artelys OPTIMIZATION SOLUTIONS | STUDY ON THE ROLE OF COGENERATION

€4-8 Bn

↓ cost for energy system

150–220 TWh

↑ energy savings across energy system

~20%

↓ remaining CO_2 emissions

13-16%* of total electricity

and **~30-36% of flexible thermally generated power** at times of low wind & sun and to cover peak demand

19-27% of total heat**

and **52-100%*** of thermal heat** in buildings, industry & district heating

* excluding off-grid RES for P2X generation.
** excluding furnaces.
*** excluding furnaces; DHC for industry is 100% CHP.

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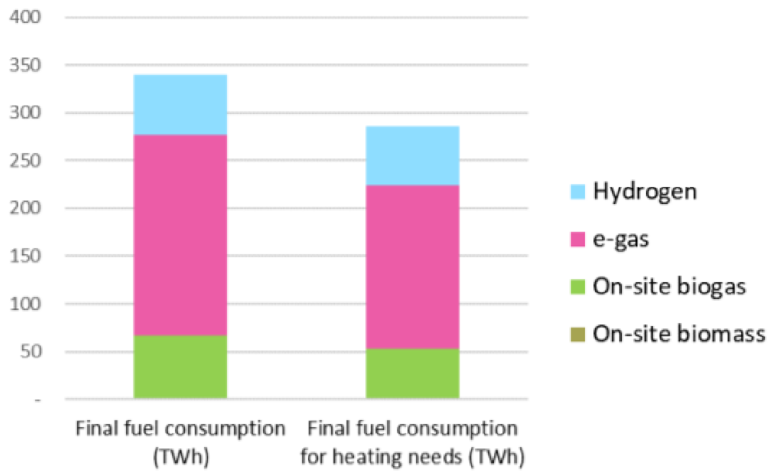
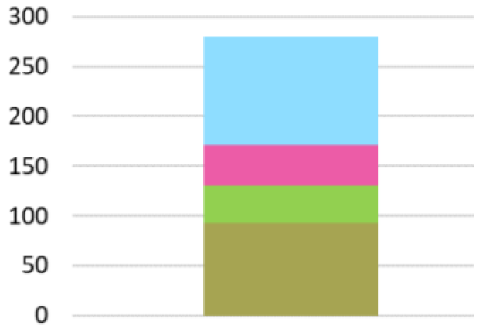
Opportunities for gas CHP in 2050

European Commission's Long Term Strategy – 1.5 TECH Scenario

Buildings gas demand



Industry gas & biomass demand



- **EC's 1.5 TECH scenario: 340 TWh** and **280 TWh of green gases** will be needed in **buildings** and **industry** to meet non-electrified demand to achieve net-zero emissions by 2050
- Optimising CHP can help maximise the use of these gaseous fuels

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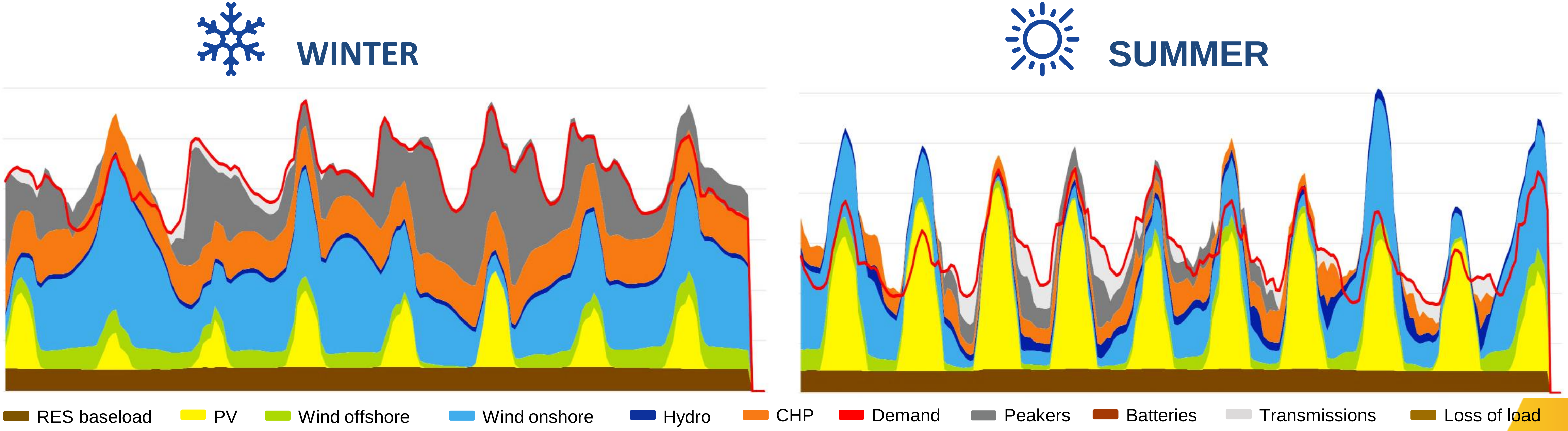
Changing role of CHP by 2050 to increasingly deliver flexibility services

CHPs will increasingly complement variable renewable generation to meet seasonal peak demand due to high shares of electrified heat.



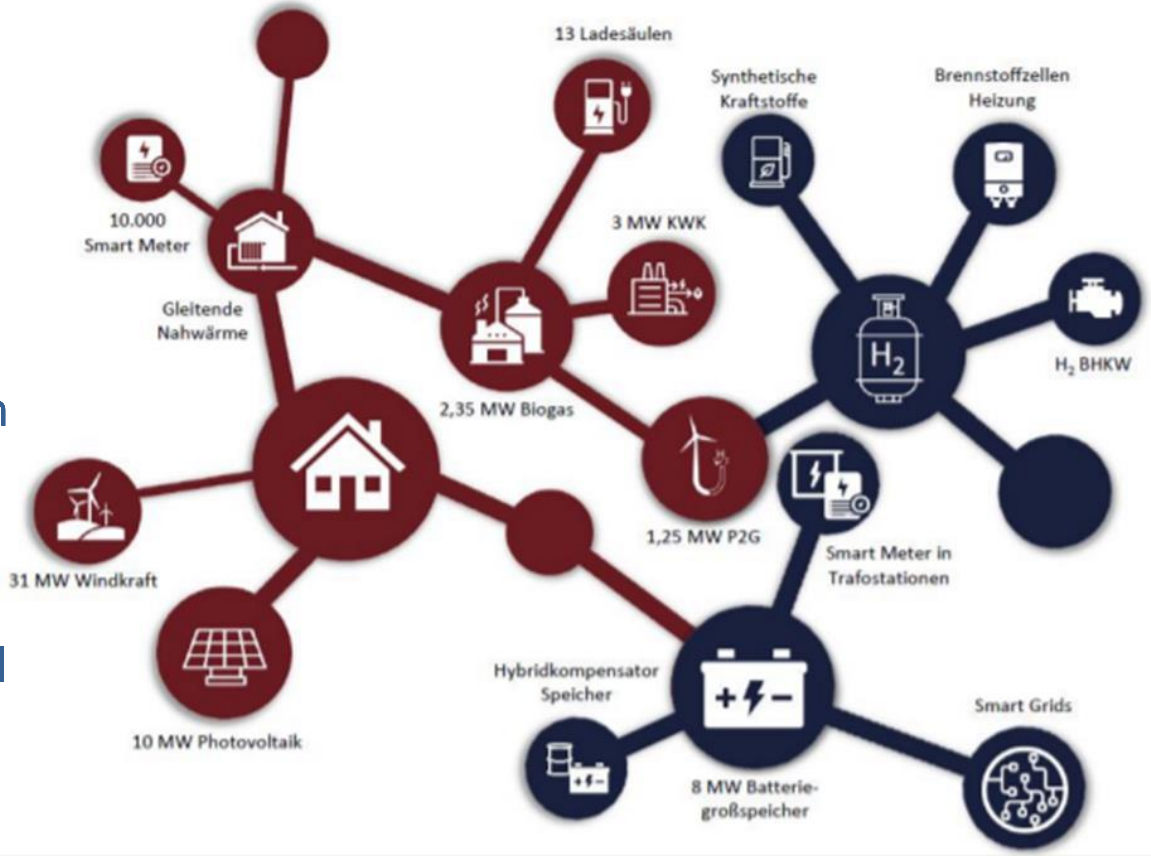
CHPs (orange) run as base load during low wind and sun periods, covering a high share of the peak demand.

CHP stops producing when variable renewable generation is sufficient to cover demand, and covers evening peaks.

Best practice I: Hassfurt City

- A mix of solutions deployed to deliver lower emissions at lowest cost for consumers: PV, wind, biogas, batteries, district heating and CHP

- CHP system is flexible is multiple ways:
  - ➢ Can ramp up and down production of electricity to help match supply and demand depending on PV/wind availability
  - ➢ Can run on up to 100% renewable H2, obtained from PV or Wind that would have been curtailed
  - ➢ Locally produced biogas is used efficiently in another CHP unit



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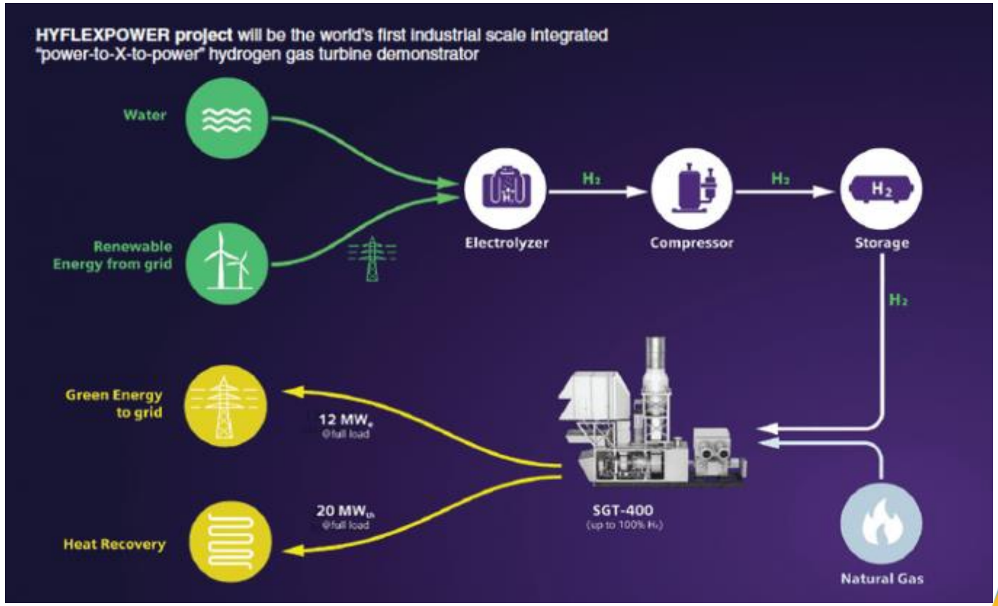
Best practice II: HYFLEX POWER

First demonstration of an integrated power-to-hydrogen-to-power plant

- *Duration: 2020-2024*
- *Budget: EUR 15 million*
- *Partners: Siemens, Engie, Centrax, Duisburg-Essen University, DLR, Lunds University, UCL, NTUA, ARTTIC*



Objectives

- Update and enhance an existing power plant within an industrial facility in Saillat-sur-Vienne, France
- Integration of energy conversion (power-to-H2) in the demonstration plant using excess energy from RES and necessary storage capabilities
- Operation at full load and production of 12 MW electrical energy with high-hydrogen fuel mixtures of at least 80% by volume H2 up to 100%

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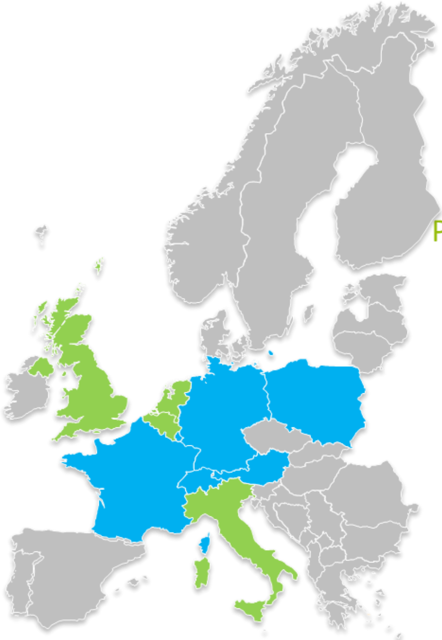
Best practice III: PACE Project

PACE at a Glance

Promoting a successful transition to the large-scale uptake of Fuel Cell micro-Cogeneration across Europe

PACE
Pathway to a Competitive European Fuel Cell micro-CHP Market



- Units deployment + installer training + targeted market & policy development activities
- Units deployment + installer training

9	> 2,800	>500	10	4	€90m	6
Partners	Fuel Cell micro-Cogeneration units	Systems per manufacturer	Countries	Countries	Total budget	Years
Representing manufacturers, utilities & research community	To be deployed across Europe between 2016-2022	Established production capacity per manufacturer	Where the units will be installed	Selected for policy & market development (Belgium, Italy, Netherlands and UK)	Including €33.9m Horizon 2020 funding via FCH JU	Project duration of 73 months (June 2016 – June 2022)

Coordination & Dissemination Partner
COGEN EUROPE

Manufacturers
SOLID POWER, BOSCH Invented for life, sunfire, VIESSMANN, BDR THERMEA GROUP

Research Partners
elementenergy, DTU, HOCHSCHULE LUZERN

>10,000
FC micro-cogeneration units/year post 2020

17

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Roadmap for RES/decarbonised gases towards carbon neutrality by 2050

- **Thermal energy will be key** in ensuring stability and efficiency complementing higher shares of electrification and intermittent RES power

- **A comprehensive roadmap is needed for the uptake of renewable and decarbonised gases, including H2, and their efficient use** in all sectors including industry and buildings

- **Gas quality standardisation is critical** to ensure a predictable and smooth transition for both solution providers and end users.

Thank you for your attention!

Alexandra Tudoroiu-Lakavice
Head of Policy
E-mail: alexandra.tudoroiu@cogeneurope.eu
Phone: +32 (0)2 772 82 90
Website: www.cogeneurope.eu
Twitter: @CogenEurope

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Jenbacher gas engines „Ready for H2“

PMG Meeting on 25th of Nov. 2021

INNIO Jenbacher GmbH & Co OG
Jenbach, Austria
www.innio.com

Dr. Klaus Payrhuber

25th of November, 2021

Transitioning to 100% Renewable fuels

Today

45% ⬅ EU ➡ 55%

Natural Gas
CHP

Biogas
CHP

Today's mix of
fossil natural gas and
renewable gas

Tomorrow

Biomethane or
Synthetic Methane
CHP

Biomethane &
CO_2 usage
CHP

Hydrogen
CHP

Biogas
CHP

Carbon neutral fuels &
green hydrogen

Jenbacher*'s experience with Hydrogen & Hydrogen mixtures

process gas

>95% H_2 as energy input

4 x 200.000 oh

CO_2 neutral

Coke gas (Profusa) COD 1998	Process gas (Krems) COD 1996	Syngas (Mutsu) COD 2003	Pure Hydrogen 2021+
H_2: ~50-70Vol% CH_4: ~20-25Vol% LHV: ~5 kWh/m³	H_2: ~15-17 Vol% CH_4: ~1.5 Vol% LHV: ~0.5 kWh/m³	H_2: ~30-40 Vol% CO: ~25-30 Vol% LHV: ~2.5 kWh/m³	H_2: … 100 Vol% Nat. Gas or Inerts LHV: ~3 kWh/m³

Commercial operation
(challenges: gas quality variations)

Future

More than 250MW installed with syngas / process gases

*Indicates a trademark

Ready for Hydrogen – what it means

PR from July 2021

JENBACHER
INNIO

“**Ready for H2**” means the Jenbacher* gas engines can operate with up to 20 (25) %(v) of hydrogen and can be converted to 100% H_2 operation.

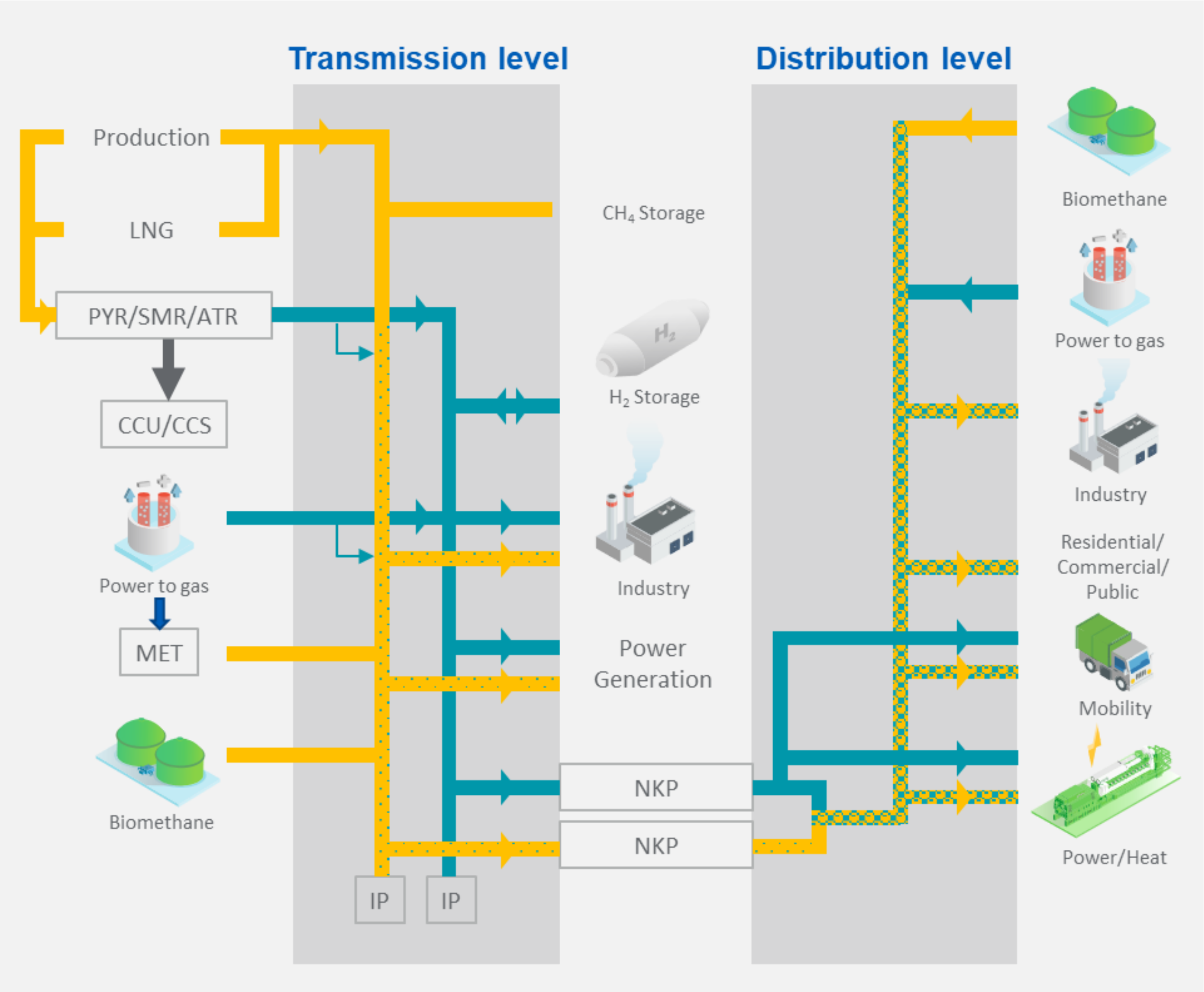
A “**Ready for H2**” designed Jenbacher gas engine plant helps to reduce future H_2 retrofit costs.

Type 4 is already available for 100% H_2 operation.

*Indicates a trademark

Ready for Hydrogen – background information

Hydrogen mixed to pipeline gas or provided through a dedicated hydrogen network



Short term

$NG+H_2$

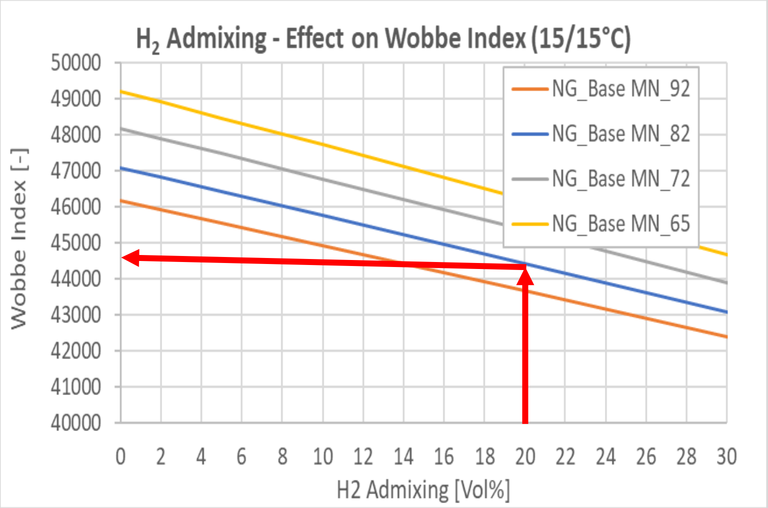
Longer term

H_2

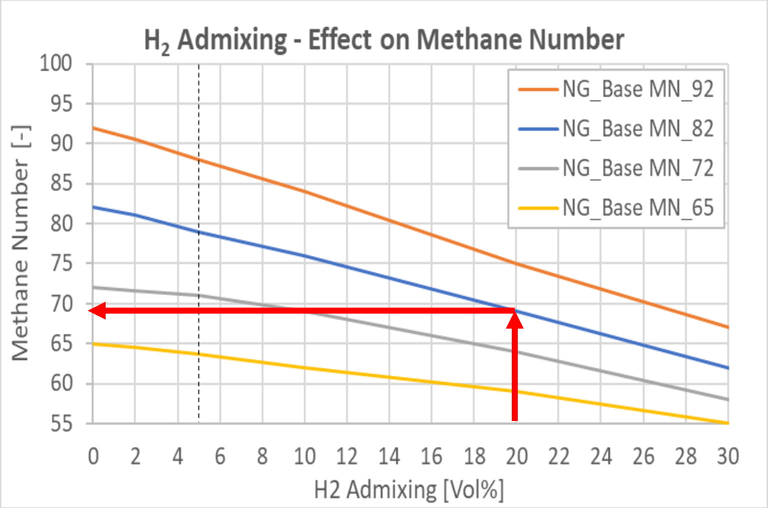
Ready for Hydrogen – background information

Hydrogen mixing to pipeline gas changes gas properties

H_2 Admixing-Effect on Wobbe Index (WI)

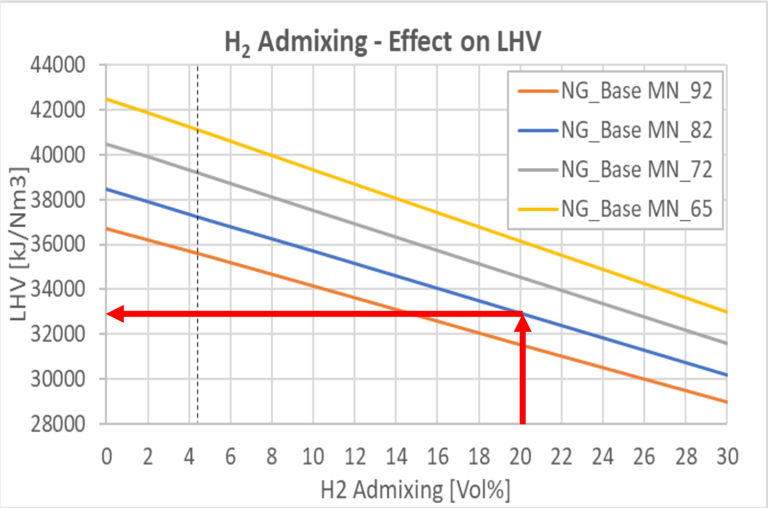


H_2 Admixing-Effect on Methane Number (MN)



20 Vol% H_2 -> **10-15 MN reduction**

H_2 Admixing-Effect on LHV

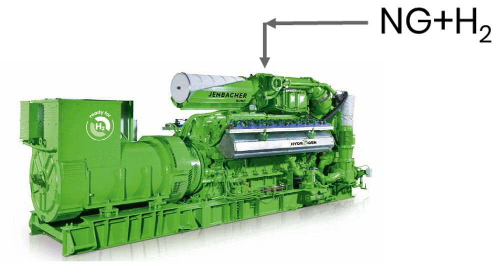


20 Vol% H_2 -> **~15% heating value**

“Ready for H2” – INNIO Jenbacher* categorization

A

H_2 in pipeline gas

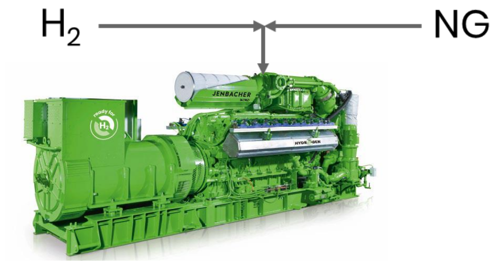


A-1: Low H_2 blending
no upgrade required
<5%v H_2

A-2: Medium H_2 blending
minor upgrades required
5-20 %v H_2

B

H_2 local admixing

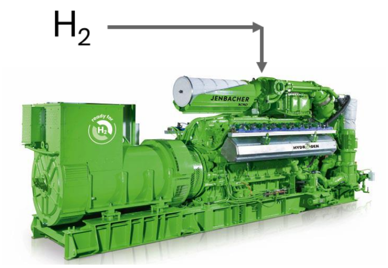


B-1: Special gas engine
dedicated product design
up to ~60%v H_2

B-2: NG / H_2 engine
upgrades required
100% NG / 100% H_2

C

Pure H_2



C: H_2 engine
upgrades required
100%v H_2

Conventional NG+H2 fuel mixture boosted system (A-1, A-2, B-1, B-2)

H2 fuel injection system (B-2, C)

A-1	A-2	B-1	B-2	C
no modifications required	existing versions available	existing versions available	pilots available (pre-serial engines)	pilots available (pre-serial engines)

*Indicates a trademark

Ready for Hydrogen – INNIO Jenbacher* product portfolio

Available from 2022 onwards

Electrical output range (kWel)

Generator Output @ 50Hz & NG fuel

0 | 1.000 | 2.000 | 3.000 | 4.000 | 5.000 | […] | 10.000

	Models	A: H_2 in pipeline gas <5%v standard	A: H_2 in pipeline gas <20%v optional
Type 9	J920 FleXtra	✓	✓
Type 6	J612 J616 J620 J624	✓	✓
Type 4	J412 J416 J420	✓	✓
Type 3	J312 J316 J320	✓	✓
Type 2	J208	✓	✓

20 or 25%v of H2 in pipeline gas is subject to relevant regulations, norms and standards for certifying fuel gas components on the Genset or balance of plant equipment.

Boundary conditions for up to 20 (25 for testing purposes) %v of H_2

- H_2 signal from pipeline gas supplier available
- Base gas without H_2 content has a MN[1)] >70
- RoC of H_2 content <4%(vol)/min
- RoC of MN[1)] <10 MN/min
- LHV fluctuation <4%/min

1) MN … Methane Number acc. EN 16726; RoC … Rate of Change
See also Jenbacher TI 1000-0300 for Fuels

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*Indicates a trademark

H_2 local admixing demo projects – H_2 content known at the plant

30%v H_2

Bozen - Italy
2017, Horizon 2020 Demo

J612, main fuel NG

Sinfonia

30%v H_2

Biogas Stream- Austria
2008 Demo

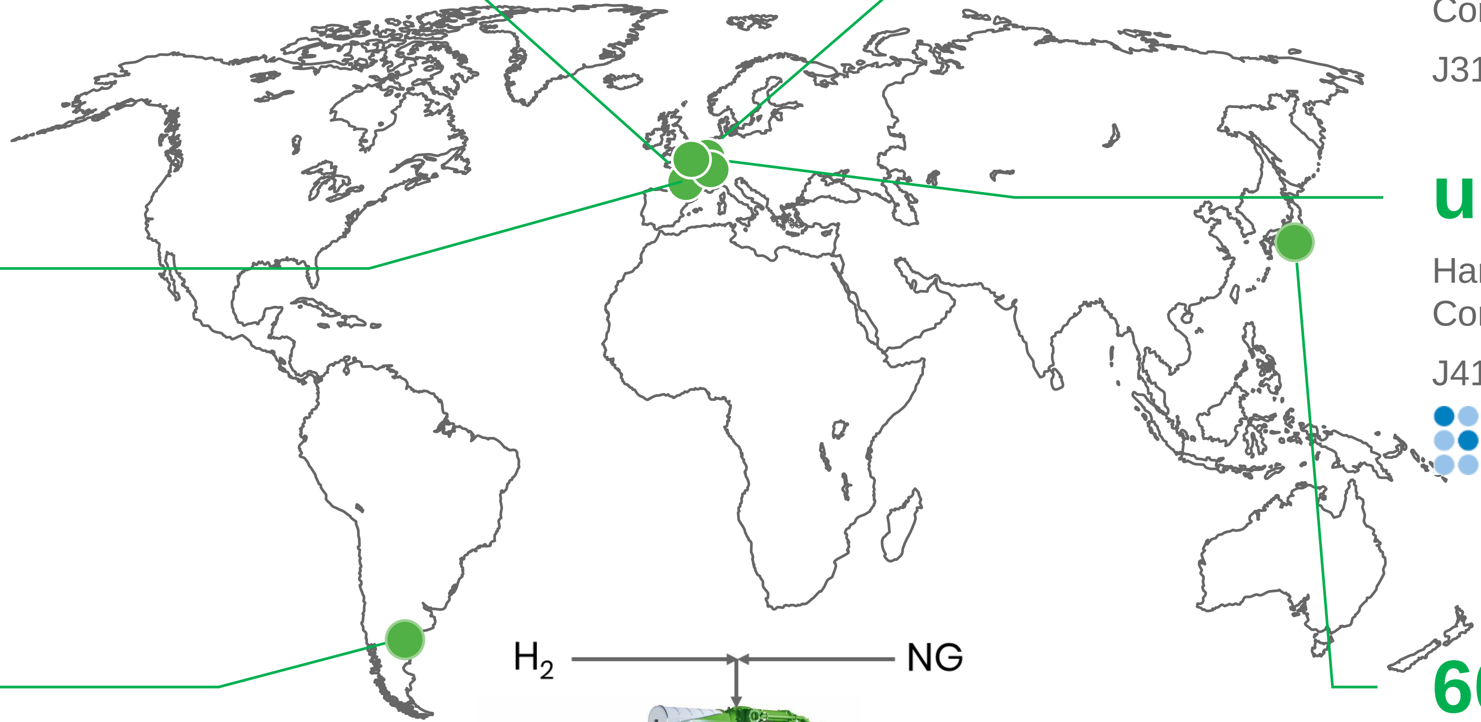
J312, main fuel NG

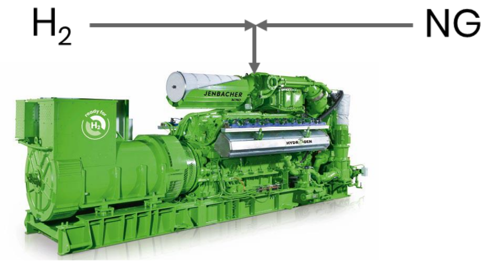
42%v H_2

Hychico – Argentina
Operating since 2008

J420, main fuel NG

HYCHICO





60%v H_2

DLR

H2ORIZON - Stuttgart
Commissioning 2020

J312, main fuel NG

up to 100% H_2

HanseWerk Natur - Hamburg
Commissioning 11/2020

J416, main fuel NG

Hanse Werk

60%v H_2

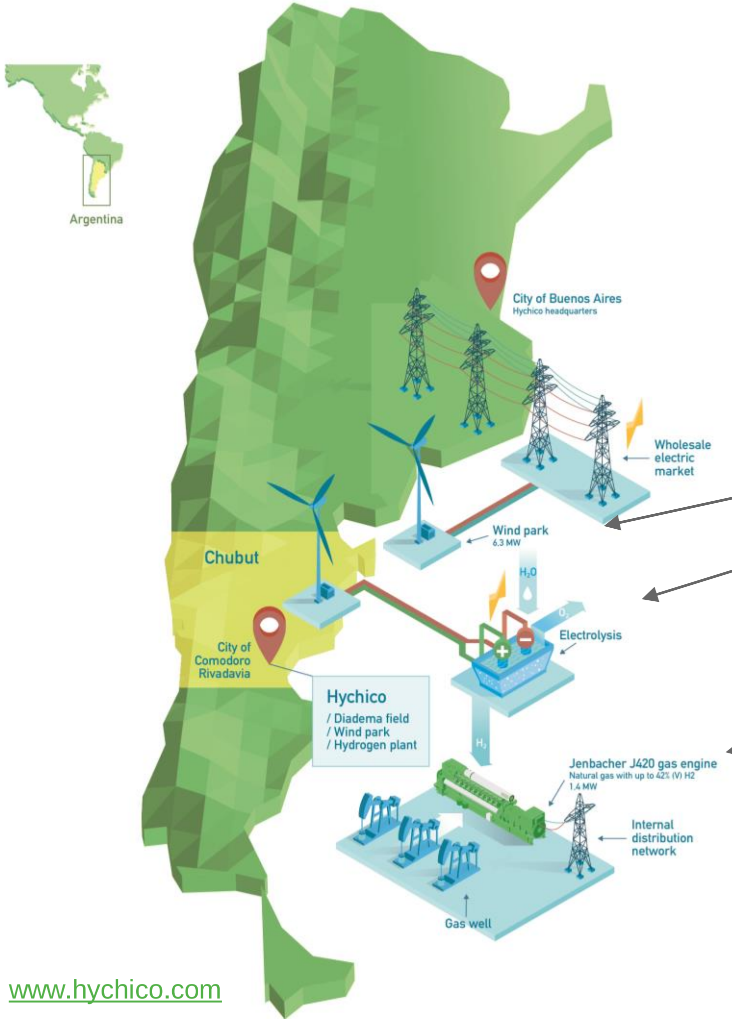
Ando Hasama - Japan
Commissioning 01/2020

J312, main fuel NG

HAZAMA ANDO CORPORATION

JENBACHER
INNIO

Hychico, Argentina site



www.hychico.com

Hychico, Diadema Wind Park and Hydrogen Plant, Chubut Province, Argentina

About the region:

Currently large oil & gas fields

2,000 GW wind power potential, compared to 600 GW global installations today

Ideal place for exporting green H_2 and e-fuels in the future

Green H_2 demo :

6.3 MW wind park with **54.9% CF (2017), avg. >50%**

0.8 MW of electrolyser (2 units), 120 Nm^3/hr H_2

H_2 with high purity (99.998%), O_2 for local market

Underground H_2 storage research

~70,000 oh
since 2008

J420 converts H_2 back to power

Output	1,415 kW_{el}
Main Fuel:	NG MN >90

Operation with **controlled H_2 blending**

0-27 v% H_2	1,415 kW
28-42 v% H_2	1,415 to 1,180 kW

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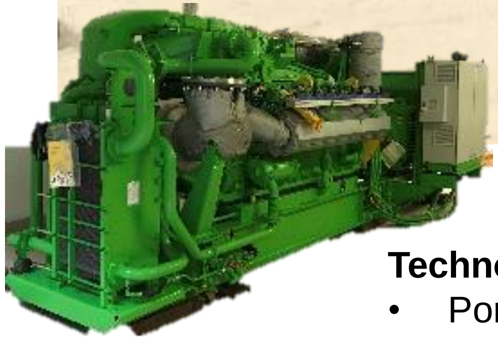
H2-Motor – demonstration of engine upgrade in the field

Retrofit 2020 – HWN Othmarschen: First MW gas engine with field conversion from natural gas to hydrogen operation

J416	Nat. Gas (design 2019)	20%v H_2 admixing (after retrofit)	100% H_2 operation (after retrofit)
Electrical output	999 kW	999 kW	>600 kW
Electrical efficiency	42%	~42%	~40%
Total efficiency	93.5%	~93.5%	~93%
NO_x emissions	<250 mg/Nm^3 @ 5%O_2	<250 mg/Nm^3 @ 5%O_2	<100 mg/Nm^3 @ 5%O_2
CO_2 emissions	216 g/kWh_{el}	201 g/kWh_{el} (-7%)	0 g/kWh_{el} (-100%)

CO2 Emissions calculated with heat bonus method



Technology

- Port injection (gas pressure 8+bar)
- Cylinder selective combustion control
- Wastegate for turbo charger

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International Association of Oil & Gas Producers

IOGP perspective on the role of hydrogen

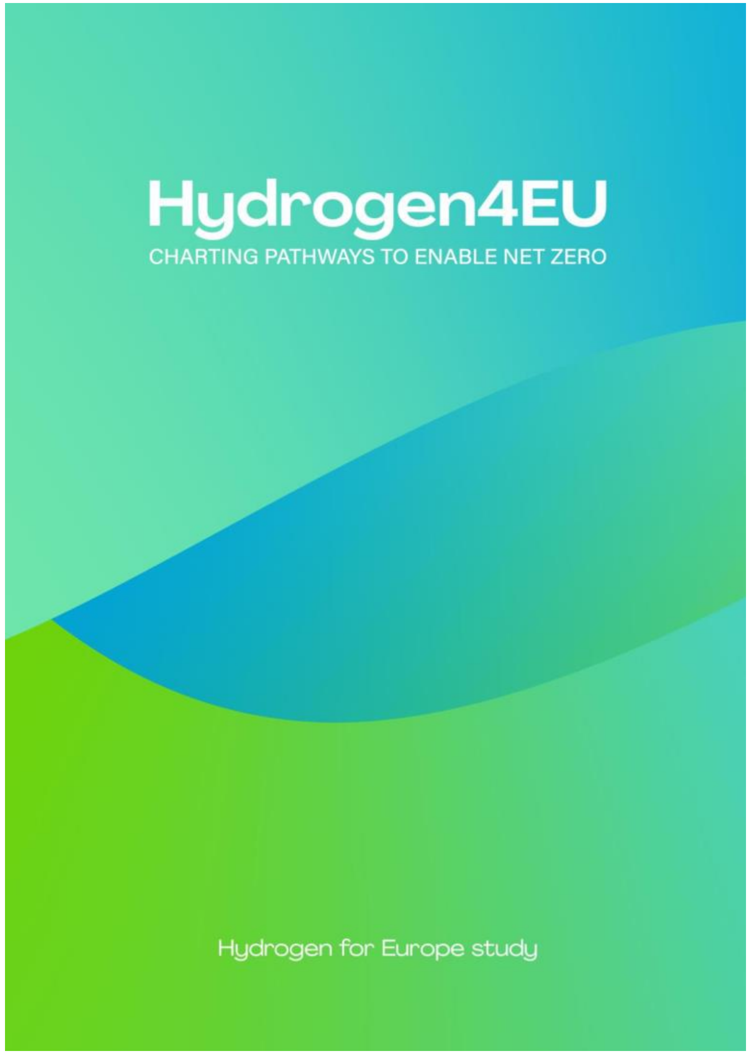
Prime movers group GQ&H2 Workshop

25 November 2021

Kees Bouwens, ExxonMobil

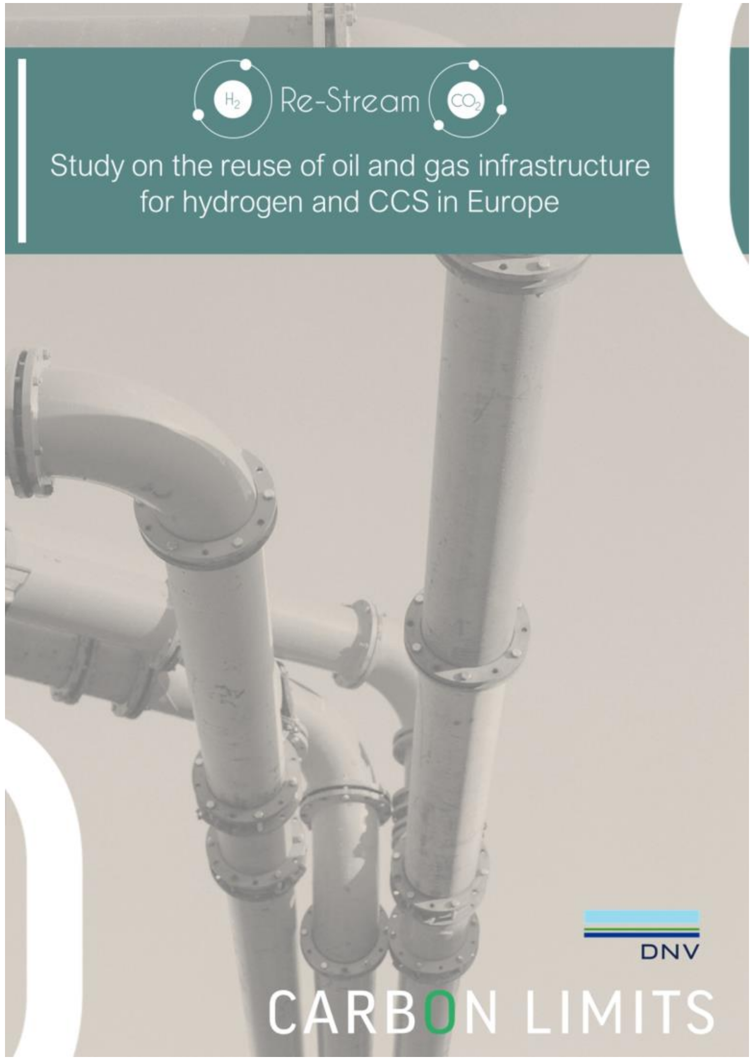
IOGP Contributions to the Hydrogen Development

- Hydrogen pathways to enable net zero
  - IOGP is one of the funding partners of the multi-client **Hydrogen4EU** study
  - This study was conducted by IFP Energies Nouvelles, SINTEF Energi AS and Deloitte Finance SAS
  - Study considers two pathways to enable net zero: Technology Diversification and Renewable Push
  - For more information: www.hydrogen4eu.com



IOGP Contributions to the Hydrogen Development

- Potential reuse of oil and gas infrastructure for hydrogen and CCS in Europe
  - IOGP, together with ENTSOG, GIE and Concawe, commissioned the **Re-Stream** study
  - This study, conducted by Carbon Limits and DNV, confirms the significant potential for reuse of oil and gas infrastructure in Europe for hydrogen and CO_2 transport
  - On 29 November 2021, Carbon Limits and DNV will host an 1.5 hr online webinar to present the study's findings and methodology at 3:30 pm CET. To register use this link
  - For more information: www.carbonlimits.no/project/re-stream-reuse-of-oil-and-gas-infrastructure-to-transport-hydrogen-and-co2-in-europe



International Association of Oil & Gas Producers

Gas Quality in the Existing Gas Network

- Completion of the Internal Gas Market was achieved without binding EU rules on gas quality
  - Supply portfolio and the system ability to co-mingle/blend different gas qualities varies widely across Member States
  - Despite this the EU gas industry has been able to handle diverse gas supplies at entry points while maintaining exit specs within narrow regional bands based on national rules
  - At IPs, no gas quality issues have been identified that the neighbouring TSOs have not been able to solve
- Decarbonisation of the gas market brings new challenges for gas quality
  - Consumers of gas should continue to receive a reliable product
  - Hydrogen and low-carbon gases should be accepted in the gas network provided there is a dedicated outlet, or it can be blended to meet end-users' needs downstream of the injection point
  - Gas system can absorb limited amounts of hydrogen; blending with natural gas is not the best use of hydrogen (when its pure value is higher), but it may provide an outlet while dedicated hydrogen infrastructure is developed in parallel

Potential Role for Hydrogen

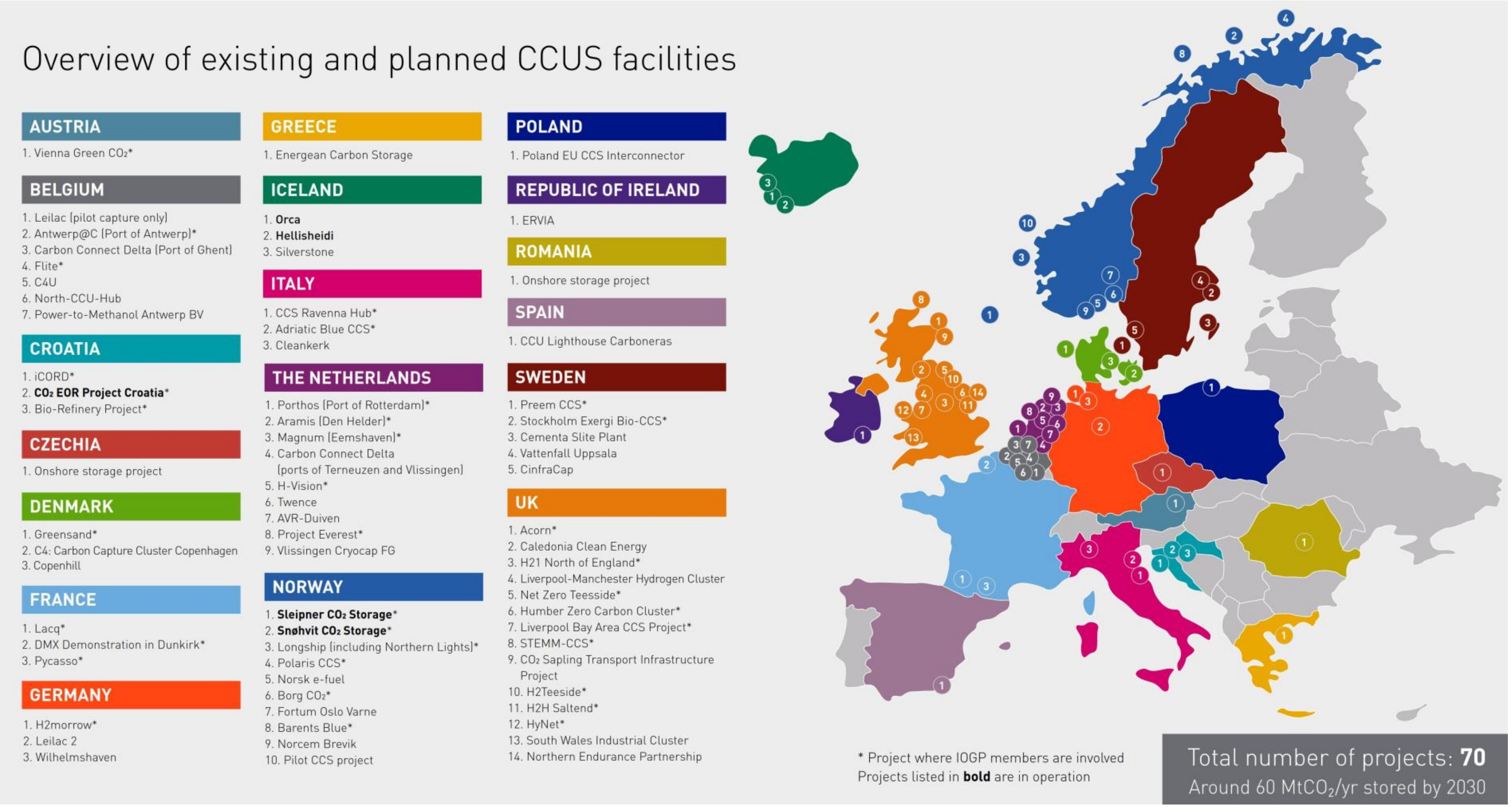
- Hydrogen4Europe study shows that hydrogen can play a major role in decarbonisation of the energy sector
  - Exceeding 100 million tons (Mt) by 2050 (about 20% of final energy consumption)
  - Primary hydrogen application is in transport sector (~50 Mt) and industry (~45 Mt)
  - Moderate uptake in building sector is expected due to trade-offs between other options to decarbonize such as biogas, direct renewables and heat pumps
- Hydrogen with CCUS can fast-track the development of a clean hydrogen economy
  - Retrofitting existing hydrogen production facilities with CCUS is a low-cost abatement option
  - Natural gas based hydrogen production with CCUS can scale-up a hydrogen market while additional renewable capacity is built to have enough renewable electricity for hydrogen production
  - In the long-term, CCUS can provide negative emissions

IOGP Member Companies’ Contributions

CCUS projects in Europe:

- Many of these are hydrogen projects

Additional to large-scale renewable hydrogen projects, such as NorthH2 projects



For more information: https://www.oilandgaseurope.org/documents/map-of-eu-ccs-projects/

For more information please contact:

Caterina De Matteis: cdm@iogp.org

Kees Bouwens: kees.bouwens@exxonmobil.com

www.oilandgaseurope.org

Registered Office
City Tower
Level 14
40 Basinghall Street
London EC2V 5DE
United Kingdom
+44 (0)20 3763 9700
reception@iogp.org

Brussels Office
Avenue de Tervuren 188A
B-1150 Brussels
Belgium
+32 (0)2 790 7762
reception-europe@iogp.org

Houston Office
15377 Memorial Drive
Suite 250
Houston, TX 77079
United States
+1 (713) 261 0411
reception-americas@iogp.org

Session 3: R&D, standardisation & H2 integration

Session 3: R&D, standardisation and H_2 integration

Introduction and Q&A moderated by **Alexandra Kostereva** | Project Manager at GERG

Hydrogen standardization updates

- **Hiltrud Schülken** | Secretary CEN TC 234 Sector Forum Gas infrastructure
- **Francoise van den Brink** | Secretary CEN/CLC/JTC 6 and CEN/CLC/SFEM/WG Hydrogen

EASEE-gas Common Business Practice - Hydrogen Quality Specification

- **Peter van Wesenbeeck** | Chair of the EASEE-gas Gas Quality Harmonisation Working Group

GERG H2 roadmap : Identifying knowledge gaps in R&D to foster collaboration

- **Tanguy Manchec** | Hydrogen Working Group Chairman at GERG

Marcogaz activities to support hydrogen integration in natural gas system

- **José Lana** | Chair of Gas Quality & Renewable Gases Working Group at Marcogaz

European Standardization Organizations

European standardization
PMG workshop session 3 2021-11-25

Hiltrud Schülken, secretariat CEN/TC 234, CEN SFG_I, SFGas GQS

Françoise van den Brink: secretariat CEN/CLC SFEM/WG hydrogen, JTC 6 and JTC 14 WG 5

Overall hydrogen standardization landscape

Overall Sector Fora: CEN/CLC/ SFEM WG Hydrogen, CEN SFGas (Infrastructure/Utilisation)

Production: ISO/TC 197 (mirrored by CEN/CLC/JTC 6)

Import/export: CEN/CLC/JTC 14 WG 5 Guarantee of origin and CEN/CLC/JTC 6

Infrastructure incl. components: CEN/TC 234, CEN/TC 235, CEN/TC 236, CEN/TC 237…

Storage: CEN/TC 234, CEN/TC 268, CEN/CLC/JTC 6

Mobility: CEN/CLC/JTC 6, CEN/TC 268, ISO/TC 197…

Built environment/application: CEN/SFG_U and dedicated CEN/TCs on appliances

Industry (High temperature and Feedstock): Sector Fora Joint Task Force Hydrogen purity/quality need for industrial end-user

Cross cutting items: CEN/CLC/JTC 6 and other TCs

Current drafts of EC Standardisation Requests to CEN and CENELEC

SReq Hydrogen

- Complete chain H2 production (new) to application
- H2 in repurposed and dedicated infrastructure, H2NG in NG infrastructure
- Methanation
- Cross-cutting items
- Revision/elaboration of ENs

Highlight: Involvement of 49 CEN/CLC/TCs; Including H2 and H2NG quality standards

SReq Appliances

- Design, construction of appliances and fittings allowing compliance with Gas Appliance Regulation (2016/426/EC)
- Revision 75 and completion of 3 identified standards

Highlight: EN 437 Test gases, Test pressures - Appliance categories (current process includes H2 and H2NG)

SReq Alternative Fuels 2

- Focus on electricity and **hydrogen**
- support to interoperable infrastructure for
  - hydrogen supply for road transport (gasous and liquified)
  - refuelling vessels and hydrogen, methanol and amonia bunkering

- Focus on 4 identified standards with different deadlines acc to maturity

Scoping of Standardization Request on hydrogen

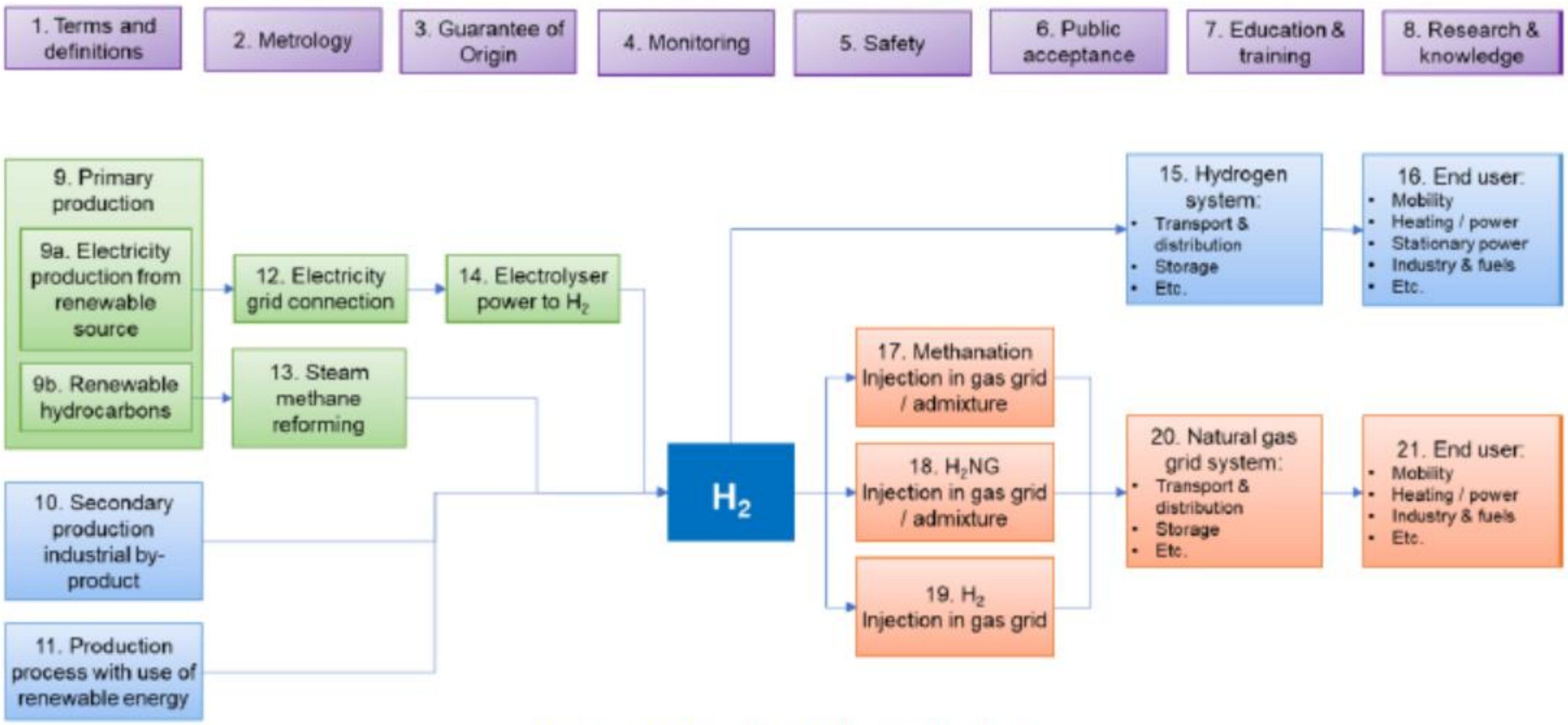


Figure 3 Flowchart H_2 production

Draft SReq Hydrogen

Draft Work Program available with input of CEN/CENELEC TCs and Sector Fora

Prioritisation criteria:

- Blocking aspects;
- Interdependencies from a technical/practical point of view;
- EC milestones: H2 Strategy – Report on Chemical Energy Storage Technologies - Energy System Integration Strategy. In addition, it needs to be considered H2NG admixtures, domestic and commercial applications.
- Funding

Steps/phases classification according to the prioritisation criteria:

- **Step 1:** high priority regarding technology and timeline and/or possible to start with;
- **Step 2:** high priority regarding technology; start not yet possible due to need of additional technology development/knowledge;
- **Step 3:** necessary to enable the use of hydrogen, but knowledge is not mature.

Draft SReq Hydrogen

Informal exchange with EC leads to following need of consideration:

- Respect of EC Hydrogen Strategy (i.e. production of renewable hydrogen, mobility and industry)
- production technologies/facilities of renewable and low-carbon H2.
- Alignment with the standardization requests for AFI and GAR.

EC-CEN/GERG PNR H2 in gas systems – Available knowledge for hydrogen standardisation

CEN CENELEC

– Comprehensive pre-normative project on 9 priority subjects along the gas chain under the umbrella of CEN/TC 234 WG 13 (Supervisory Body)

– Knowledge collection from > 1000 studies/sources and identification of gaps

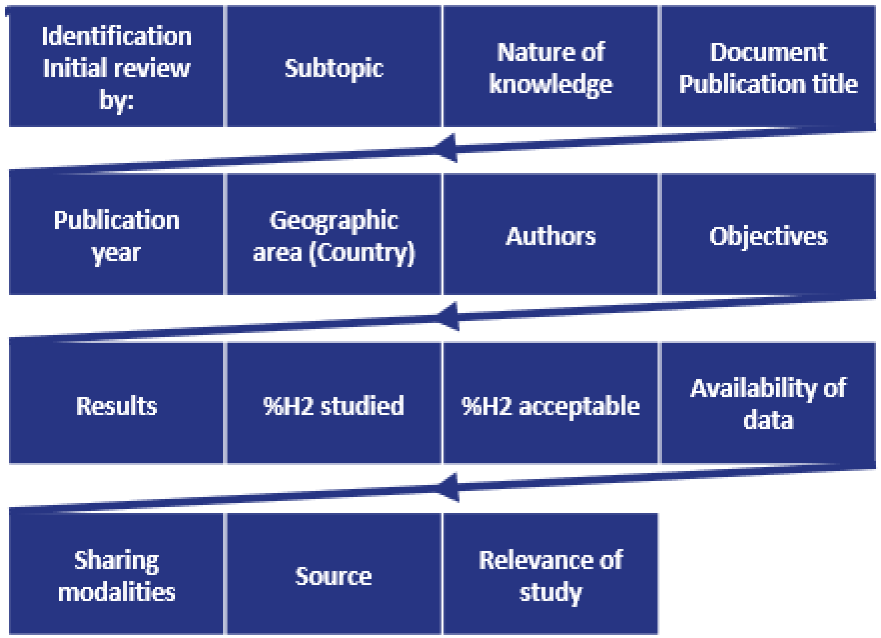
– Involvement of all relevant CEN-CLC TCs and partner organisations

List of work packages and Team leadership

	Priority / topic area	Lead
1	Safety	DNV
2	Gas Quality	GRT Gaz
3	Underground storage	DBI
4	Power Generation and Engines	DNV
5	Industry	Engie
6	Steel Pipes	GRT Gaz
7	Network Equipment	DBI
8	End use commercial and domestic	DGC
9	Gas Quality Requirements for industrial users	GRT Gaz
	Project administration on behalf of CEN	DIN
	Coordination, interfaces and transverse subject management	GERG

cen DIN GERG THE EUROPEAN GAS RESEARCH GROUP

EC-CEN/GERG PNR H2 in gas systems
Availablity of study results



- Final report approval at CEN/TC 234 WG 13 meeting on 2021-11-29 including a list of sources with identified findings.
- Reporting to EC by 2022-01-30
- Availability of the project results to be clarified; broad distribution and use preferred (after confirmation by EC)
- Follow-up projects to be requested to EC in the CEN context and other European organisations

CEN/CLC/SFEM/WG hydrogen

The SFEM/WG Hydrogen is made up of various international industry, research, and governmental partners. The main objective of this working group is to perform an analysis of the state of the art of technology and standardization and a gap analysis on the main barriers, challenges and needs in the field of hydrogen.

The working group published a report in 2015 and an updated report in 2019.

The two reports are mainly gap analyses on the hydrogen sector and what is needed in terms of (pre-normative) research and standardization.

References:

https://doi.org/10.2790/66386

https://doi.org/10.2760/449204

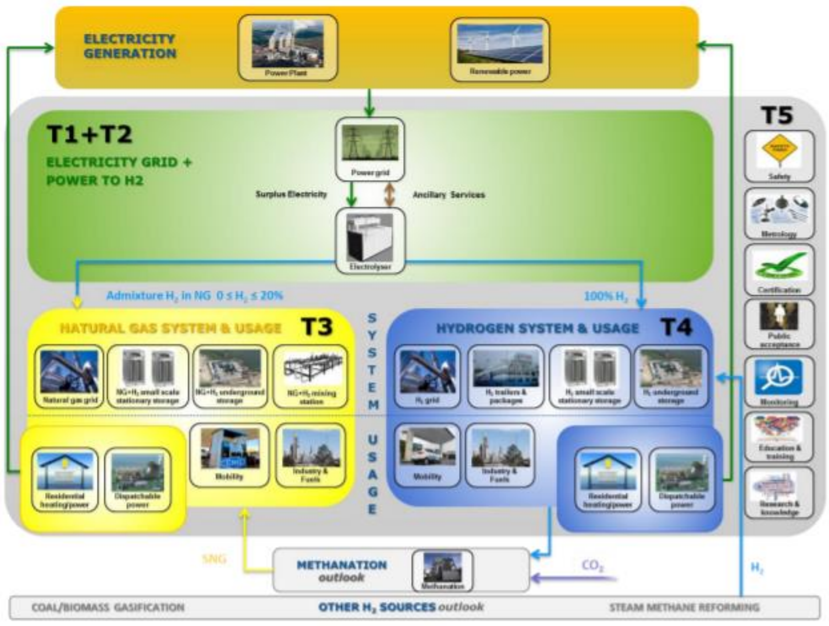


Figure 1 Scope of work of the CEN-CENELEC SFEM WG Hydrogen

Current focus of CEN/CLC/SFEM/WG hydrogen in 2021/2022

The aim is to further explore the need for standardization and (pre-normative) research with regard to below topics, and engage a broader range of experts.

February 2022: 3 workshops:

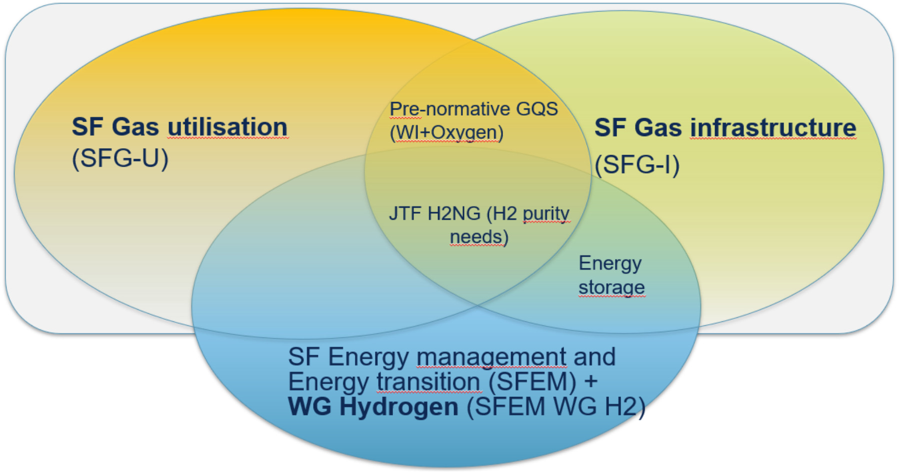
- heavy-duty
- maritime
- horizontal topic liquefied hydrogen

Possible other workshops:

- decarbonization capacity of hydrogen and how its environmental benefit can be assessed
- aviation
- trains

The organization of these workshops will be a collaboration between JRC, FCH JU, Hydrogen Europe, the Hydrogen Council and the SFEM/WG Hydrogen.

CEN/SF Gas infrastructure + CEN/SF Gas utilization

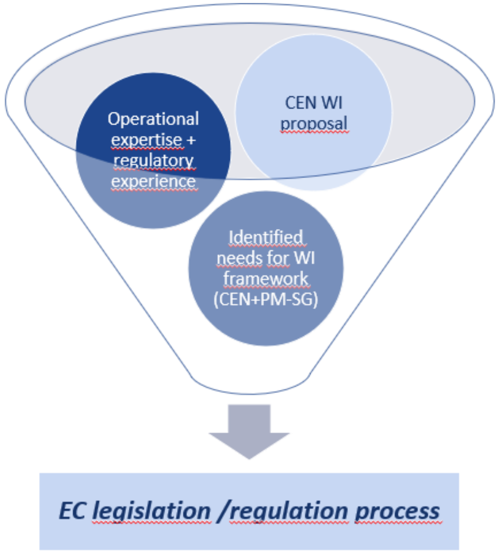


- Advisory and coordinating bodies for standardisation activities related to
  - SFG-I : Gas infrastructure = grid and components
  - SFG-U: Gas utilisation = appliances and applicatio
- Membership of all related CEN and CEN-CLC Technical Committees and Stakeholder Organisations
- Support of coherent approaches for hydrogen standardisation for gas grid, components, appliances and applications
- Cooperation with SF Energy Management (SFEM) and its WG Hydrogen

CEN/SF Gas infrastructure + CEN/SF Gas utilization

Recent projects

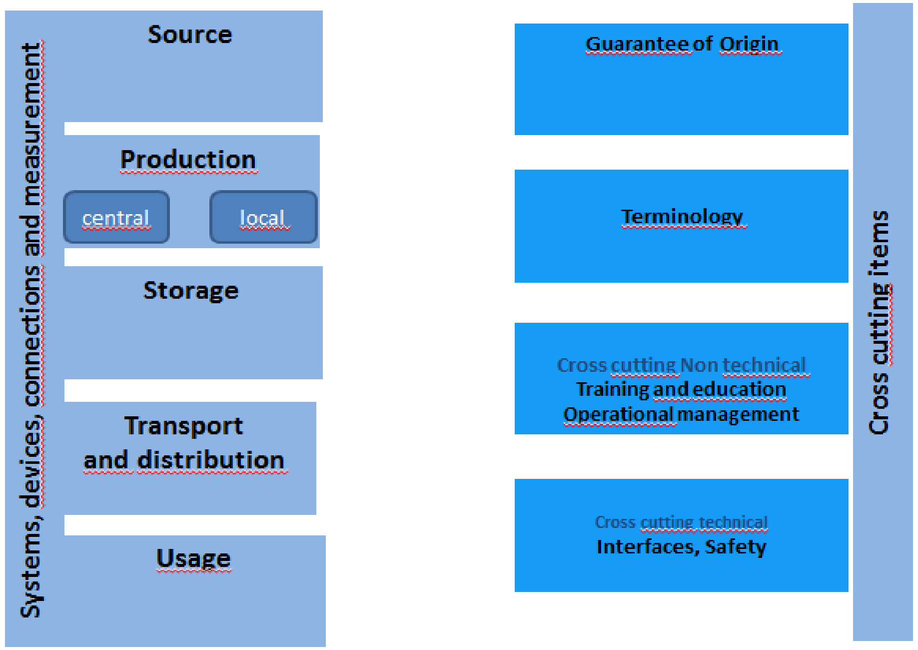
- CEN-CLC Guide 38 on Multi-fuel stations (SFG-I, 2021)
- Joint Pre-normative study on H-gas quality parameter
  - Wobbe Index aspects (2021) – reference to PMG SG 1 WI
  - Oxygen (ongoing)



Current projects 2021/2022

- Workshop on different aspects on leakages related to hydrogen
- Workshop on voluntary self-certification/assessment for hydrogen suitability
- Further exchange on joint aspects to facilitate coherent hydrogen standardisation (e.g. materials)

CEN/CLC/JTC 6 Hydrogen in energy systems



- Mirror committee of ISO/TC 197
- Development of EN ISO Standard (EN 24078) on "Terms and Definitions" under VA with ISO/TC 197
- In collaboration with CEN/CLC/JTC 14 WG 5 giving input to the standard on Guarantee of Origin (EN 16325)
- Under development Technical Report on Hydrogen safety
- Under discussion:
  - Zoning distances
  - Liquified hydrogen
  - Education

Every meeting brainstorm session to follow up developments

CEN/TC 234 Gas infrastructure

- Standardisation for design, construction, operation and maintenance of gas infrastructure from input into the gas transmission networks up to the inlet of the gas appliance, including gas quality, management, etc.
- Gas includes all combustible gases, e.g. natural gas, biomethane, synthetic gases, hydrogen and their **blends**
- **Currently working on**
  - inclusion of hydrogen in standards
  - elaboration of Technical Specification for quantification of methane emissions in gas transmission, distribution, storage and LNG terminals
  - regular revisions

CEN/TC 234 H2 Roadmap
CEN/TR 17797 'Consequences of H2 in the natural gas infrastructure'

CEN CENELEC

Dedicated analysis of the relevant technical and safety aspects of hydrogen and its blend with natural gas in the scope of CEN/TC 234 including:

- Terms and Definitions
- Aspects with relevance for all parts of the gas infrastructure:
  - Safety characteristics for H2NG admixtures
  - H2NG and H2 in contact with materials
  - Energy content of H2 in comparison to NG
- Aspects related to the different parts of the gas infrastructure
- Conclusions - H2 Readiness of the gas intrastructure
- Expected revisions and need of new standard deliveries

- In final voting by CEN Members until 16 Dec 2021
- Publication only in 1st Quarter 2022
- **Technical content of draft Technical Report recommended for use!**

Quality of H-gas and its blends with hydrogen

- Preparations of revision of **EN 16726:2015/A1:2018** have started
- Screening of revision need in dedicated Task Forces
  1. Wobbe index (taking into account the SFGas GQS TF 1 WI proposal)
  2. Calorific value(s) & Relative density
  3. **Effects of hydrogen admixtures**
  4. Sulfur
  5. Oxygen (awaiting proposal from CEN SFGas GQS TF 3)
  6. Methane number

CEN/TC 234 work program related to H2NG or H2 in NG infrastructure

- **prCEN/TR 17797** Gas infrastructure - Consequences of hydrogen in the gas infrastructure and identification of related standardisation need in the scope of CEN/TC 234 (WI 00234080) – in formal vote by 16/12/2021
- **WI 00234096** Gas infrastructure – Quality of gas – Hydrogen used in converted/rededicated gas systems – WD in 12/2021 awaited
- **EN 16726:2015/A1:2018** Gas infrastructure – Quality of gas – Group H – revision in preparation
- **FprEN 12583:2021** Gas Infrastructure - Compressor stations - Functional requirements – FV starts 2021-12-02
- **FprEN 12732:2021** Gas infrastructure - Welding steel pipework - Functional requirements – *FV approval on 2021-09-02; publication in preparation, DAV 2021-11*

Current CEN/TC 234 work program related to H2NG or H2 in NG infrastructure

- **prEN 17649** Gas infrastructure - Safety Management System (SMS) and Pipeline Integrity Management System (PIMS) - Functional requirements – *ENQ Comments treatment; delivery for FV by 12/2021*
- **prEN 1594** Gas infrastructure - Pipelines for maximum operating pressure over 16 bar - Functional requirements – *WD circulated; delivery for ENQ by 12/2021*
- **WI 00234087, 88, 90** Gas infrastructure – Injection stations - *WIs activated, Titles changed, part 4 deleted*
  - Part 1: General requirements *(including now preparation of combustible gas mixtures)*
  - Part 2: Specific requirements regarding injection of biogas
  - Part 3: Specific requirements regarding injection of hydrogen
- **EN 12007series –** Gas infrastructure – Pipelines for maximum operating pressure up to 16 bar - Functional requirements *– H2 inclusion for next revision in preparation in parallel to current revision*
- **EN 12327 –** Gas infrastructure – Pressure testing, commissioning and decommissioning procedures - Functional requirements *– H2 inclusion for next revision in preparation in parallel to current revision*

Hydrogen quality in converted NG systems

- **Elaboration of a Technical Specification for H2 quality specification**
  - purity of > 98% H2 for a transition phase until further purification of pipework given
  - reflection of current ability of the natural gas pipework
- **Two key aspects:**
  - verification of possible concentration of H2
  - consideration of trace components originated in generation process and coming from main and downstream infrastructure)
- **Liaison work with**
- Sector Forum Joint TF H2 purity/quality needs for industrial end-users (SFEM WG H2, SFGas)‘,
- CEN-CLC/JTC 6, CEN/TC 408, ISO/TC 197 and
- CEN Partner Organisations (e.g AFECOR, EASEEgas, EHI, EUROMOT, Marcogaz)

Sector Fora joint TF Hydrogen purity/quality need for industrial end-user

- **Starting point:**
  CEN/TC 234 WI 00234096 (CEN/TS) Gas infrastructure – Quality of gas – Hydrogen used in converted/rededicated gas systems **proposing > 98% H2 concentration** respecting remainings in the pipework **for a transition phase**
- **Focus:**
  Combustion and non-combustion/feedstock applications in industrial end-uses
- **Aiming**:
  - Identification of actual abilities and necessities of industrial end-uses regarding H2 purity/quality (including impact of possible impurities)
  - Identification of potential PNR and standards need

Sector Fora joint TF Hydrogen purity/quality need for industrial end-user

- **Proposed scoping:**
  - Identification/mapping of relevant industries (sub-categories)
  - Identification of the volume of these industries in relation to the need of H2
  - Assessment of impacts by the quality of hydrogen
  - Identification of quality needs in their processes
  - Assessment of the impact of the $< 2\%$ impurity in case of $> 98\%$ H2 concentration (including source of the impact)
  - Identification of steps needed to accept/receive a higher level of H2 quality

Guarantee of Origin

A Guarantee of Origin <–> Who, What, Where, When

An electronic document with the sole purpose to demonstrate to the final customer that a certain share or quantity of energy has been produced from renewable sources

The Renewable Energy Directive (RED II)

Member States or the designated competent bodies shall put in place appropriate mechanisms to ensure that guarantees of origin are issued, transferred and cancelled electronically and are accurate, reliable and fraud-resistant. Member States and designated competent bodies shall ensure that the requirements they impose comply with the standard CEN - EN 16325.

Standardization process started 2020

CEN/CENELEC/JTC 14 WG 5 <   > Expert Members

Guarantee of Origin

A guarantee of origin states at least the following:

- the energy source,
- the start and end dates of production
- whether the guarantee of origin relates to: **i) electricity, ii) gas, including hydrogen, or iii) heating or cooling**
- the identity, location, type and capacity of the installation
- whether the installation has received investment support and the type of support scheme
- the date and country of issue and a unique identification number

A joint way forward

- Standardisation will provide the basis for the decarbonisation of the energy system by the use of hydrogen and in line with the EC Hydrogen Strategy
- The use of low-carbon hydrogen and natural gas admixtures is needed as a transition phase to achieve the goals
- To make this possible joining the expertise and experiences is needed!
- Good cooperation is ongoing!

support the decarbonisation by voluntary standards at European level

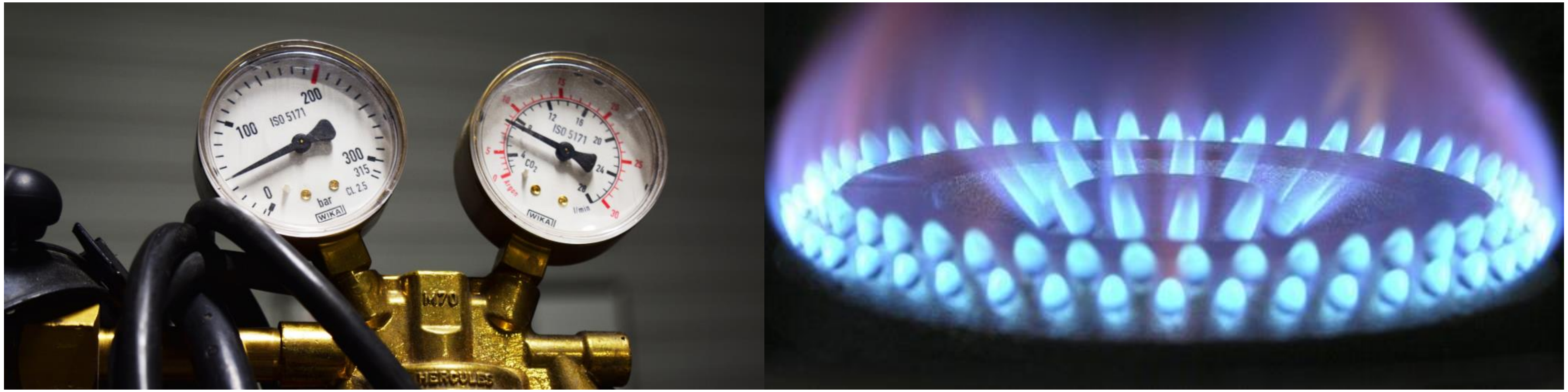
Thank you! Any questions?

www.cencenelec.eu

Follow us:

Tag us @standards4EU

Hiltrud Schülken secretariat CEN/TC 234, CEN/SFG_I, CEN/SFGas GQS
Hiltrud.Schuelken@dvgw.de
Françoise van den Brink: secretariat CEN/CLC SFEM/WG hydrogen, CEN/CLC/JTC 6, CEN/CLC/JTC 14 WG 5
Francoise.vandenbrink@nen.nl

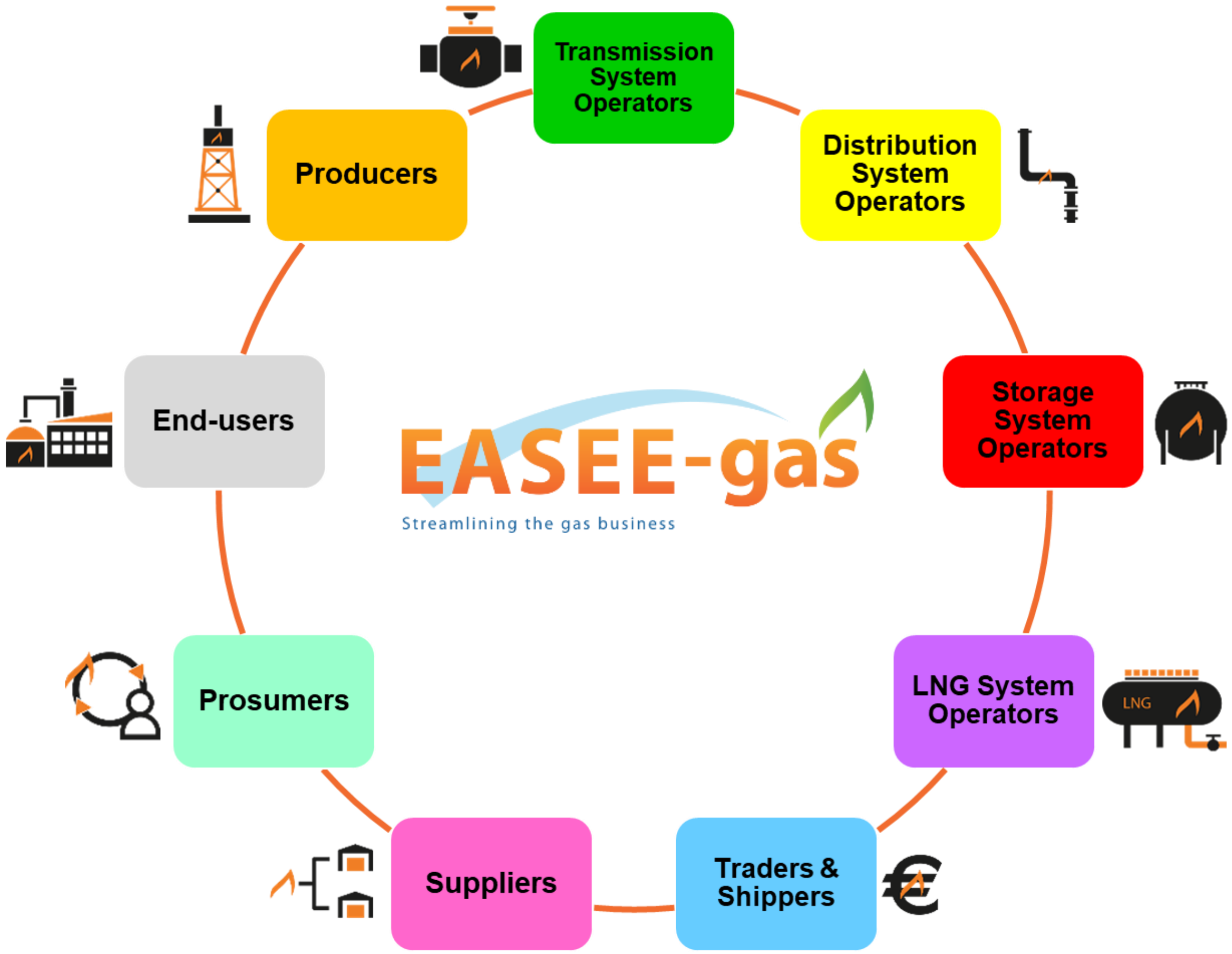


Hydrogen in natural gas infrastructure
Common Business Practice (CBP)

Peter van Wesenbeeck | Chair - EASEE-gas Gas Quality Harmonsation Working Group

Introducing EASEE-gas

80+ companies representing the whole gas value chain



Introducing EASEE-gas

Accelerating the transition towards tomorrow’s energy system by facilitating the interoperability of energy systems

Facilitating the good functioning of the gas markets by drafting Common Business Practices

EASEE-gas
Streamlining the gas business

Background information

Reason

- Transition to renewable and low carbon gases
- Facilitate the hydrogen market development by (partially) using the (natural) gas infrastructure
- Only "fuel cell grade" standards available at start of the work

Goal

- A Common Business Practice for Hydrogen by analogy with the CBP-2005-001-02 Harmonisation of Natural Gas Quality

Way of working

- Inventory of requirements/limitations at production, transmission and end-use of hydrogen
- Specification based on common denominator

EASEE-gas
Streamlining the gas business

Development of CBP

Scope

- Specification is tailored to (high temperature) industrial heating and feedstock use
  - Expected large market share
  - Considering the characteristics of the various hydrogen production techniques and the technical limitations of the natural gas infrastructure
  - But doesn’t meet **specific** requirements of **some** of the industrial (feedstock) users and therefore on-site pre-treatment can be needed.

Transition period

- After switching from natural gas to hydrogen, the composition can be influenced by natural gas residues present in the pipeline
- Specific conditions apply during the transition period for the sulphur content, to allow for higher hydrocarbons to be present and to introduce a temporary specification for the hydrocarbon dewpoint

Draft CBP Hydrogen in natural gas infrastructure – available end 2021

Parameter	Unit	Min	Max
Hydrogen	mol-%	98,0	-
Carbon monoxide	ppm	-	20
Total sulphur content[a]	mg S/m^3(n)	-	21[b]
Carbon dioxide	ppm	-	20
Hydrocarbons (including Methane)	mol-%	-	1,5[b]
Inerts (Nitrogen, Argon, Helium)	mol-%	-	2,0
Oxygen	ppm	-	10[c]
Total halogenated compounds	ppm	-	0,05
Water dewpoint	°C at 70 bar(a)	-	-8
Hydrocarbon dewpoint[b]	°C at 1-70 bar(a)	-	-2[b]

[a]) Non-odorised hydrogen

[b]) It is acknowledged that the presence of residues in the pipeline as a result of natural gas transmission, makes it necessary to relax the specification during the **transition phase** for the total sulphur content, to allow for higher hydrocarbons to be present and to introduce a temporary specification for the hydrocarbon dewpoint.

[c]) Where the hydrogen can be demonstrated not to flow to installations or end-user applications sensitive to higher levels of oxygen, (e.g. feed stock users or hydrogen storages), a higher limit of up to 1000 ppm may be applied.

- The gas shall not contain constituents other than listed in the table above at levels that prevent its transportation, storage and/or utilization without quality adjustment or treatment.

GERG Hydrogen Research Roadmap

PRIME MOVERS GROUP – 25TH OF NOVEMBER 2021

TANGUY MANCHEC,
HYDROGEN WORKING GROUP LEADER

The European Gas Research Group

- **Collaborative R&D group** for gas with strong industry focus
- Over 30 members - gas companies, research centres and universities
- Links to Brussels Institutions and External Organisations
- Established in 1961

GERG Members and Friends

Addressing Research Priorities
GERG Working Groups

Methane Emissions

Biomethane

Hydrogen

Brainstorming phase

Gathering of insights from GERG industry professionals and experts.

→

Definition of research topics

Scoping of research knowledge gaps and evaluation of criticality.

→

Production of the roadmap

Summary of results and recommendations for the most prominent research topics.

→

Project creation in the GERG Programme Committees:
Distribution and Utilisation
Transmission and Storage
LNG

Hydrogen Research Roadmap 2021

GERG
THE EUROPEAN GAS RESEARCH GROUP
60 YEARS

Gas Quality
- Meters, analysers and sensors
- Quality of H2NG blends & dedicated H2 grids
- Gas properties and billing

Asset Materials
- Pipeline integrity
- Impact of H2 on other components & new materials
- Impact of H2 on compressors

End-Uses
- Industrial end-use
- Domestic and commercial appliances
- Combustion of H2NG blends

Maintenance and Safety
- Odorisation
- Safety: leak, flammability & explosivity
- Maintenance & monitoring

Underground Storage
- Salt caverns, Aquifers and Depleted O&G Fields

New Technologies
- H2 injection & blending
- Ammonia & other H2 carriers
- Separation of H2 & natural gas from the blend

Key figures

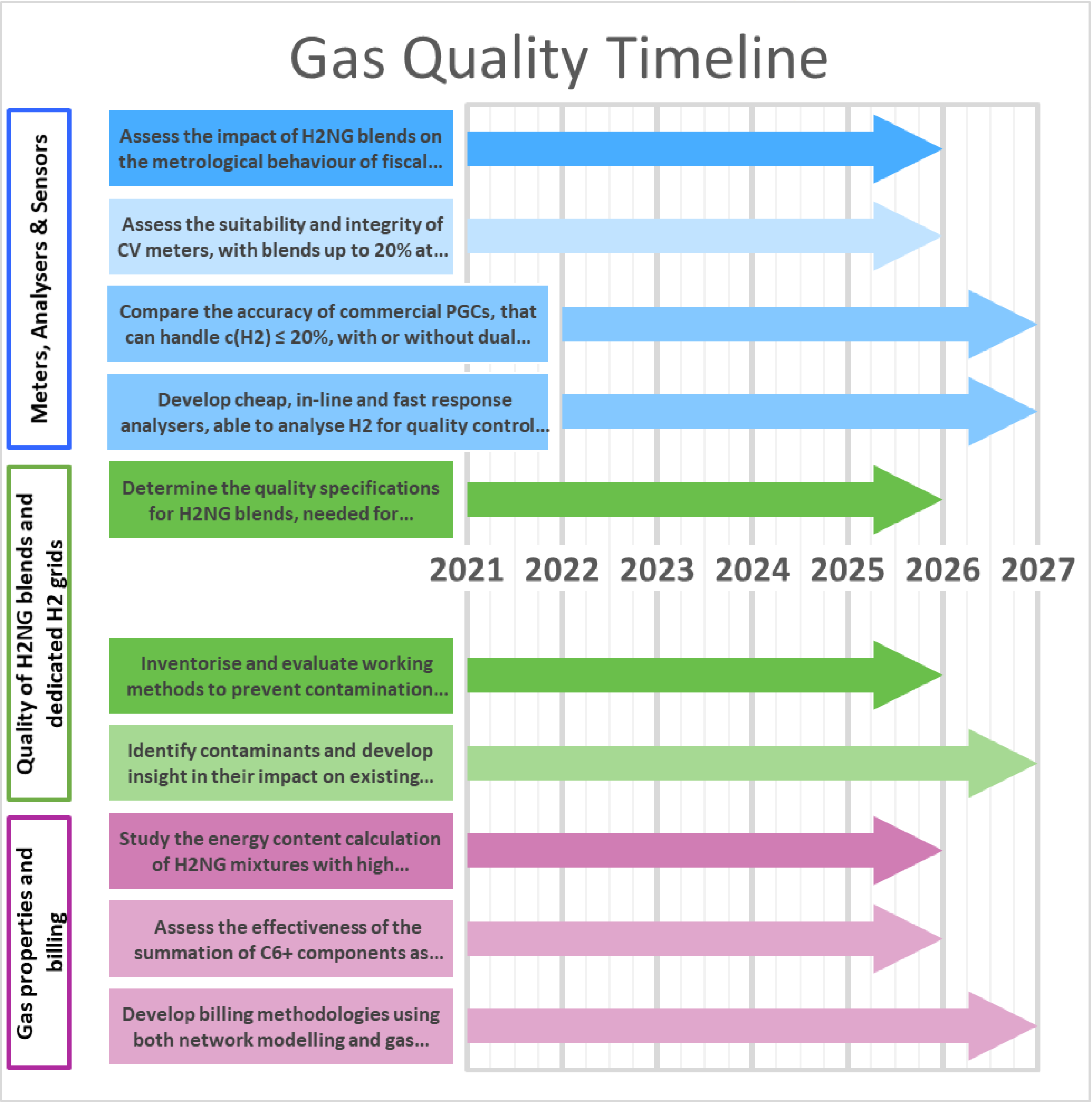
>100
Hydrogen Experts

16
Categories

6
Timelines

115
Research Topics

Strong coordination with other associations:
PRCI, EPRG, APGA, Future Fuels CRC, NYSEARCH, Hydrogen Europe, etc.



The Hydrogen R&D Journey

Some significant GERG projects

CEN H2 PNR: Removing the technical barriers to use of hydrogen in natural gas networks and for (natural) gas end users (2020-2021)
With funding from the EC, via CEN, this project delivered by GERG defines pre-normative research requirements for the introduction of hydrogen in European natural gas grids.

THYGA: Testing Hydrogen admixture for Gas Applications (2020-2023)
Project studying the impact of blends of natural gas and hydrogen on end use applications, specifically in the domestic and commercial sector.

HYREADY: Engineering Guidelines for Preparing Natural Gas Networks for Hydrogen Injection (2017-2021)
22 project partners led jointly by DNV and DBI-GUT, aim to provide engineering guidelines to European gas system operators to make sure their networks are ready to accept hydrogen-natural gas mixtures.

ELEGANCY: Enabling a low-carbon economy via hydrogen and CCS (2017-2020)
Coordinated by SINTEF Energy Research, the project provides innovative, cutting-edge solutions to key technical challenges for H2-CCS chains.

HIPS: Hydrogen in Pipeline Systems (2012)
Through this GERG member project, over 30 partners worked on a benchmark study to understand the impact of hydrogen blending in gas networks up to 10% v/v.

NaturalHy: Preparing for the hydrogen economy by using the existing natural gas system as a catalyst (2004)
About 40 European partners studied how a transition to a hydrogen economy could be facilitated in a short timeframe based on use of the existing gas infrastructure to convey a natural gas/hydrogen mixture.

Thank you for your attention!

To learn more, join us online at next week’s GERG Anniversary Conference

Register here!

Key R&D elements emerging

Gas Quality

* Impact of H_2NG blends on the metrological behaviour of fiscal flow meters.
* Quality specifications for H_2NG blends, needed for injection in the NG grids; and for H_2 dedicated grids.
* Working methods to prevent contamination of H_2 when transmitted with former NG transmission systems.
* Energy content calculation of H_2NG mixtures with high accuracy by updating the state equations of H_2NG blends.

Asset Materials

* Defect assessment criteria as function of H_2% in metallic pipelines.
* Interaction of hydrogen with metallic and polymer pipeline welds: this is dependent on the welding technique used.
* Best practices of oxygen passivation for steel under H_2NG is essential to mitigate the effect of hydrogen.
* Suitability of existing valves components for H_2NG blends.
* Impact of H_2NG blends on existing pressure regulators.
* Performance and operational envelope of reciprocating and centrifugal compressors for increasing concentrations of H_2 for existing NG machines.

End-Uses

* Impact of hydrogen on burners.
* Impact of the speed of change of H_2 concentration on industrial applications.
* Impact of H_2/H_2NG on main industrial processes in order to evaluate the need of modifications/retrofitting.
* Appliance adjustments in the presence of hydrogen, including H_2% sensors.
* Hydrogen detection for combustion control (CHP, boilers).
* Cost-effective adaptation of sensitive existing appliances to H_2/H_2NG.
* Impact of H_2/H_2NG on energy efficiency compared to natural gas.
* Reference test gases suitable for H_2NG blends.

Maintenance & Safety

* Assessment of existing odorants compatibility with various H_2%.
* Odorants for 100% H_2 and removal techniques for end-use applications requiring pure H_2.
* Effect distances for H_2NG and H_2 leakages.
* Effectiveness of leak detection technologies for H_2NG & H_2.
* Effect of H_2 on blow-down.
* Need of an authoritative documentation on the GWP of H_2.
* Work approach applicable to incidents with large H_2/H_2NG leakages.
* Effectiveness of repair methods for pipelines under H_2NG blends.

New Technologies

* Blending methods and potential improvements to fulfil metrology and quality requirements of the final H_2NG admixture.
* Assessment of existing H_2 carriers and their impact on CO_2 footprint performance, safety, and pollutants emissions.
* Benchmark suitable H_2NG separation technologies for low- and high-pressure networks.

Underground Storage

* Tubing and casing compatibility with hydrogen for UGS environments.
* Other tubing components (packers, valves, wellheads etc.) compatibility with hydrogen for UGS environments.
* Suitability of high-pressure equipment during hydrogen transmission and storage stages.

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Technical Association of the European Gas Industry

Marcogaz activities to support hydrogen integration in natural gas system

José A. Lana, Chairman WG Gas Quality & Renewable Gases

Prime Movers Group on Gas Quality & H2 handling Workshop, 25th November 2022

About MARCOGAZ

MARCOGAZ is the technical association of the European gas industry

DECARBONIZATION

INFRASTRUCTURE | END USE | SUSTAINABILITY

NATURAL GAS

HYDROGEN & BIOMETHANE

SYNTHETIC GASES

53 YEARS

30 MEMBERS

20 COUNTRIES

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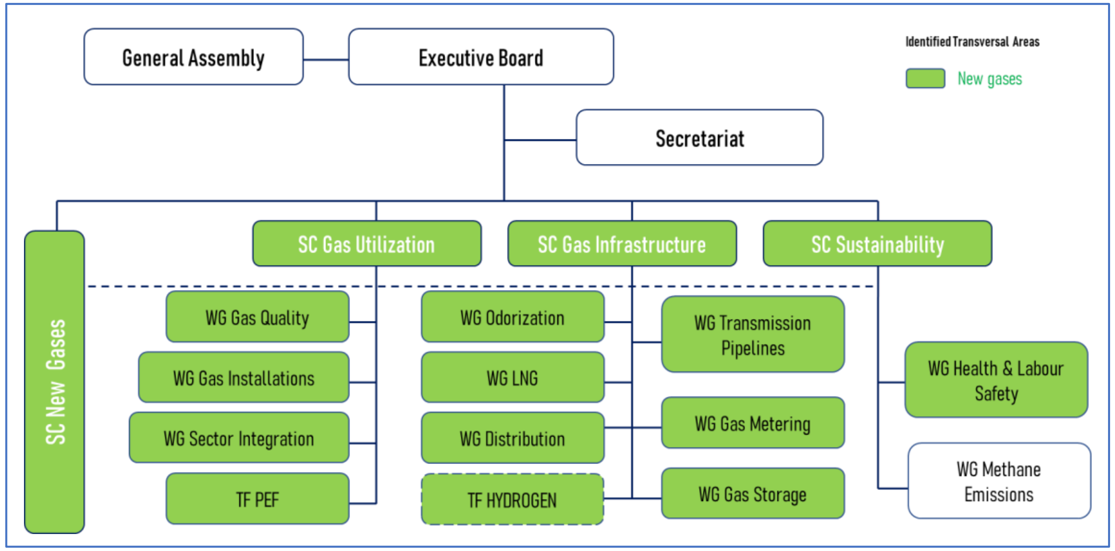
MARCOGAZ and hydrogen

- Gas industry is mobilized to inject hydrogen into the gas system, or to repurpose a part of the infrastructure asset – this is already a reality.
- MARCOGAZ is fully involved with technical experts on all the technical topics required to strengthen the injection approach, working closely with the research and the standardization bodies.
- MARCOGAZ vision
  - Blending hydrogen into natural gas system allows:
    - Capitalizing the production of hydrogen from renewables that otherwise would be wasted.
    - Ensuring direct gas supply to end consumers from injection of hydrogen into the natural gas grid.
    - Reducing electrical grid congestion and curtailment of renewable power.
    - Avoiding long transport of hydrogen using pressurized containers.
  - Retrofitting for blending is an intermediate solution and it goes in parallel with repurposing and/or building new hydrogen pipelines when needed.

MARCOGAZ structure for dealing with hydrogen

- Hydrogen is present in most of the MARCOGAZ Working Groups (WGs):
  - Many *public position papers* have been produced in last years about many aspects related the interaction of hydrogen and natural gas
- *Task Force Hydrogen*
  - Dedicated to evaluate the impact of hydrogen into natural gas chain
- Recently created *Standing Committee New Gases (SCH2+)*
  - Mission
    - To coordinate and promote the work between the technical groups on ***hydrogen***, biomethane and synthetic gases.
    - Facilitate liaison with experts in other associations.
    - Drive the agenda on hydrogen and green gases.
    - Participation of almost all MARCOGAZ WGs



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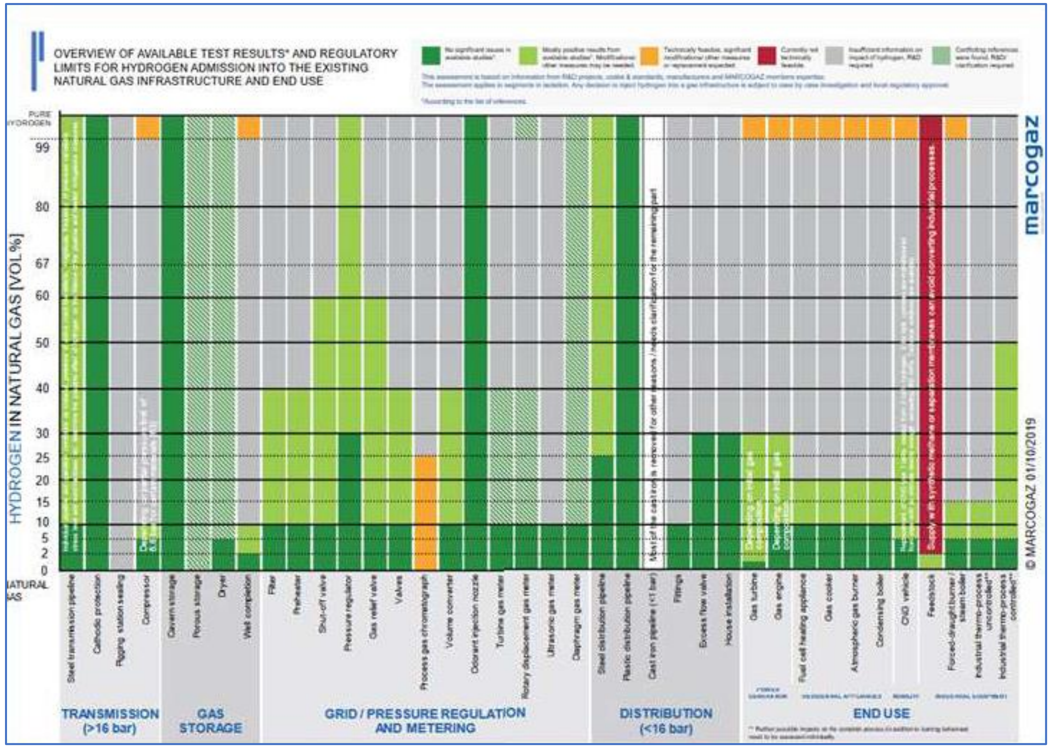
MARCOGAZ Task Force Hydrogen

- Task Force Hydrogen, 2018/2019
  - *Infographic* covering the impact of %H2 in the different natural gas chain assets
    - Based on best available knowledge at that time
    - Very well known reference in Europe
- Task Force Hydrogen, 2020/2022
  - Aim: to *update Infographic*
  - New information:
    - Mitigation needs for the utilization of H2 and associated cost
    - Safety aspect



Other hydrogen related papers (look at here)

- WG Gas Odorisation
  - *Odorisation of natural gas and hydrogen mixtures*, July 2021
- WG Liquified Natural Gas
  - *Liquefied natural gas and hydrogen as transportation fuel*, June 2021
- WG Health & Labour Safety
  - *Detection and measuring of pure hydrogen and blends of natural gas and hydrogen*, April 2021
  - *Impact of hydrogen on existing ATEX equipment and zones*, April 2021
- WG Gas Quality & Renewable Gases
  - *Hydrogen regulation/standards survey*, December 2020
  - *Impact of hydrogen in natural gas on end-use applications*, October 2017
- WG Underground Gas Storage
  - *Injection of hydrogen/natural gas admixtures in underground gas storages*, December 2016
  - *Acceptance of Renewable Gases in Underground Storage Facilities* (in preparation)

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Thank you!

marcogaz@marcogaz.org | @marcogaz_EU
marcogaz.org | be.linkedin.com/company/marcogaz

Concluding remarks by Hendrik Pollex, Director System Operation area at ENTSOG

Thank you for your attention

For more information, please
visit the dedicated website of the group