

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.***

Table of Contents

- 1** *Why do we spent effort studying energy supply via hydrogen?*
- 2** *Where could hydrogen come from? @what costs?*
- 3** *How much hydrogen is currently admissible in NG grids?*
- 4** *How much hydrogen is technically feasible in NG grids?*
- 5** *Why is hydrogen transport in NG pipelines a top-ranked issue in Germany?*
- 6** *What is needed next?*

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



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

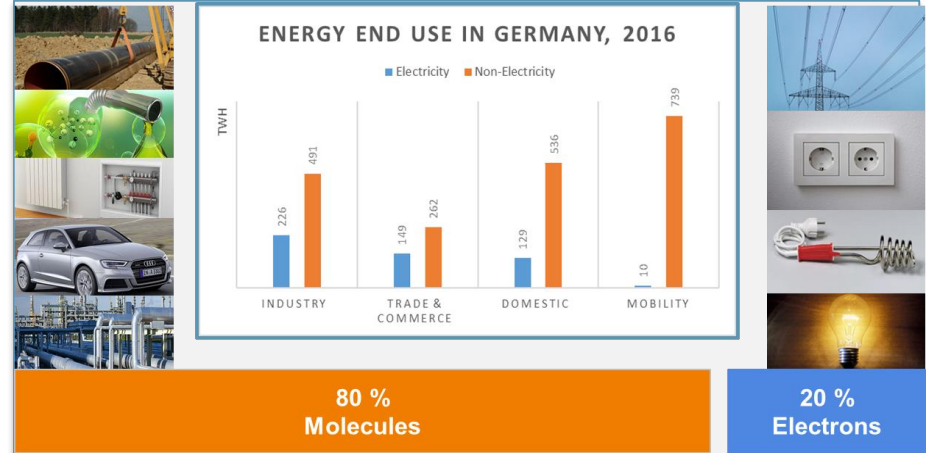
1 Why do we spent effort studying energy supply via hydrogen?

A matter of relevance:

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)

A matter of ability:

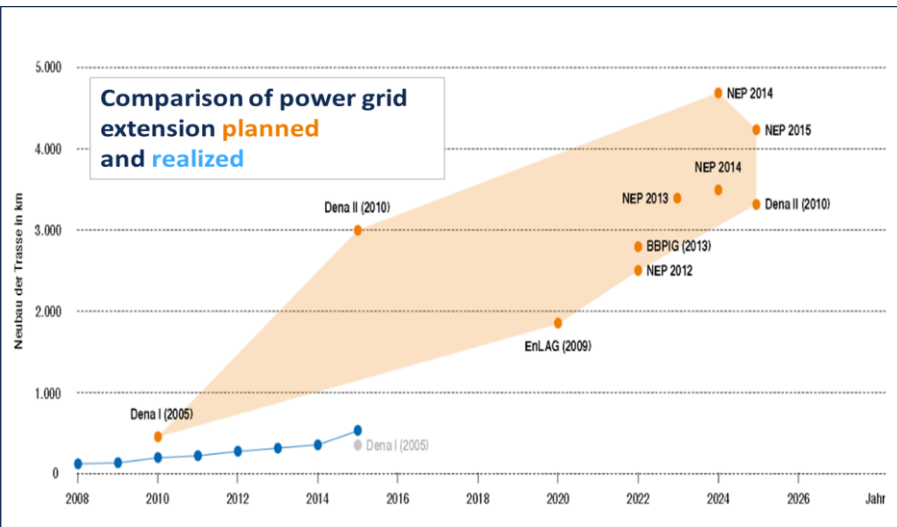
Electrification cannot deliver the high power peaks needed (for example for heating in winter). Gas can.



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

A matter of speed:

Power grid extension is a limiting factor, whereas the gas grid is in place.



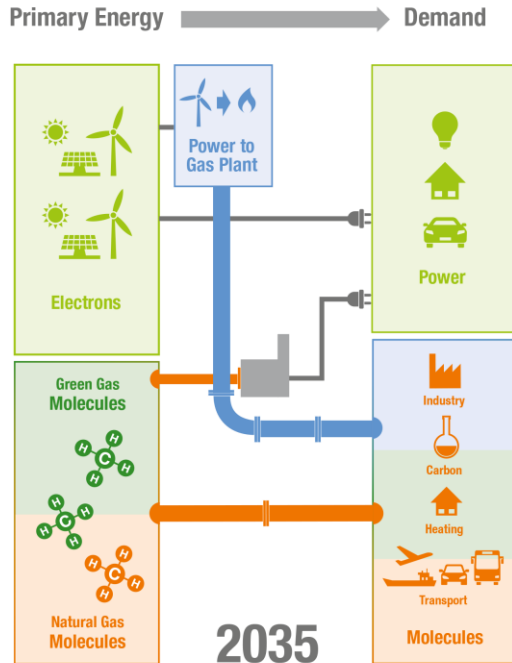
A matter of cost and environmental impact:

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?

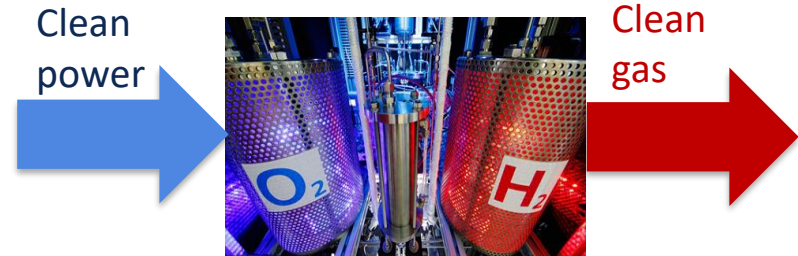
A matter of demand:
Industry needs “molecules”.



Molecules used for

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

Hydrogen can “green”: Production and consumption *can* be provided carbon-free.



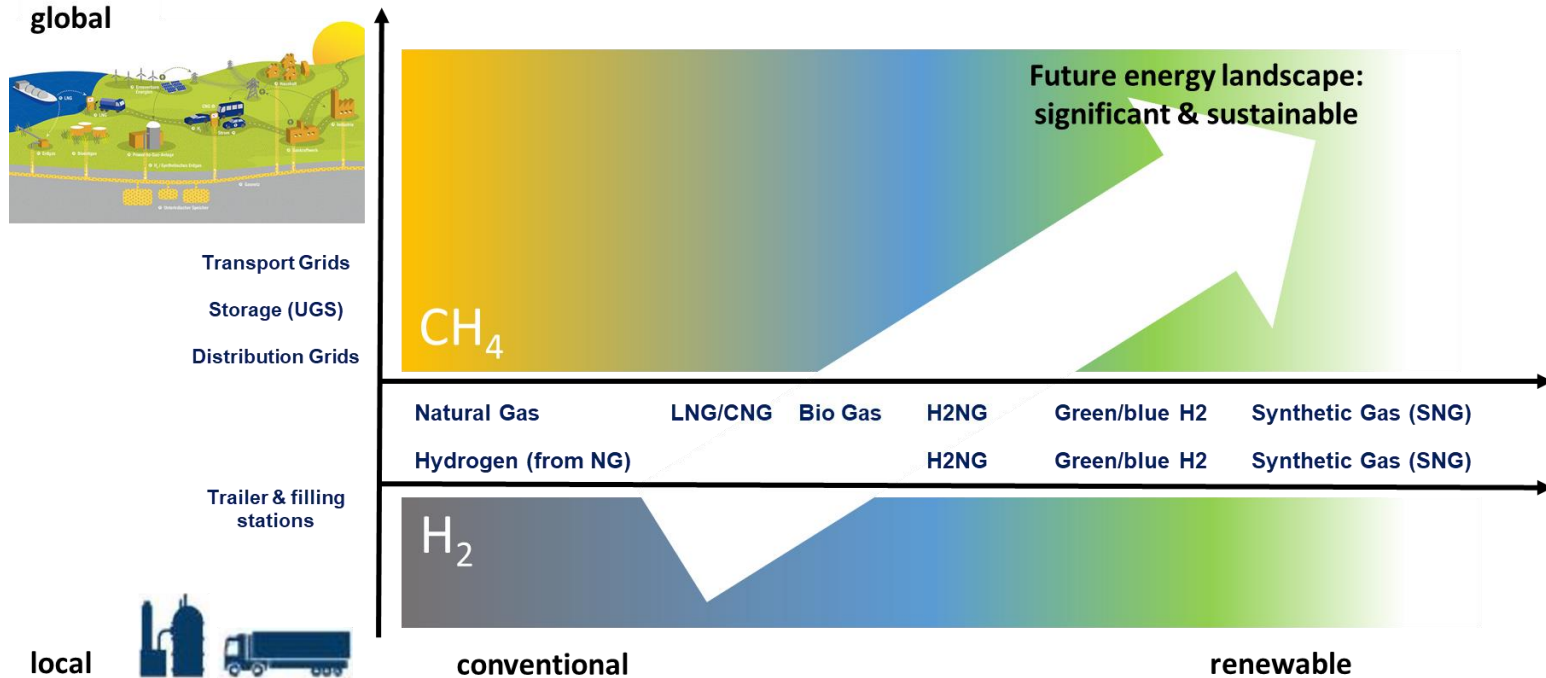
Hydrogen applications are efficient. Example: FCEV



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

A matter of opportunity:

The natural gas industry - being of largest importance for the EU welfare and delivering more energy than the power segment - has „discovered“ hydrogen.



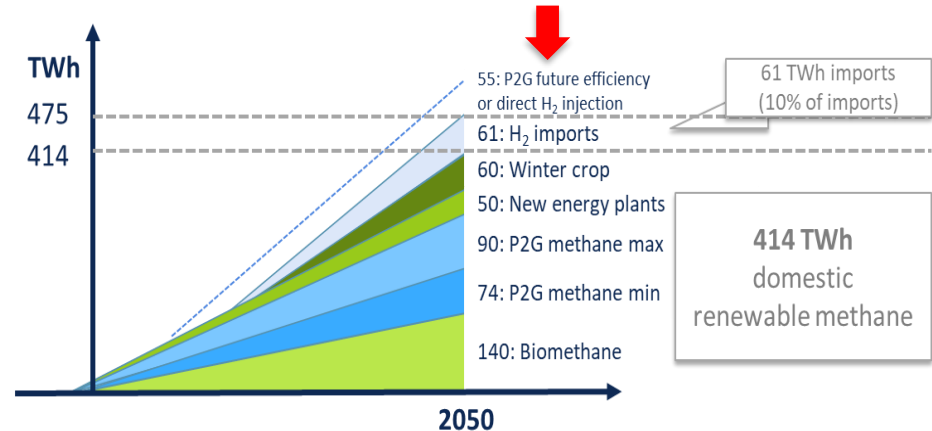
1 Why do we spent effort studying energy supply via hydrogen?

A matter of fact:

Countries like Germany have already quantified the de-carbonisation potential with hydrogen.

| | Power Sector | Heat Sector | Transport Sector |
|----------------|--|--|---|
| Fuel Switch |  Coal → Gas |  Oil → Gas |  Diesel → CNG/LNG |
| Content Switch |  Natural Gas |  Natural Gas → Biogas / Syngas |  Hydrogen |
| Modal Switch |  Power2Gas |  CHP F-Cell Efficiency |  Hydrogen |

Source: DVGW, 2018



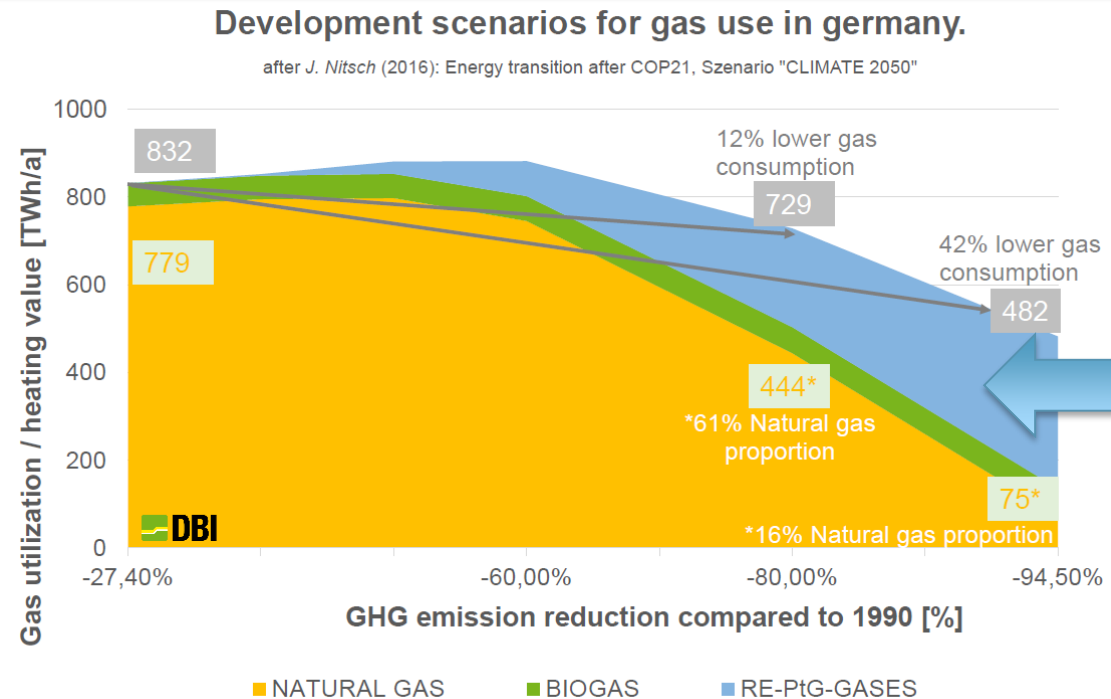
Source: DVGW & ECOFYS, 2018

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?

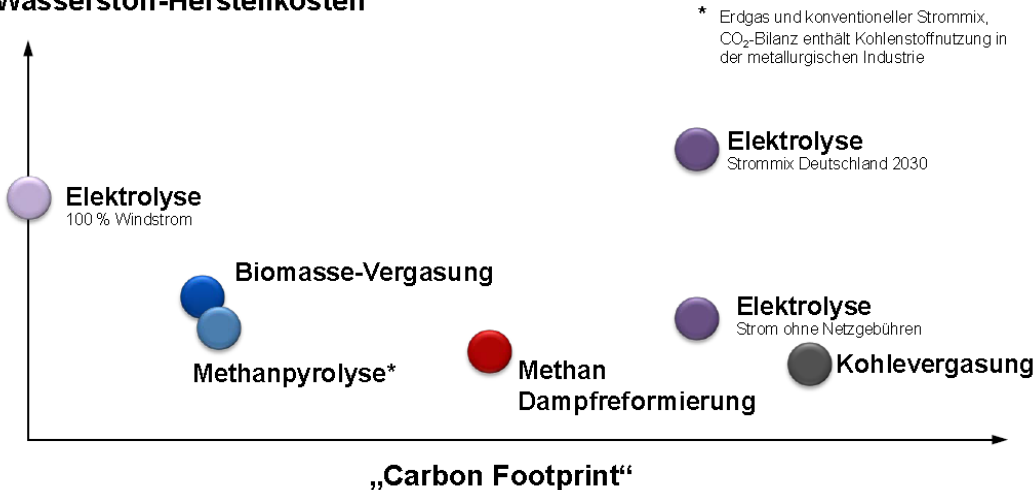
- From power via electrolysis
 - From green power producing **green** H₂
- From gas via steam reforming
 - From green gas producing **green** H₂
- From gas via pyrolysis
 - producing **blue** H₂
- From gas via CCS or CCU
 - producing **blue** H₂

Wasserstoff

Herstellkosten und „Carbon Footprint“



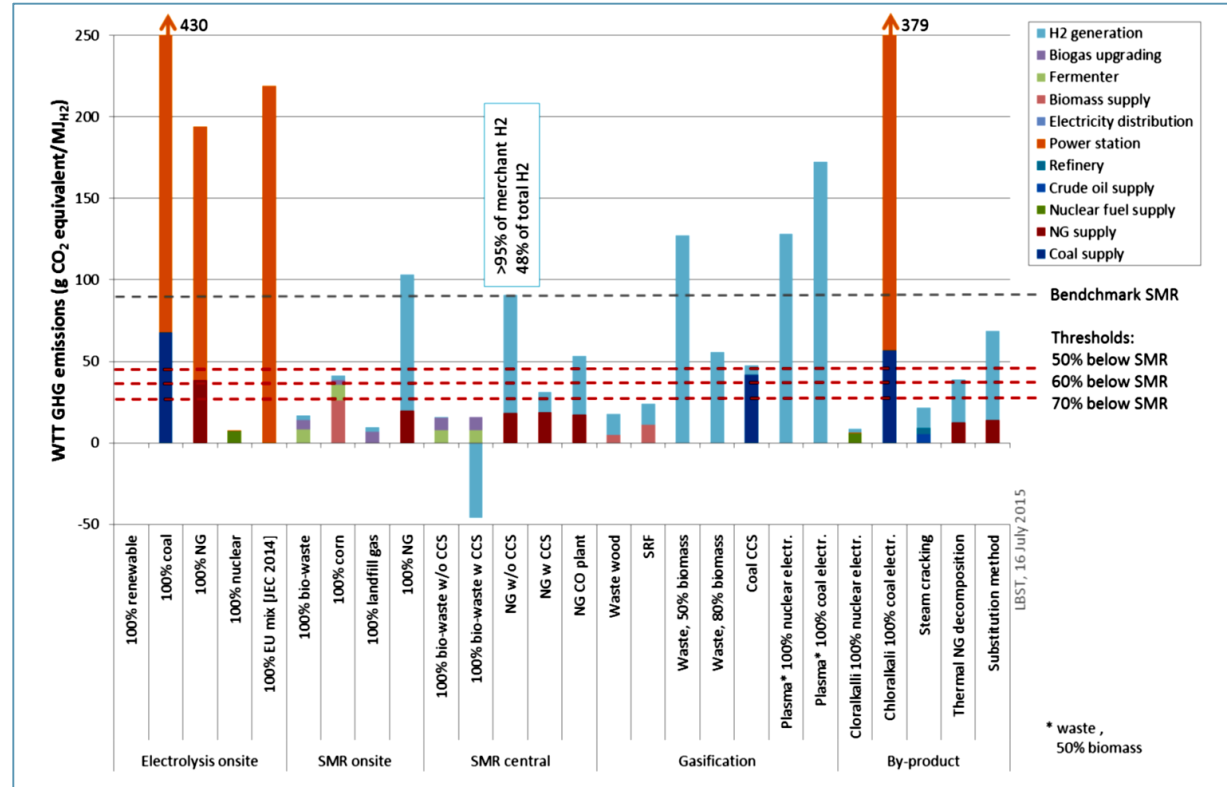
Wasserstoff-Herstellkosten



Quelle: Machhammer et al 2016: Financial and Ecological Evaluation of Hydrogen Production Processes on Large Scale. Chem. Eng. Technol. 2016, 39, No. 6, 1185-1193

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)



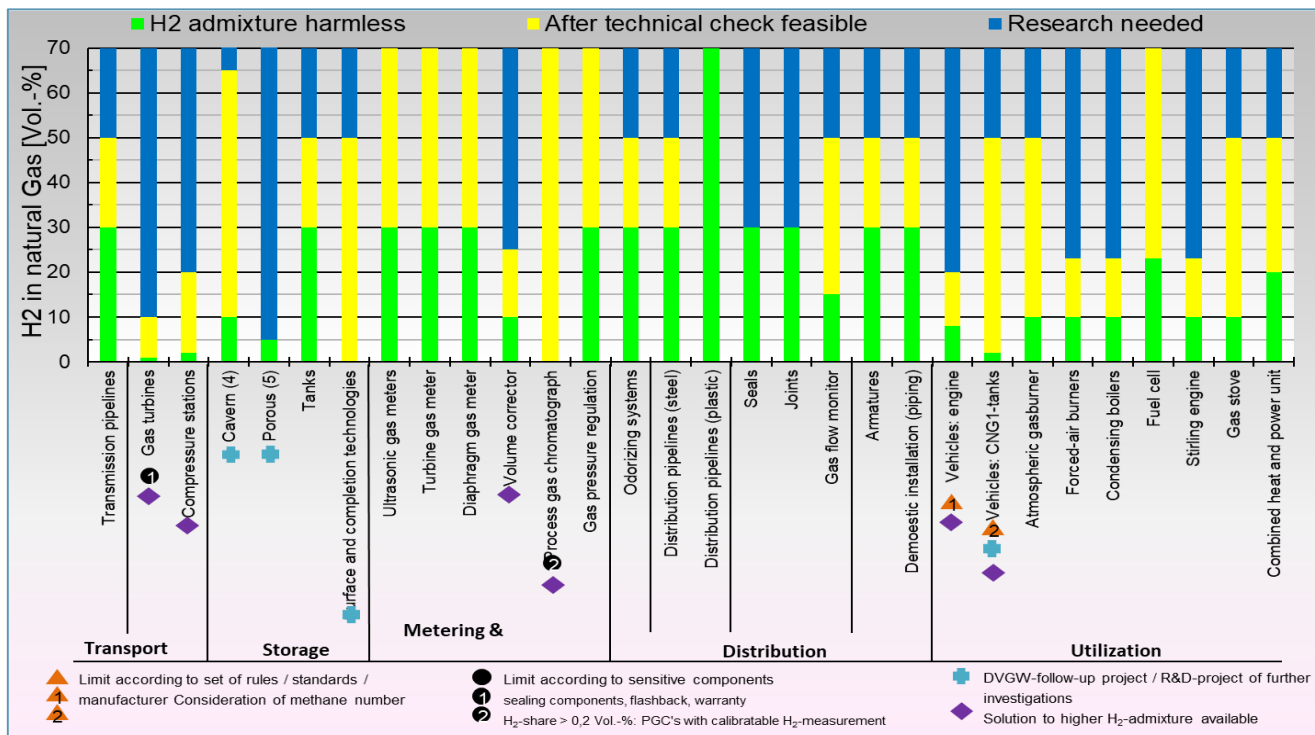
GHG emissions of hydrogen production on an LCA basis (cradle to gate)
(Source CertifHy, FCH-JU 633107, Del. 2.4, 2015)

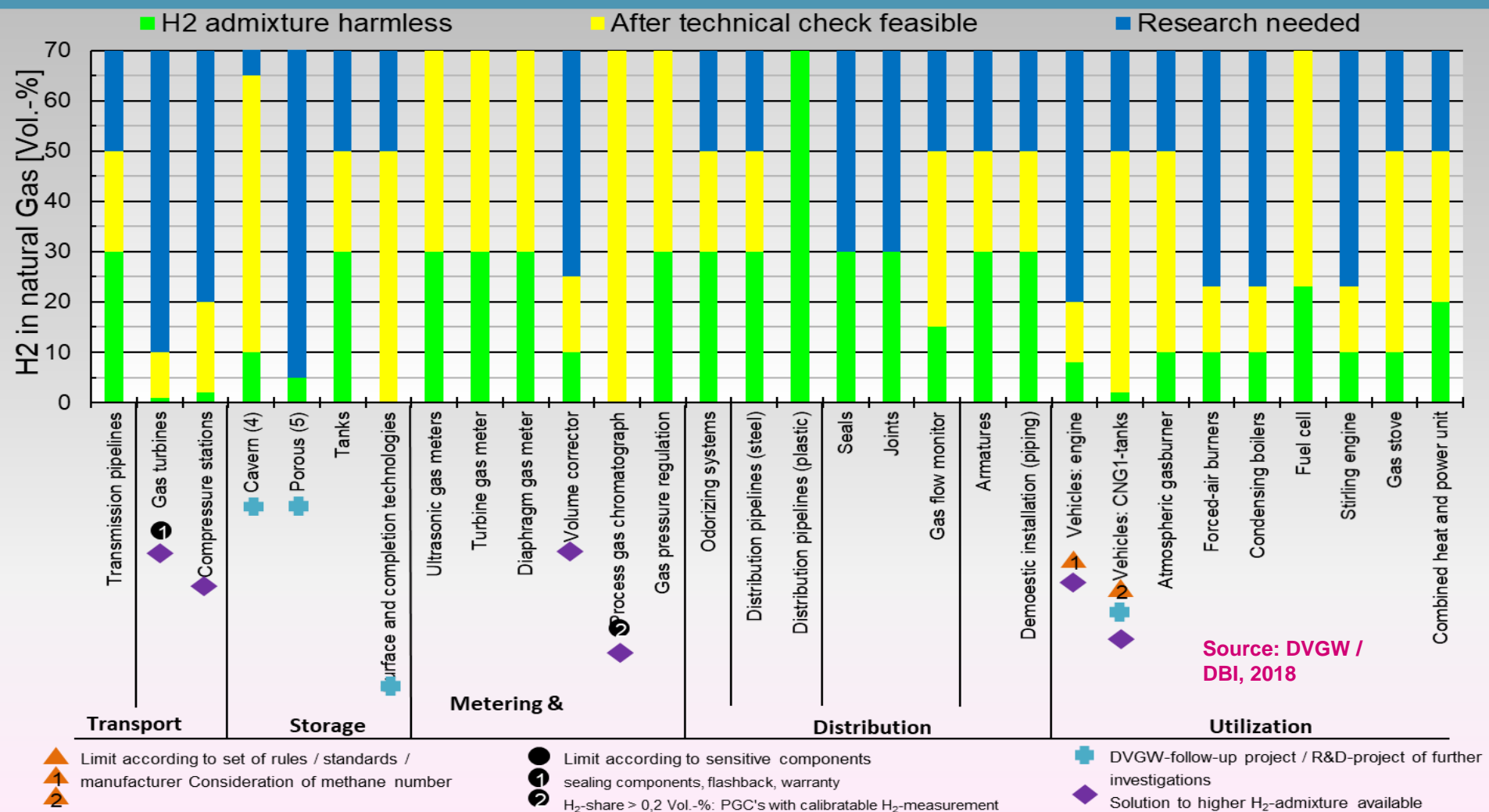
How much hydrogen is currently admissible in NG grids?

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

How much H₂ in NG seems to be technically feasible?

Based on a broad set of studies, DVGW permits 10% H₂ in the gas grid and is preparing the transition to higher double-digit concentrations

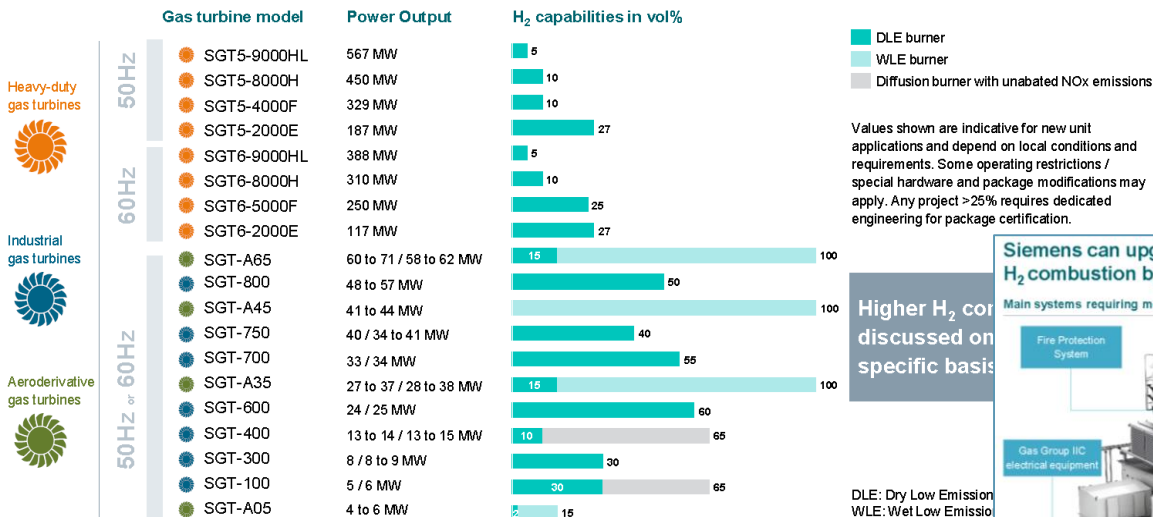




How much H₂ in NG seems to be technically feasible?

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

Siemens Hydrogen Gas Turbines for our sustainable future – The mission is to burn 100% hydrogen



SIEMENS
Ingenuity for Life

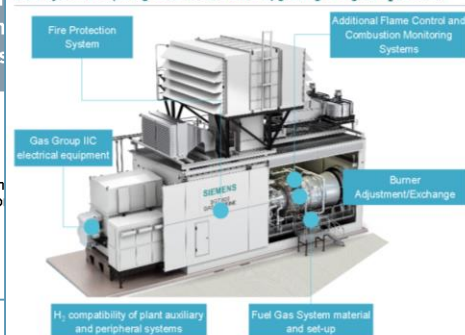
Higher H₂ content
discussed on a
specific basis

DLE: Dry Low Emission
WLE: Wet Low Emission

Siemens can upgrade existing Siemens Gas Turbines for H₂ combustion by modifications of fuel/combustion systems

SIEMENS
Ingenuity for Life

Main systems requiring modification when upgrading to higher H₂ content



Consequences and solution:

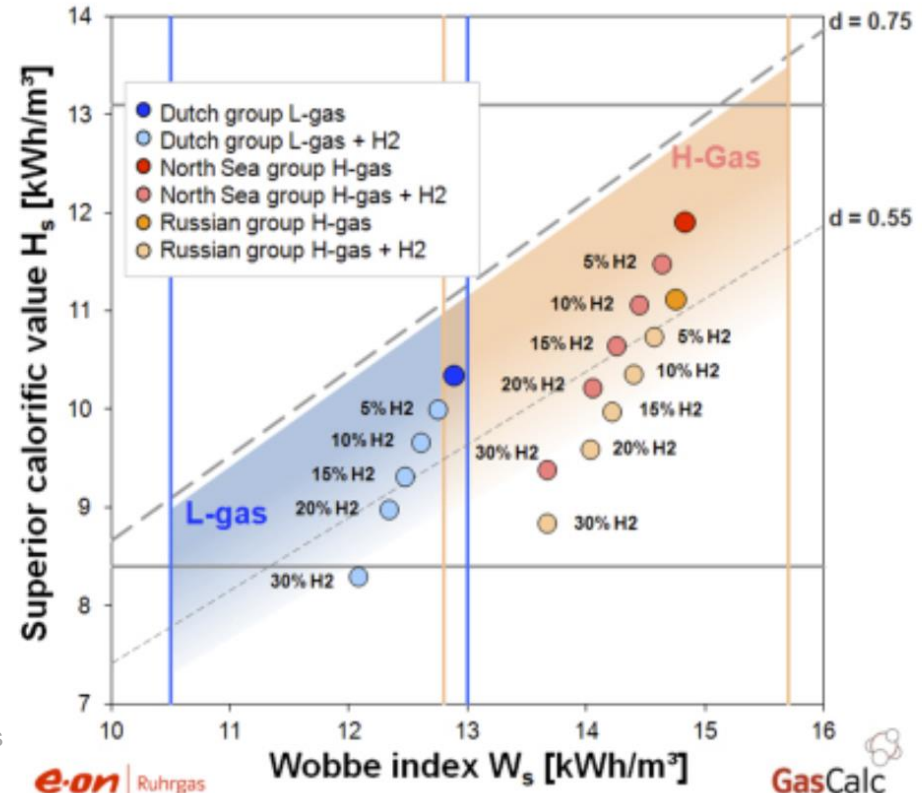
- Project specific evaluation and decision on required modifications
- Power output control to ensure compliant NOx emission levels
- Conventional / non-H₂ fuels may be required for start-up and shut-down
- Re-certification with respective authorities might be required

4 How much H₂ in NG seems to be technically feasible?

Gas remains gas (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



How much H_2 in NG seems to be technically feasible?



0% H_2



10% H_2

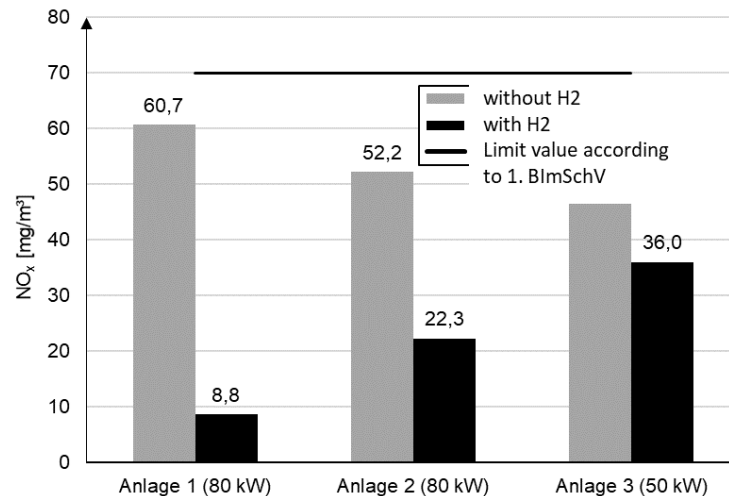


20% H_2

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

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 NO_x emissions



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

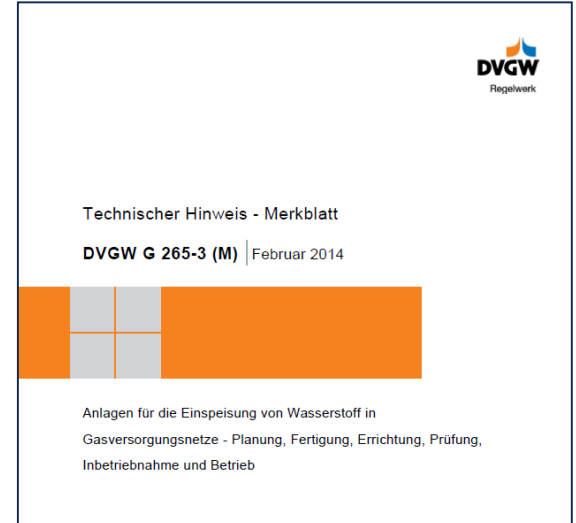
DVGW

DVGW

How much H₂ 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 G 265-3 (M)
**Plants for the injection of
hydrogen in gas grids –
design, construction,
testing, commissioning and
operation**

How much H₂ in NG seems to be technically feasible?

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



RAG.AUSTRIA.ENERGIE

- 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 () 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



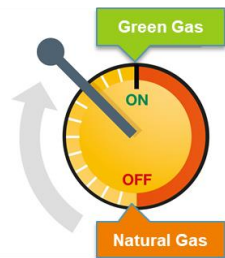
- Marcogaz Task force Hydrogen



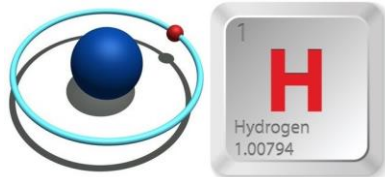
Why is hydrogen transport in NG pipelines a top issue in Germany?



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



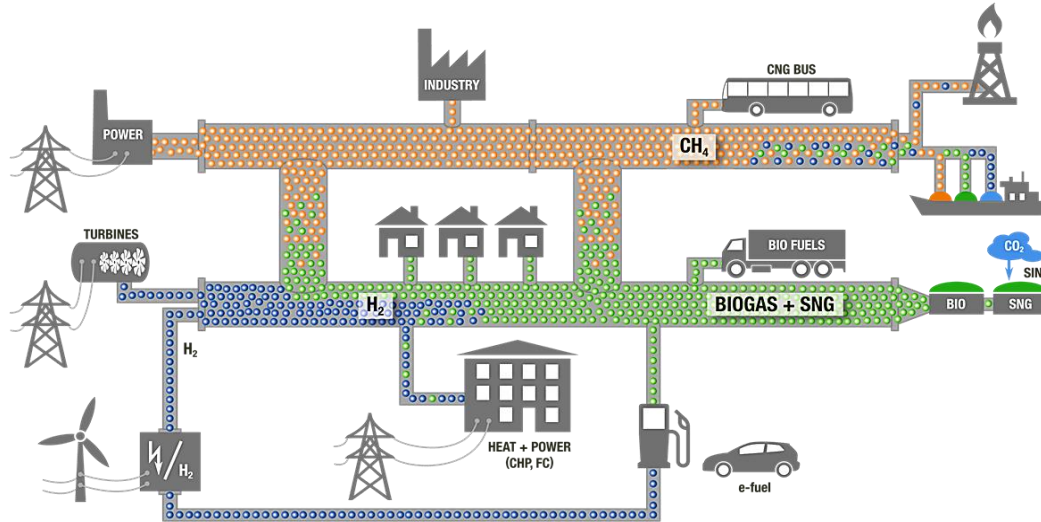
Gases (natural gas, biogas, hydrogen, syngas) allow a steady and continuous path towards Paris without risks or disruptive hiccups.



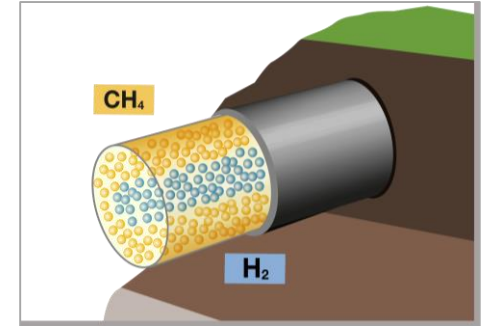
Gases - such as hydrogen - are chemical energy storages which are indispensable in the energy transition and in a world of growing fluctuating generation.

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

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

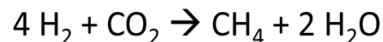
Promising R&D and demos in hydrogen and syngas:



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%

CH₄



Adsorptive
CO₂
separation



Mahler AGS GmbH, „Mahler AGS –
Gewebezug und Gewerzeugung“, 2015

Membrane
separation



Evonik/Himmel
Gestechnik

Gas washing

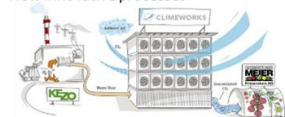


Ingenieurbüro für
Umwelttechnik und
Maschinenbau GmbH



Air Liquide Engineering & Construction,
Rectisol™ - Syngas cleaning

New innovative processes



© Climeworks AG, Zürich

Germany industry provides sufficient sources for
(green, grey...) CO₂ for methanation.
(unpublished DVGW study 2018)

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

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

Promising R&D and demos in hydrogen and syngas:

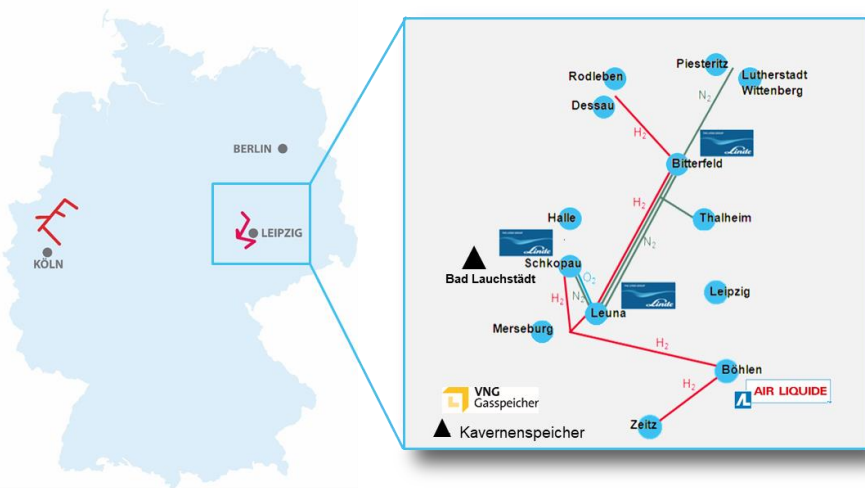


Hypos = consortia to test
Interaction of natural gas and
H₂ grids, to store H₂ and to
supply an entire city with H₂

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:



Recommendations

| | Power Sector | Heat Sector | Transport Sector |
|----------------|--|-------------|------------------|
| Fuel Switch | <ul style="list-style-type: none"> Capitalise budget and time benefits of natural gas in all sectors Set fair benchmarks (such as “Well to Wheel” for NGV) | | |
| Content Switch | <ul style="list-style-type: none"> Define a green gas target per country Stimulate green gas growth through annual quota or CO₂ pricing Prepare gas infrastructure for hydrogen | | |
| Modal Switch | <ul style="list-style-type: none"> 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

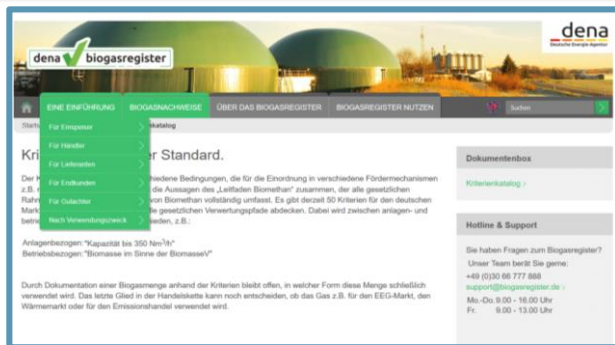
- Investments in H₂ readiness need to be rewarded
- Regulatory framework need to be design barrier free
- P2G and e-fuel ram-up program and “Reallabore”

(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 H₂ 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 H₂ > 36,4 g CO_{2eq}/MJ_{H2} independent of energy origin
- Green H₂: < 36,4 g CO_{2eq}/MJ_{H2} and renewable energy origin
- Blue H₂: < 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 H₂-ready and certified component (DVGW started work on this)



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



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