WS2 GAC meeting in Brussels on
07 December 2018

Hydrogen integration in natural gas grids: quantitative assessment of its carbon footprint, technical feasibility and economic rationale.

Prof Dr Gerald Linke, CEO DVGW, German Gas and Water Association

DVGW

Table of Contents

DVGW

The German Gas & Water Association

159 Years DVGW is the **first** Technical-Scientific Association of the World

Independent & scientific

Deutscher Verein des Gas- und Wasserfaches (DVGW)

DVGW is authorised through German Energy Act as The Standard Setting Body and Certifying Body

DVGW holds independent R&D Centres

DVGW is a non-profit organisation

80 million € annual budget 700 FTE

9% Member‘s fee
13% free R&D fee

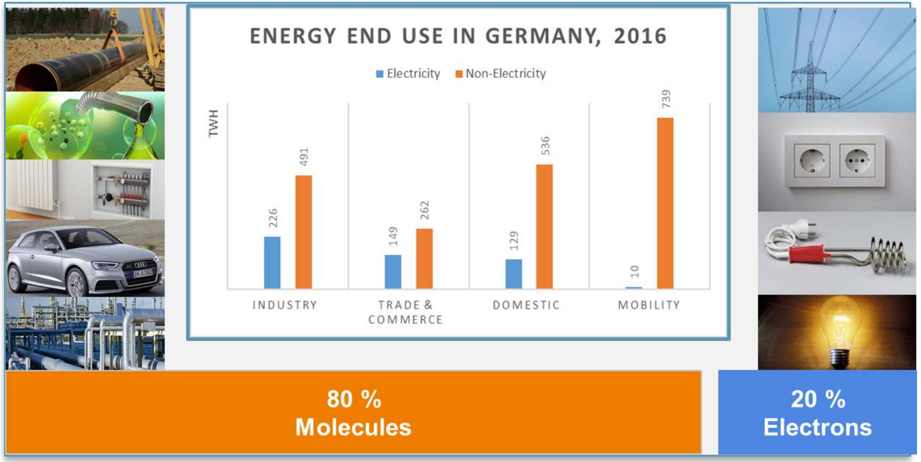
> 2.000	> 1.300	> 250	> 10.000
Suppliers & Grid Operators	Companies	Local Authorities	Individuals

78% **through independent activities** such as studies, **R&D**, training, dissemination, IT-services (safety, security, …)

DVGW

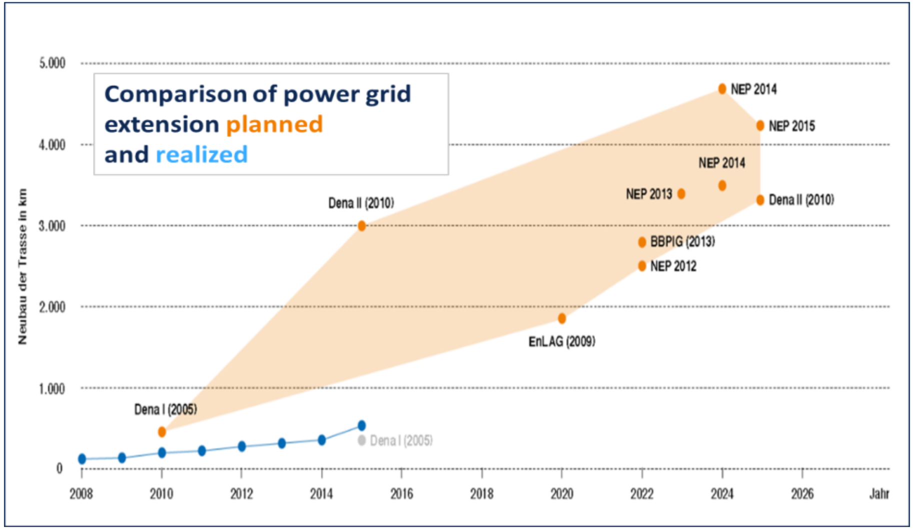
1 Why do we spent effort studying energy supply via hydrogen?

<u>A matter of relevance:</u>
The EU energy supply is mainly built on „molecules“ and not „electrons“.
Therefore, climate actions focusing merely on the power segment are insufficient.
(Figure: Germany)



<u>A matter of ability:</u>
Electrification cannot deliver the high power peaks needed (for example for heating in winter). Gas can.

1 Why do we spent effort studying energy supply via hydrogen?

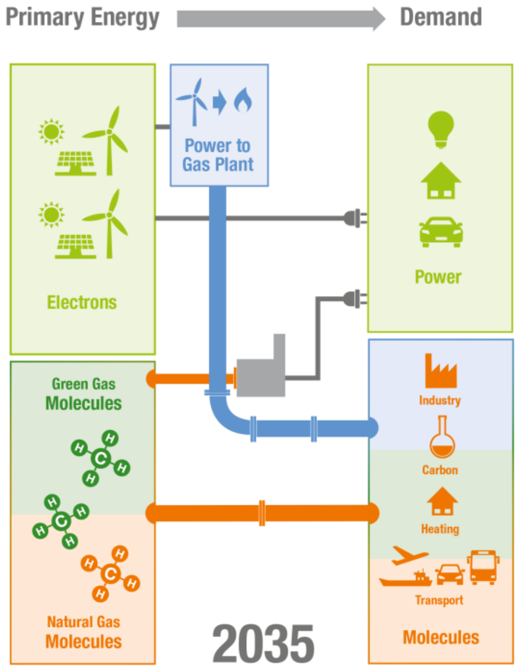


<u>A matter of speed:</u>
Power grid extension is a limiting factor, whereas the gas grid is in place.

<u>A matter of cost and environmental impact:</u>
One gas pipeline (ø 1,20 m) transports the same amount of energy like eight parallel high-voltage pylons (each 3 GW).

1 Why do we spent effort studying energy supply via hydrogen?

<u>A matter of demand:</u>
Industry needs "molecules".

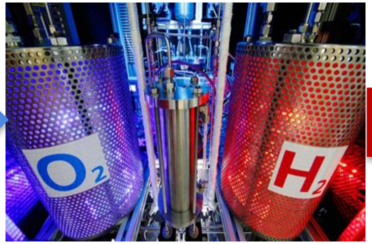


<u>Molecules used for</u>

- ✓ High temperature processes
- ✓ Chemistry
- ✓ Non-energetic purposes
- ✓ Transport

<u>Hydrogen can "green":</u> Production and consumption *can* be provided carbon-free.

Clean power

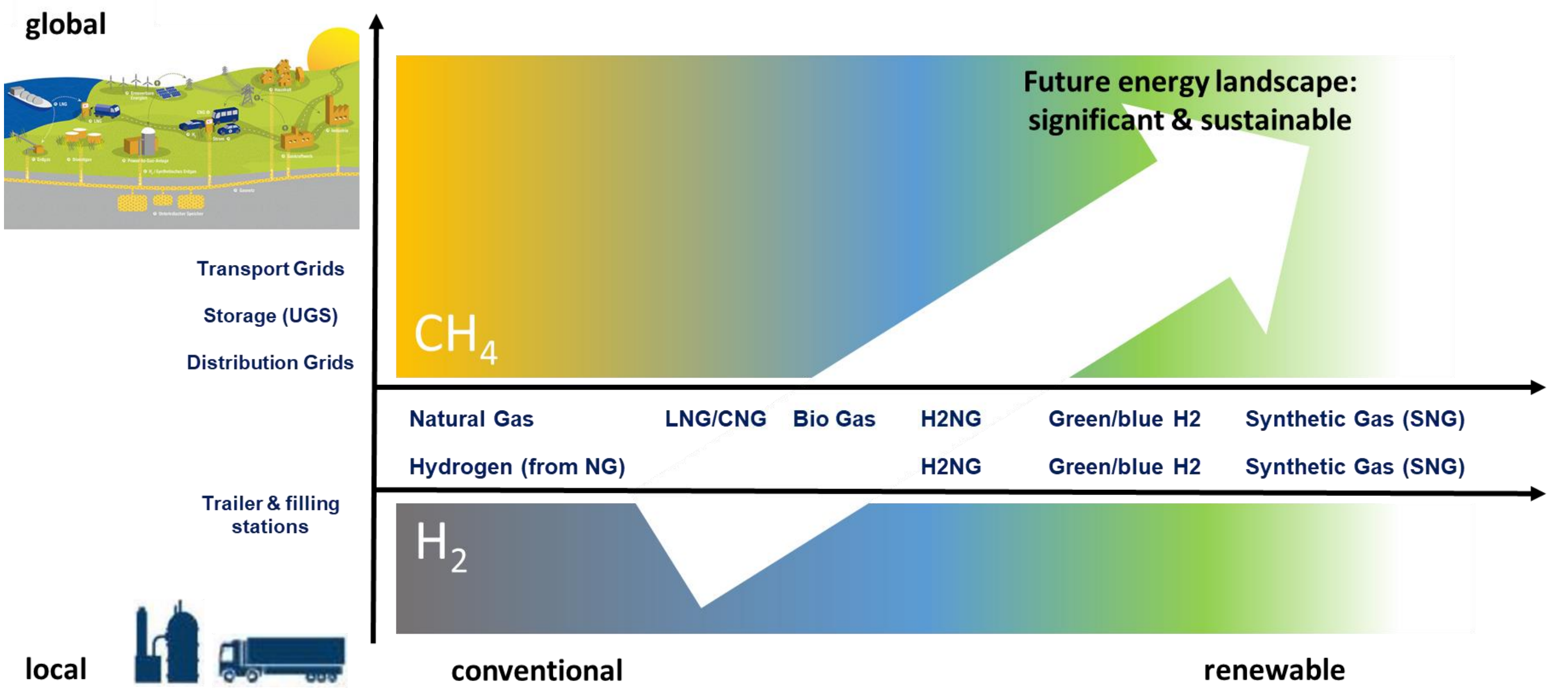


Clean gas

<u>Hydrogen applications are</u> efficient. Example: FCEV

1 Why do we spent effort studying energy supply via hydrogen?

<u>A matter of opportunity:</u>
The natural gas industry - being of largest importance for the EU welfare and delivering more energy than the power segment - has „discovered“ hydrogen.

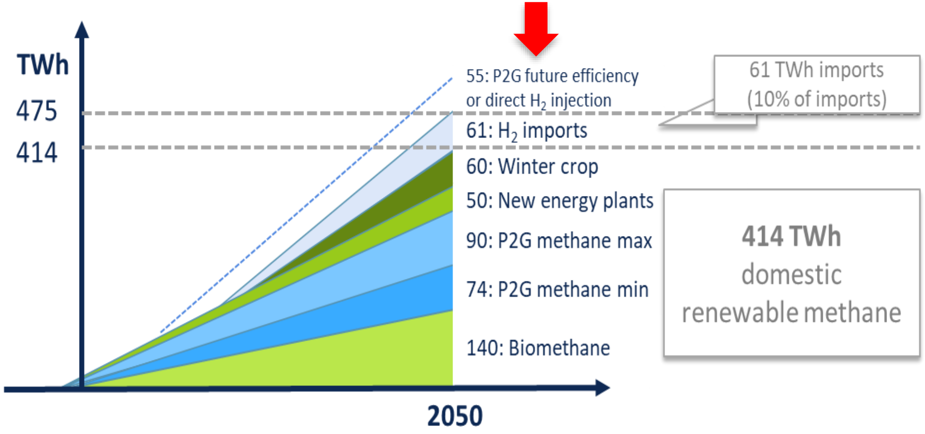


DVGW

1 Why do we spent effort studying energy supply via hydrogen?

<u>A matter of fact:</u>
Countries like Germany have already quantified the de-carbonisation potential with hydrogen.

Source: DVGW, 2018



Source: DVGW & ECOFYS, 2018

DVGW

1 Why do we spent effort studying energy supply via hydrogen?

<u>A matter of fact:</u>

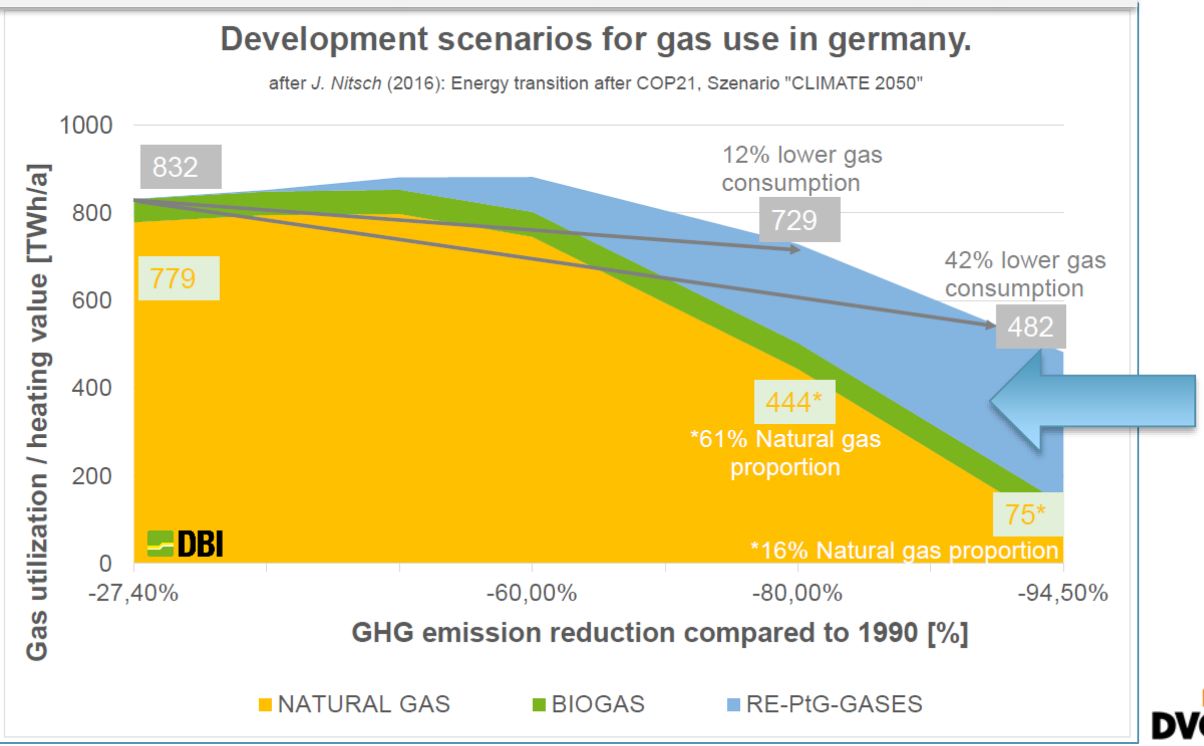
Germany has already quantified the de-carbonisation potential with hydrogen and has implemented more than 30 power-to-gas projects with

- H_2 injection into gas grid
- H_2 conversion to SNG (methanation)

1 Why do we spent effort studying energy supply via hydrogen?

A matter of need:
Academics believe that highest emission reduction targets can only be achieved via hydrogen:

- Development of gas demand depends on GHG reduction target
- **Natural gas use** serves up to about 60% for the GHG reduction and then decreases steadily.
- **Gas consumption** is declining moderately despite ambitious reduction targets.
- **REN-gases*** will be the main component of gas in the future.
- ***This could be also other decarbonised gases.**



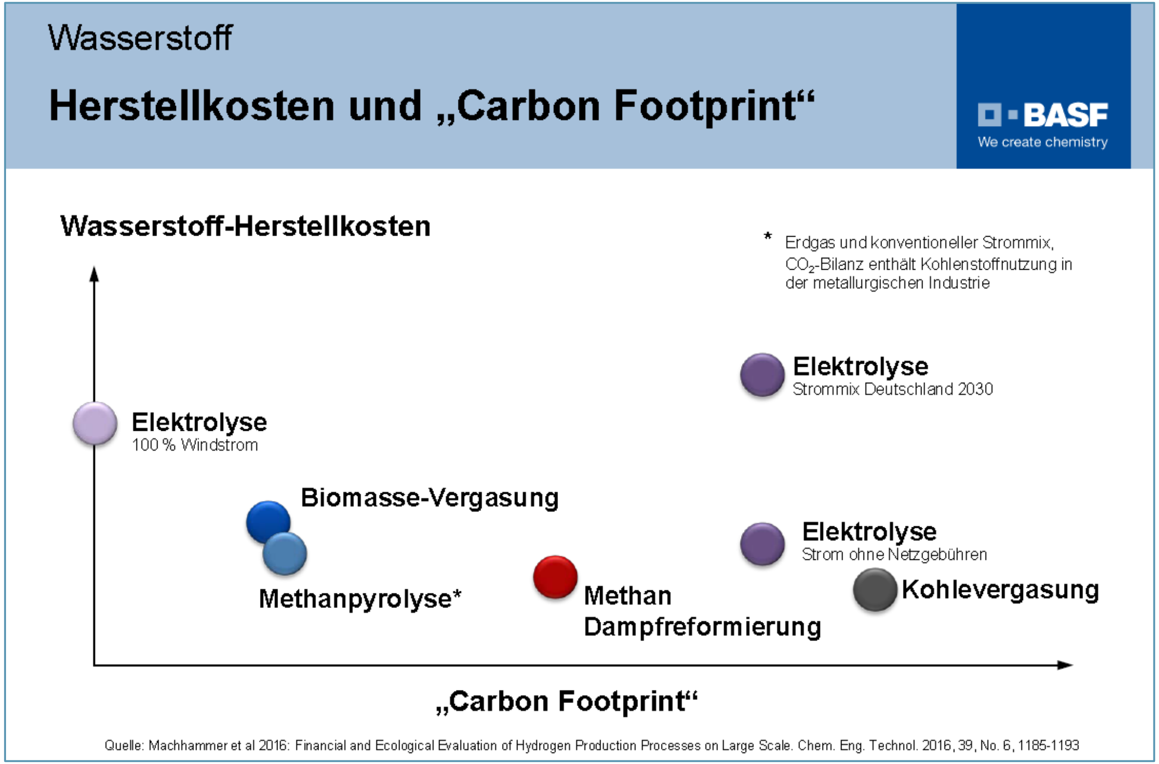
2 Where does the hydrogen come from? @what cost?

- From power via electrolysis
- From green power producing green H_2

- From gas via steam reforming
- From green gas producing green H_2

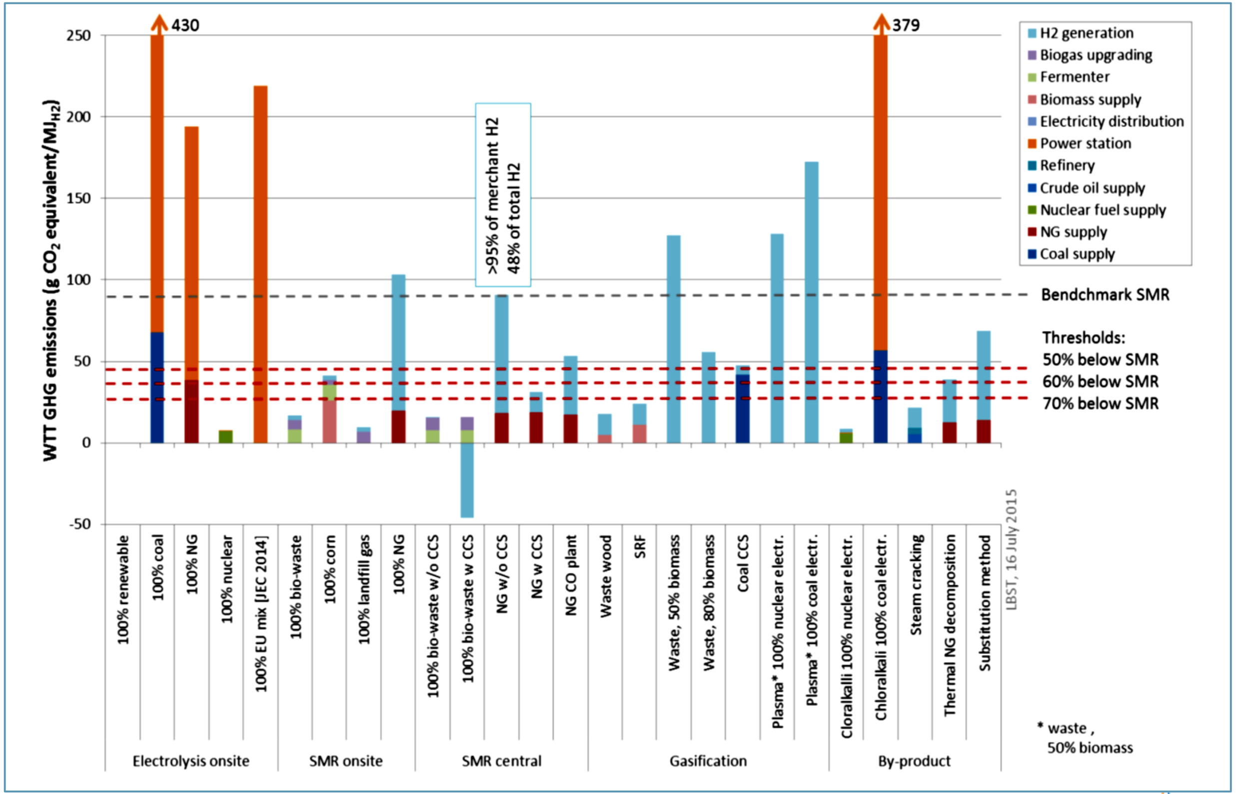
- From gas via pyrolysis
- producing blue H_2

- From gas via CCS or CCU
- producing blue H_2



Where does the hydrogen come from? @what cost?

The Fuel Cell and Hydrogen Joint Undertaking (a public-private partnership between industry and the European Commission) has set as the target that for 2025 the retail price of H2 should be between 4.5 euro/kg and 7 euro/kg. Three studies (McKinsey, Roads2Hy, FCH-JU) converge on the conclusion that retail price will gradually decrease and it will be around 5 – 7€/kg by 2030 (Source CertifHy, FCH-JU 633107, Del. 1.2, 2015)



GHG emissions of hydrogen production on an LCA basis (cradle to gate)

(Source CertifHy, FCH-JU 633107, Del. 2.4, 2015)

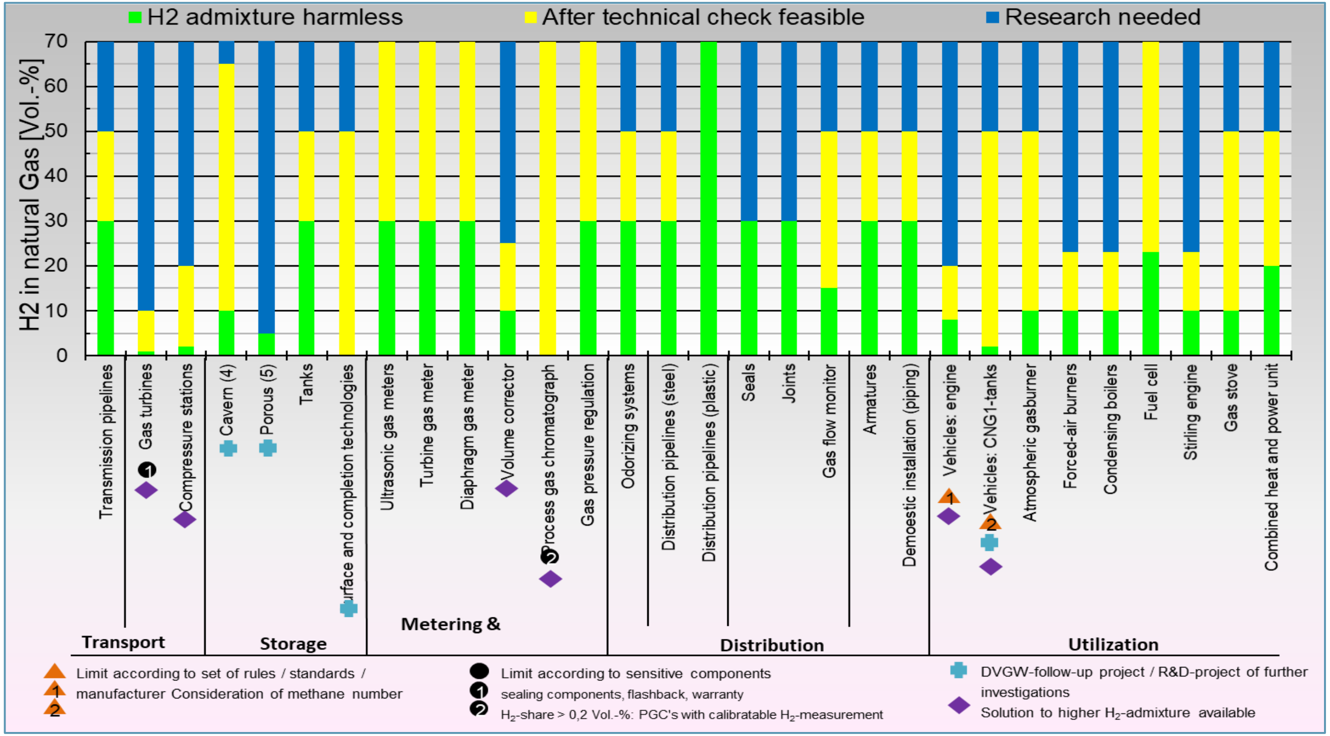
DVGW

3 How much hydrogen is currently admissible in NG grids?

This is limited by national standards which are heterogeneous - unfortunately.

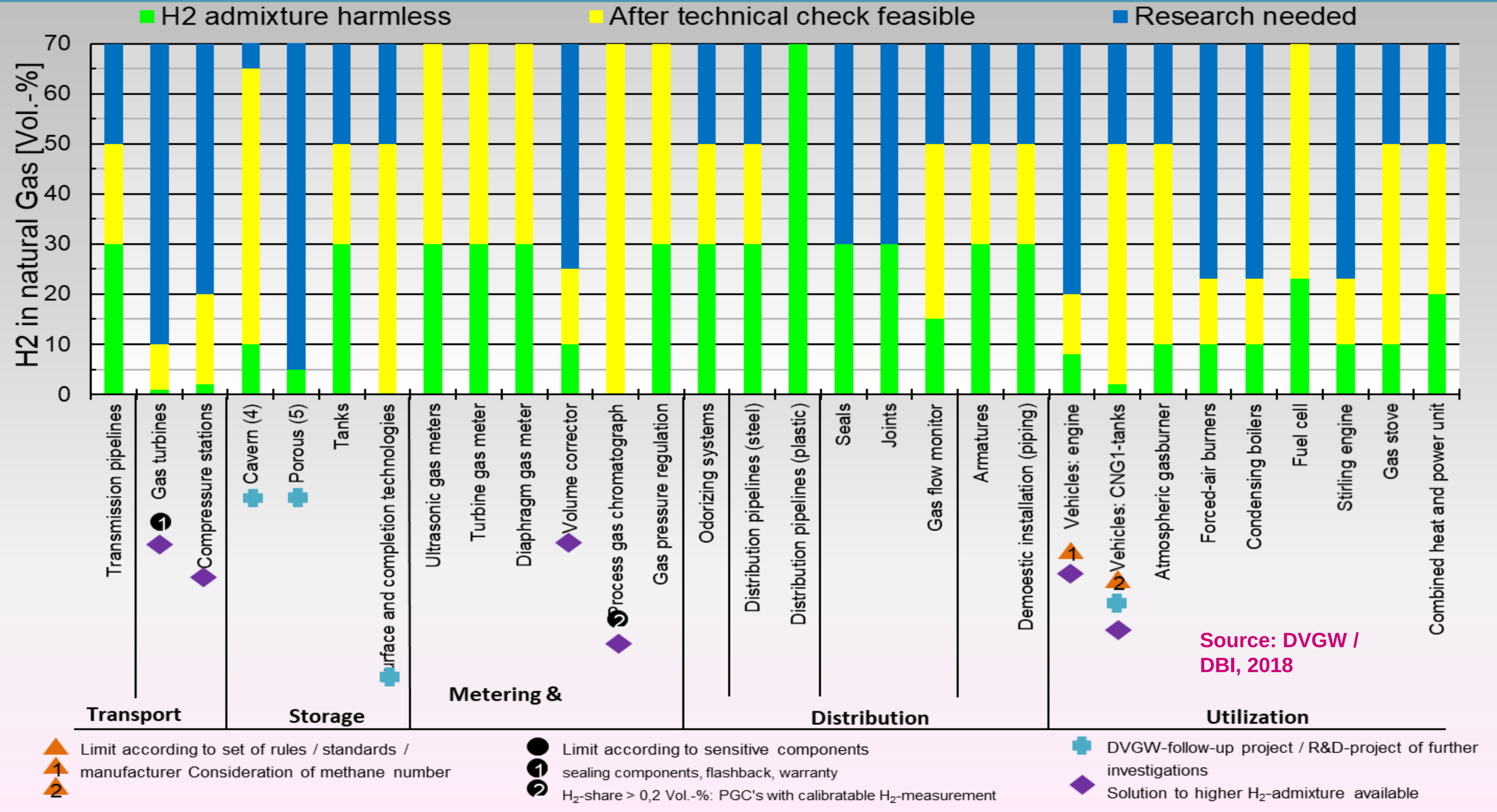
4 How much H_2 in NG seems to be technically feasible?

Based on a broad set of studies, DVGW permits 10% H_2 in the gas grid and is preparing the transition to higher double-digit concentrations



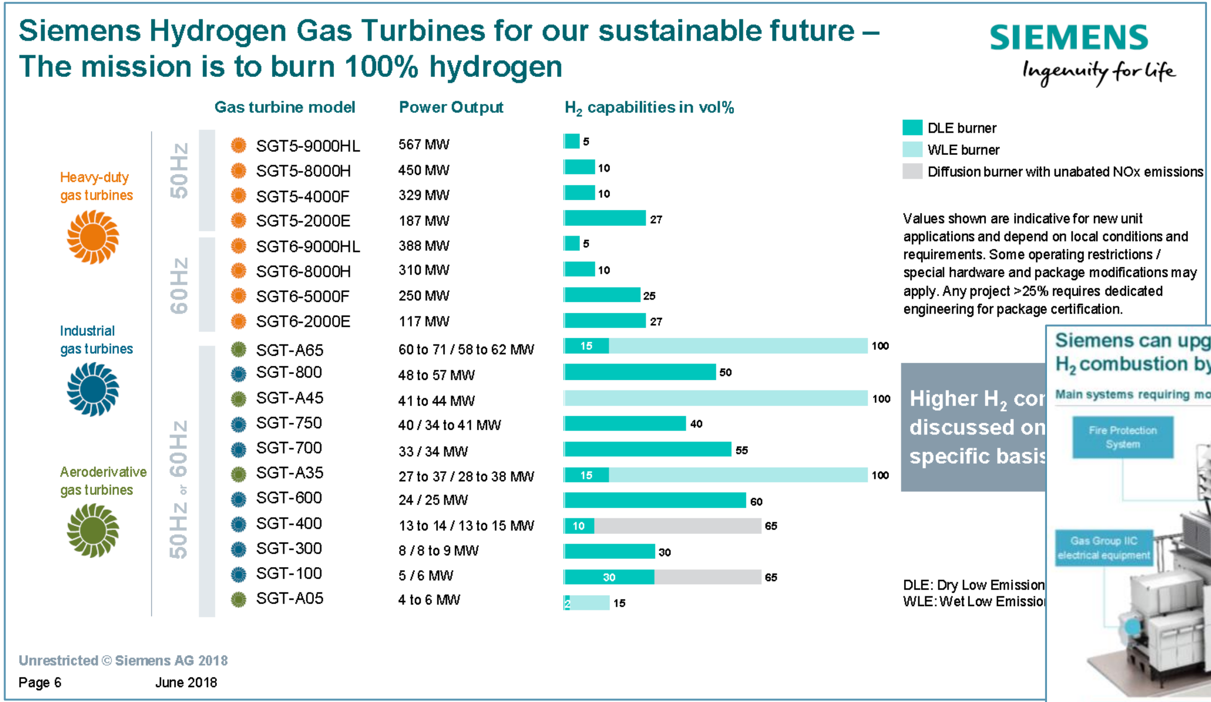
Source: DVGW / DBI, 2018

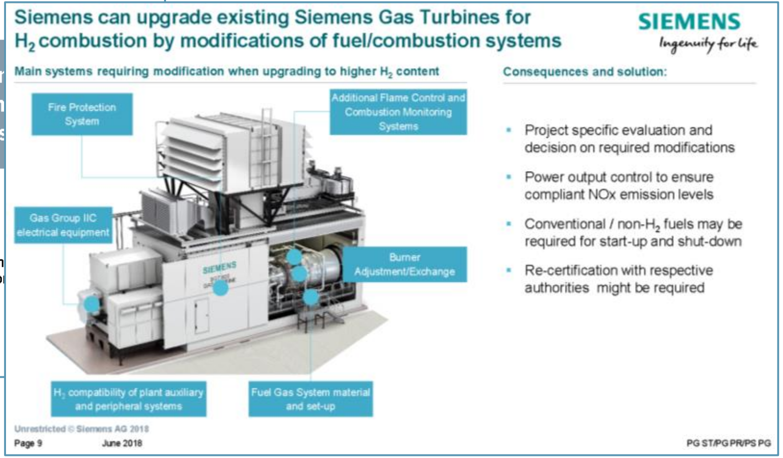
DVGW


H2 admixture harmless
After technical check feasible
Research needed
H2 in natural Gas [Vol.-%]
70
60
50
40
30
20
10
0
Transmission pipelines
Gas turbines
Compressure stations
Cavern (4)
Porous (5)
Tanks
urface and completion technologies
Ultrasonic gas meters
Turbine gas meter
Diaphragm gas meter
Volume corrector
Process gas chromatograph
Gas pressure regulation
Odorizing systems
Distribution pipelines (steel)
Distribution pipelines (plastic)
Seals
Joints
Gas flow monitor
Armatures
Demoestic installation (piping)
Vehicles: engine
Vehicles: CNG1-tanks
Atmospheric gasburner
Forced-air burners
Condensing boilers
Fuel cell
Stirling engine
Gas stove
Combined heat and power unit
Transport
Storage
Metering &
Distribution
Utilization
Source: DVGW / DBI, 2018
Limit according to set of rules / standards / manufacturer Consideration of methane number
Limit according to sensitive components
1 sealing components, flashback, warranty
2 H2-share > 0,2 Vol.-%: PGC's with calibratable H2-measurement
DVGW-follow-up project / R&D-project of further investigations
Solution to higher H2-admixture available

4 How much H_2 in NG seems to be technically feasible?

Bottlenecks / limitations of the "beginning" (2008) have been removed. Example: SIEMENS turbines

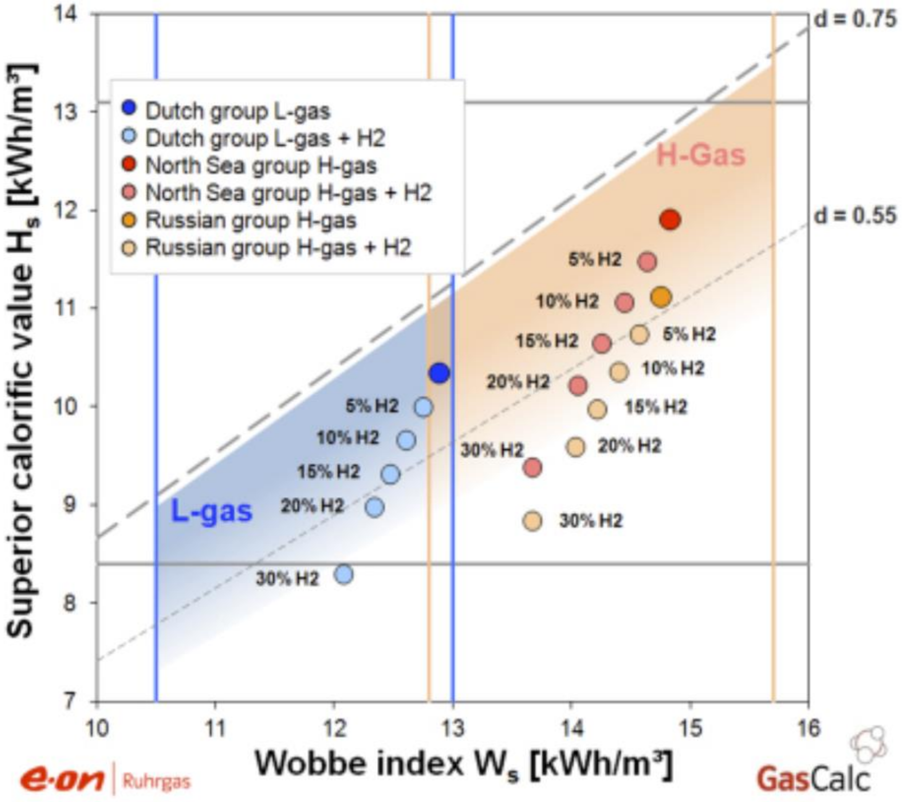




4 How much H_2 in NG seems to be technically feasible?

<u>Gas remains gas</u> (of the first gas family) - as defined through parameters like Wobbe index and caloric value - even if hydrogen is injected, which means that all applications should operate properly within the specified limits.

And for gases with higher hydrogen content (up to 50%) Germany has a complete set of standards (of the so-called second gas family).



Source: Power-to-gas – storage concepts for renewable energy, EDI 2012

4 How much H_2 in NG seems to be technically feasible?

0% H_2

10% H_2

20% H_2

Source: M.J. Kippers, J.C. De Laat, R.J.M. Hermkens Kiwa Gas Technology, Apeldoorn, J.J. Overdiep, GasTerra, A. van der Molen, W.C. van Erp, Stedin, A. Van der Meer, Joulz: **Pilot Project on Hydrogen Injection in Natural Gas on Island of Ameland in the Netherlands**; Poster Präsentation im Rahmen der IGRC, Seoul 2011

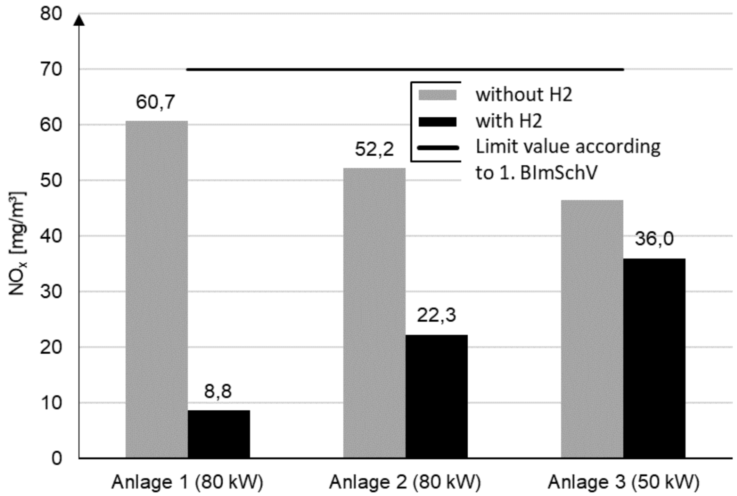
DVGW

4 How much H_2 in NG seems to be technically feasible?

Experiences/demonstration cases: P2G-Plant energiepark Mainz

- Successful injection of hydrogen for approx. 2 years with a hydrogen concentration of up to 10% by volume (1,000 households into an existing subnetwork with single-sided feed-in)

- Heat generators were examined and it could be proved that the H2 injection increased the air ratio λ and therefore lowered CO and NOx emissions



How much H_2 in NG seems to be technically feasible?

Experience/demonstration cases: Klanxbüll & Neunkirchen

Appliances installed across distribution grid

9 different technologies	condensing boilers, HWS boilers, gas cookers, CHP units, fan-assisted burners, commercial appliances, …
27 different manufacturers	
Age of appliances	1 – 17 years

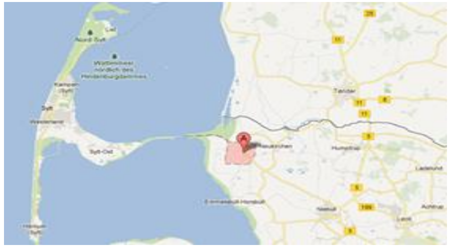
First injection phase from 19 May to 16 July 2014

Hydrogen concentration	2%, 3% and 4%
Total injection period	59 days (intermittent)

Second injection phase form 6 January to 21 April 2015

Hydrogen concentration	4%, 6,5% and 9%
Total injection period	102 days (continuous)

No technical problem



Schleswig-Holstein Netz AG

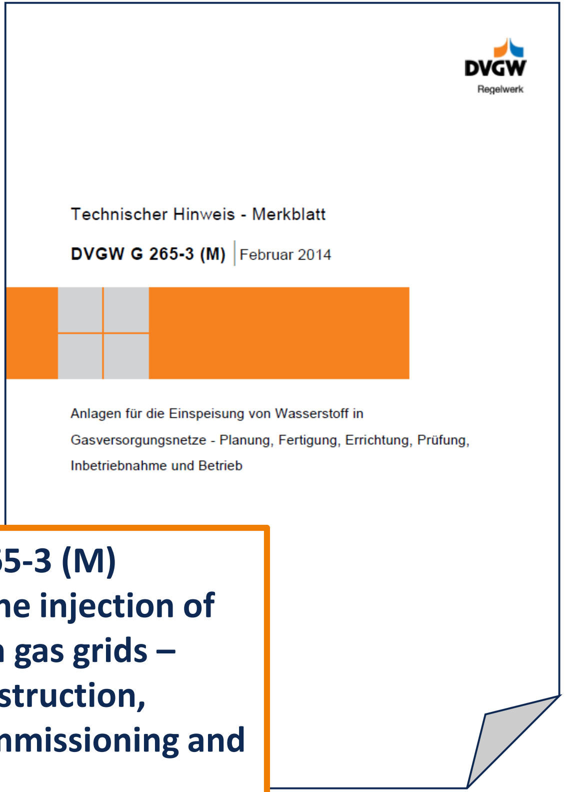
e·on DVGW

DVGW

4 How much H_2 in NG seems to be technically feasible?

Hydrogen injection plants are already part of the German natural gas grid, specified in standards like DVGW G 265-3 (M)

Hydrogen – predominately generated from renewable energy – is per legislation equal to biogas (§ 3 Nr. 10c EnWG)


DVGW
Regelwerk

Technischer Hinweis - Merkblatt

DVGW G 265-3 (M) | Februar 2014

Anlagen für die Einspeisung von Wasserstoff in Gasversorgungsnetze - Planung, Fertigung, Errichtung, Prüfung, Inbetriebnahme und Betrieb

DVGW G 265-3 (M)
Plants for the injection of hydrogen in gas grids – design, construction, testing, commissioning and operation

How much H_2 in NG seems to be technically feasible?

- Underground Sun Storage: http://www.underground-sun-storage.at

- EDGaR: http://www.edgar-program.com/

- HYPOS: HYDROGEN POWER STORAGE & SOLUTIONS EAST GERMANY
approx.: 90 partners (R&D and demonstration for cost reduction)

- HYREADY: JIP initiated by DNV GL in cooperation with DBI in order to develop industrial guidelines for H2 in gas grids. Contact: Onno.Florisson@dnvgl.com

- HIPS-NET: European Network (GERG) more than 35 partners to establish a common understanding on the acceptable H2 concentration in the gas grid by condensing knowledge and initiate projects on open issues. Contact: Gert.Mueller-Syring@dbi-gut.de

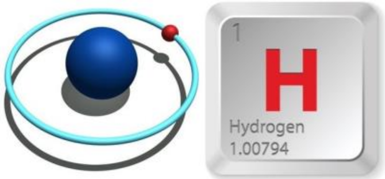
- Sector Forum "Energy Management" – WG Hydrogen
Aiming to prepare standardization for hydrogen

- Marcogaz Task force Hydrogen

5 Why is hydrogen transport in NG pipelines a top issue in Germany?

Green hydrogen is a means to lower emission from gas and therefore a welcomed contribution to fulfill climate targets.

Gases (natural gas, biogas, hydrogen, syngas) allow a steady and continuous path towards Paris without risks or disruptive hiccups.

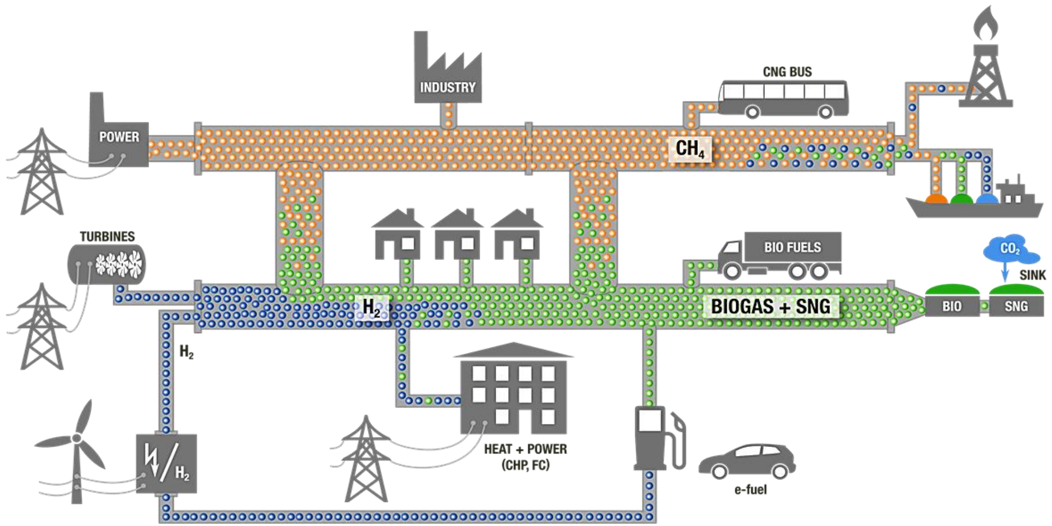


Gases - such as hydrogen - are chemical energy storages which are indispensable in the energy transition and in a world of growing fluctuating generation.

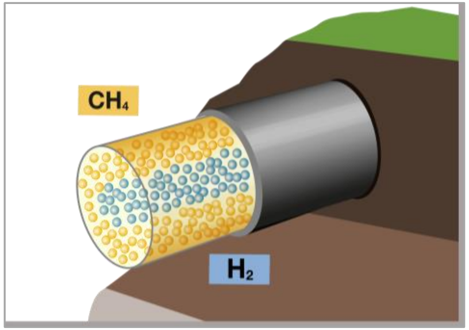
DVGW

5 Why is hydrogen transport in NG pipelines a top issue in Germany?

NG grids can find a second life in becoming the carrier for hydrogen
NG grid can serve as a pipeline in a pipeline by transporting two substances simultaneously.



Source: DVGW, 2018



Source: DVGW, 2018

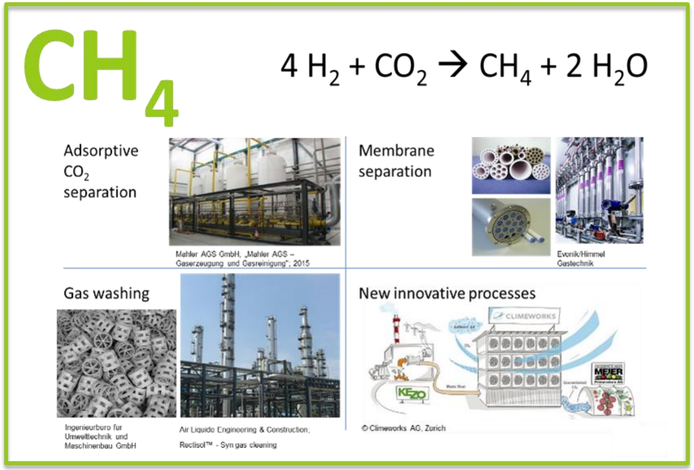
DVGW

5 Why is hydrogen transport in NG pipelines a top issue in Germany?

Promising R&D and demos in hydrogen and syngas:

We might see the transport of hydrogen (up to 20%) as a mid-term but temporarily option as methanation will become highly efficient.

Efficiency of electrolysis plus methanation ($e^- \rightarrow H_2 \rightarrow CH_4$) > 80%



Germany industry provides sufficient sources for (green, grey...) CO_2 for methanation.

(unpublished DVGW study 2018)

DVGW

5 Why is hydrogen transport in NG pipelines a top issue in Germany?

Promising R&D and demos in hydrogen and syngas:

EU R&D Project STORE&GO

- Demonstration of 3 innovative methanation concepts in Germany, Switzerland and Italy
- Fully integrated in existing energy grids
- Cross cutting activities on the role of PtG in the European energy system

German R&D Project MethQuest

- Producing methane from renewable sources adapted energy and cost efficient production processes
- Development of flexible, efficient and clean mobile and stationary applications (CHP, CNG and ship engines)
- Sector coupling concepts based on developed technologies

DVGW

5 Why is hydrogen transport in NG pipelines a top issue in Germany?

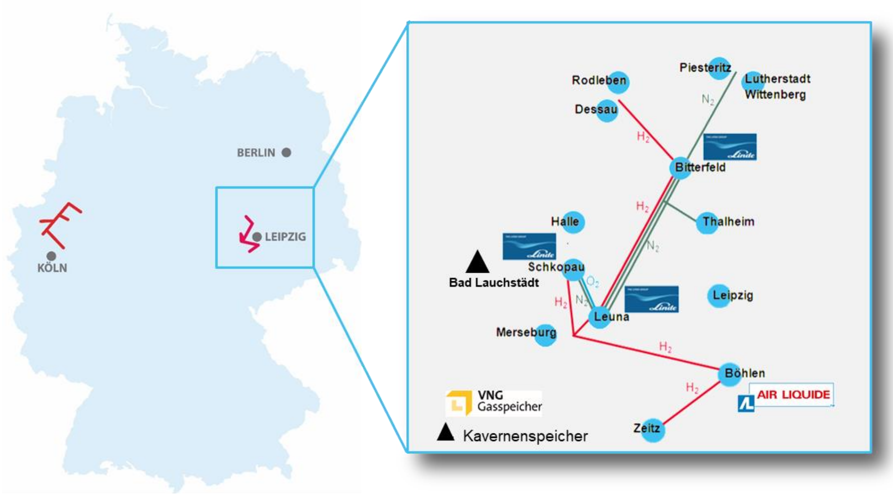
Promising R&D and demos in hydrogen and syngas:

HYPOS

Hypos = consortia to test Interaction of natural gas and H_2 grids, to store H_2 and to supply an entire city with H_2

Local advantages in HYPOS-Region

- H2 gas grid for chemical industry (150 km)
- Cavern storage and
- Highest potential of PV + wind power in Germany



- First European gas cavern for RES Hydrogen
- Rededication of Natural Gas transport pipeline to H2
- Supply for chemical industry, domestic customers
- Parameter:
  - Cavern size: 42 Mio. m³ (working gas)
  - Max. operation pressure: 140 bar
  - Supply capacity: 100.000 m³/h
  - Connection pipeline: ca. 20 km (30 bar)
- Partners:

DBI · VNG Gasspeicher · ontras Gastransport GmbH · Fraunhofer IWM · terrawatt · Linde · HYPOS · DVGW

6 What is needed next?

DVGW Recommendations

	Power Sector	Heat Sector	Transport Sector
Fuel Switch	• Capitalise budget and time **benefits of natural gas** in all sectors • Set **fair benchmarks** (such as "Well to Wheel" for NGV)		
Content Switch	• Define a **green gas target** per country • Stimulate green gas growth through **annual quota** or **CO_2 pricing** • Prepare gas infrastructure for **hydrogen**		
Modal Switch	• **Remove barriers** between power and gas systems • Design a **P2G ramp-up program** and foster sector coupling • Stimulate increase of heating **efficiency** (e.g. via KfW aid) • Utilise **e-fuels** in HT industry and other critical areas		

With a focus on hydrogen

- Investments in H_2 readiness need to be rewarded
- Regulatory framework need to be design barrier free
- P2G and e-fuel ram-up program and "Reallabore"

6 What is needed next?

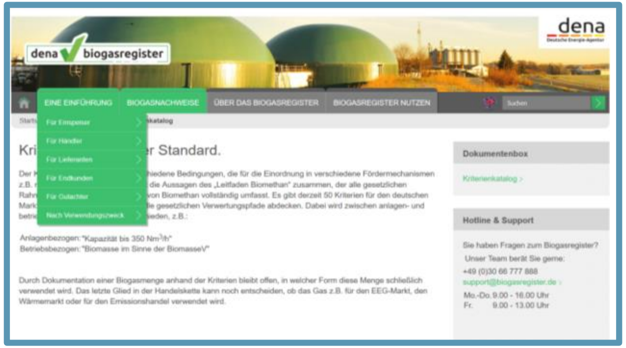
(1) Legal definition of green hydrogen and green gas

Low carbon hydrogen (CertifHy proposal as adopted by the FCH-JU):
> 60% GHG reduction (cradle-to-gate) in comparison to current H_2 production (central SMR from NG) which is
60% of 91 g CO_{2eq}/MJ_{H2} = 36,4 g CO_{2eq}/MJ_{H2}
It may be adopted also for green gas, however based on a cradle-to-grave LCA.

- Grey H_2 > 36,4 g CO_{2eq}/MJ_{H2} independent of energy origin
- Green H_2: < 36,4 g CO_{2eq}/MJ_{H2} and renewable energy origin
- Blue H_2: < 36,4 g CO_{2eq}/MJ_{H2} and fossil/nuclear energy origin

(2) Proof of origin: A system like the German Biogas Register from dena could be used as a blueprint or a proposal from CertifHy

(3) Product catalogue of H_2-ready and certified component (DVGW started work on this)



DVGW

6 What is needed next?

Simplification of approval and commissioning processes: see governmental initiative PORTAL GREEN

Deliverables:
Guidelines for legal approval processes
Project duration:
01.01.2018 – 31.12.2020
Budget: 1,3 million €

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Konsortium

Bergische Universität Wuppertal

DBI GUT Gas- und Umwelttechnik GmbH

DVGW

GRS

uniper

DVGW

Thank you for your attention and have a look at 40 real-scale installations of the future gas system

www.dvgw-energie-impuls.de

http://www.wvgw.de/dyn_pdf/energie-impuls/

Prof. Dr. Gerald Linke, CEO DVGW, German Gas and Water Association