EXPLANATION OF ZOOM

FIRST STEP: PUT ON YOUR MIC AND YOUR VIDEO

SECOND STEP: PUT ON THE GALLERY VIEW SO THAT WE ALL COULD SEE US

We recommend the use of a **head-set** for a better audio quality.

At the beginning of the webco please show your **webcam** for a short welcome.
To reduce data traffic, please switch them off afterwards. Use the webcam if you are speaker and in the breakout rooms.

Please mute your **microphone** as long as you are not speaking. For the welcome and in the breakout rooms do not mute your microphone. Do not forget to deactivate the mute function, if you want to say something!

For questions or remarks during the presentation please use the **chat function**.

– The moderator will announce your question after the presentation.

– Urgent questions, which are important for understanding, can also be asked in between.

Welcome to our

7th HIPS-NET Workshop

web conference, 3rd & 4th June 2020

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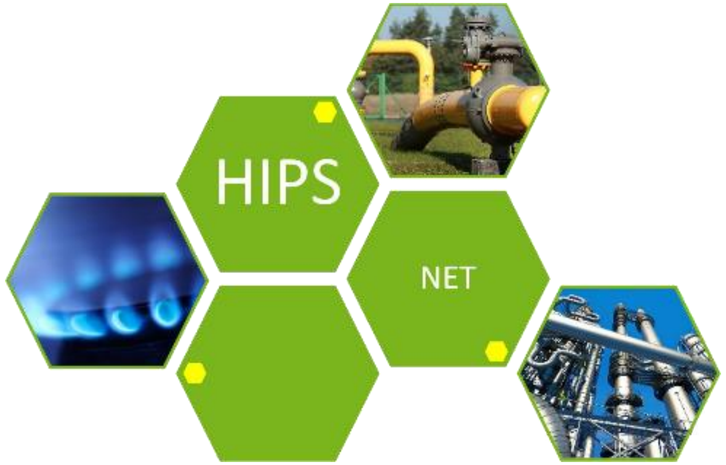
Mentimeter

Short introduction of participants and Agenda



HIPS-NET members (June 2020)

AGENDA – FIRST DAY

- Short introduction of participants and new partners ✓

- Presentations

1	How to proof the importance of blending to the sceptics?	Eva Hennig, Thüga Group
2	H_2 transport in the North Sea and on land: recent TNO projects	Néstor Díez González, TNO

- Outlook for tomorrow & feedback for 1st day

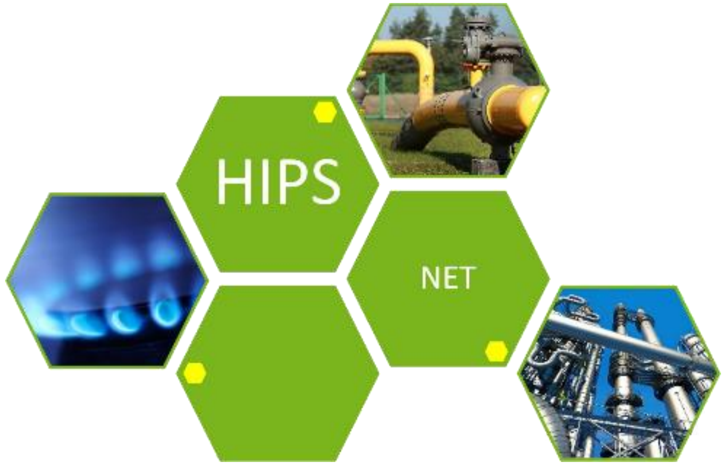
Presentation 1:
How to proof the importance of blending to the sceptics?

Eva Hennig

Thüga Group

7th HIPS-NET Workshop

web conference, 3rd June 2020



Aktiengesellschaft

7th HIPS-NET Workshop

How to proof the importance of blending to the sceptics?

3./4. June 2020 Eva Hennig

THE THÜGA GROUP CONSTITUTES WITH NEARLY 100 COMPANIES THE LARGEST ALLIANCE OF MUNICIPAL UTILITIES SERVING REGIONS AND CITIES IN GERMANY

Turnover
€ 21.5 billion

Gas sales
118.8 billion kWh

Heating Sales
10.0 billion kWh

Investments
€ 1.3 billion

Electricity sale
57.5 billion kWh

Water sales
330.8 million m³

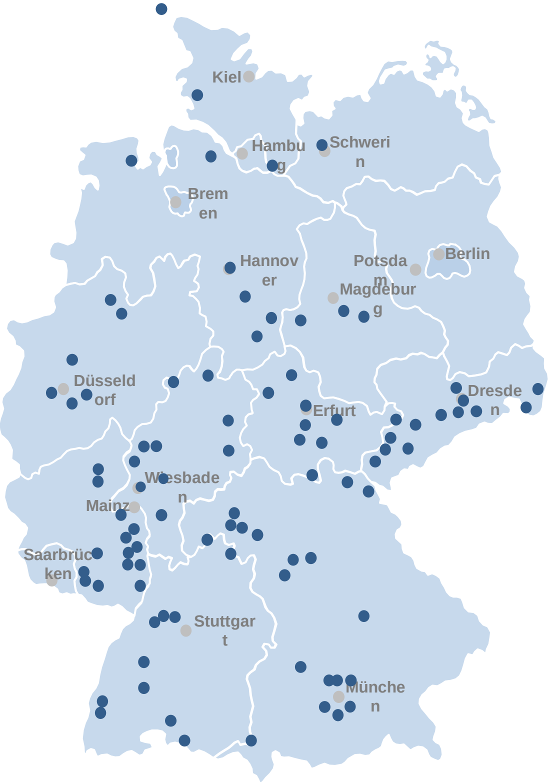
Gas customers
2.0 million

Electricity customers
4.4 million

Employees
20.300

Heating customers
0.1 million

Water customers
1.0 million

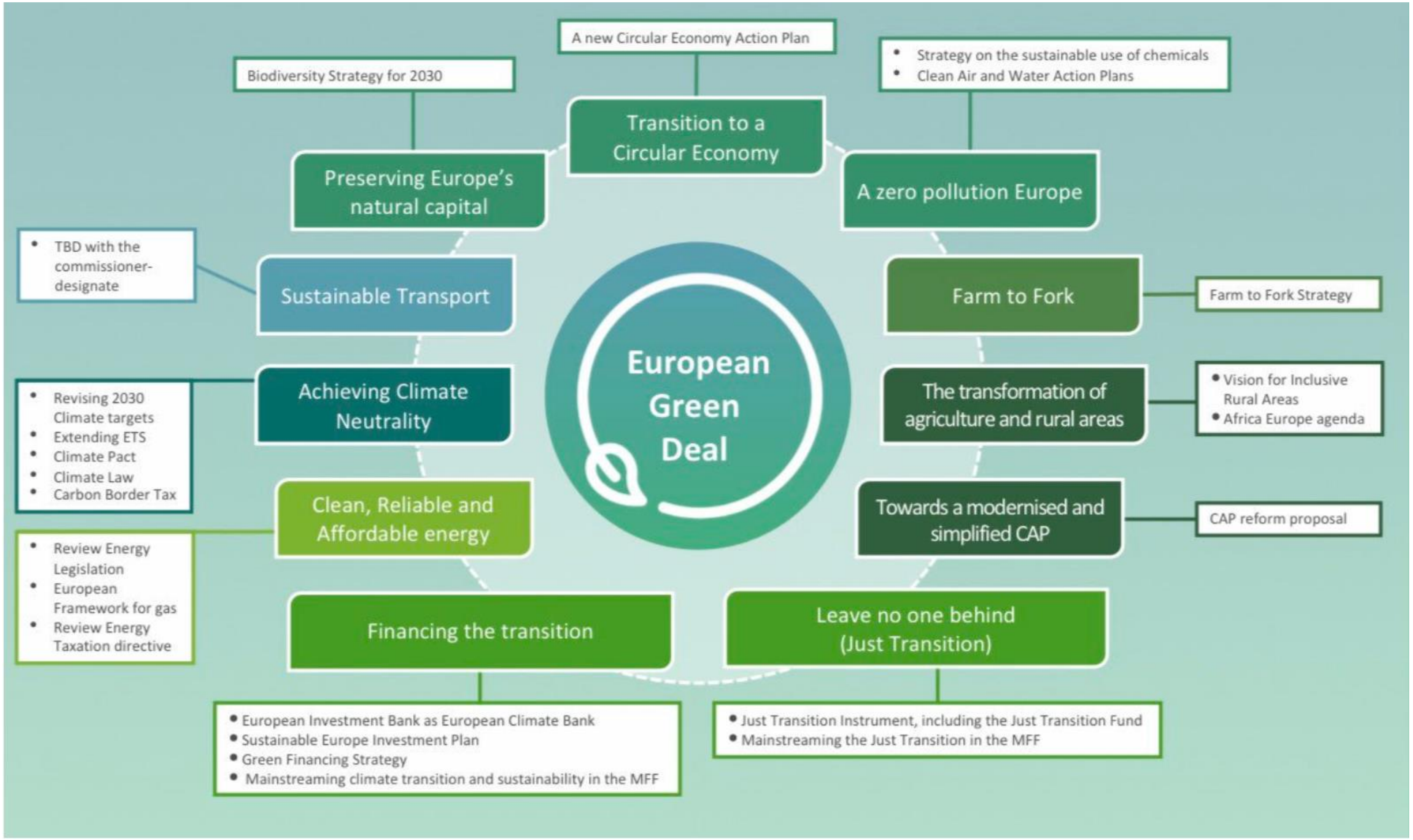


Hydrogen projects:

- Very large interest of the cities and regions for <u>local</u> hydrogen projects. Sector integration is deeply rooted within Thüga companies due to the multi-utility concept
- 2013 first PEM in Germany injecting H2 into the grid of DSO of Frankfurt
- Since 2018 continuous injection into DSO grid in Freiburg
- „Reallabor“ Heide, injection of 20 % H2 in the DSO grid as part of a complex project with refinery, TSO-grid, cement factory, underground storage, green kerosene for airport.
- „Reallabor“ North Germany with P2G from wind and usage of H2 in all sectors
- 100 % grid and methane pyrolysis in concrete planning
- Buy Hydrogen-Ready: project with associations from DE, A, CH and many German DSO to classify new/existing components on their H2-Readiness

thüga Aktiengesellschaft

THE GREEN DEAL IS SO MUCH BIGGER THAN THE CLEAN ENERGY PACKAGE. IN NEARLY ALL SECTORS CONSIDERABLE CHANGES ARE PLANNED TO REACH PARIS 1,5 °C TARGET.



THE TIMELINE IS CONTINUOUSLY CHANGING. COVID 19 HAS SLOWED IT ONLY A LITTLE.

From 2020

- Funding call for public recharging and refuelling points
- Assessment of legislative options to boost production & supply of sustainable alternative fuels for all transport modes
- Initiative to stimulate lead markets for climate neutral &cir-cular producers for energy intensive sectors
- Proposal legislative waste reforms
- Guidance for MS to address energy poverty
- **Integration of Sustainable Development Goals (SDG) in European semester**
- Identify&remedy incoherent legislation
- Initiatives to screen& benchmark green budgeting practices of MS&EU
- Align all new EC initiatives with objectives of Green Deal and promote innovation
- Measures to support deforestation-free value chains
- Green agenda for Western Balkans
- **Strengthen EU´s Green Deal diplomacy**
- Bilateral efforts to induce partners to act&ensure com-parability of action& policy
- Proposal for an 8th Environmental Action programme

In 2020

- **Strategy for sustainable& smart mobility**
- Proposal to support 0 carbon steel making process by 2030
- New EU forest strategy
- **„Renovation Wave" initiative for building sector**
- **TEN-E regulation evaluation&review**
- Strategy on offshore wind
- Review of the non-financial reporting directive

2020/2021

- **New EU strategy on adaptation to climate change**
- Examination of draft national strategic plans with reference to Farm-to-Fork and the Green Deal

From 2021

- Measure addressing main drivers for biodiversity loss
- Initiatives to increase &better manage capacity of railways&inland waterways

In 2021

- Revised proposal for a directive on combined transport
- Review of alternative fuels infrastructure directive and the TENT-T Regulation
- Proposal for more stringent air pollutant emission standards for combustion-engine vehicles
- **Review of relevant state aid guidelines**
- **Proposal for a carbon border adjustment mechanism**
- Zero pollution action plan for water, air, soil
- Revision of measures to address pollution from large industrial installations
- Measures, including legislative, to significantly reduce the use&risk of chemical pesticides, fertilizers &antibiotics

January 2020

- Proposal on a Just Transition mechanism incl. Just Transition Fund&Sustaina-ble Europe Invest-ment Plan

March 2020

- Circular economy action plan
- EC adopts industrial strategy ✔
- Proposal of European climate law ✔
- Launch of European climate pact
- EU Biodiversity strategy for 2030
- Farm-to-Fork strategy

June 2020

- Assessment of National Energy + Climate Plans
- ***Methane Emission strategy***
- ***Hydrogen Strategy***
- ***Strategy for smart sector integration***

Summer 2020

- Chemicals strategy for sustainability
- **Comprehensive plan to increase EU 2030 climate targets to at least 50%, and towoards 55% in a responsible way**

Autumn 2020

- **Renewed Sustainable Finance Strategy**

October 2020

- Legislation on batteries supporting Strategic Action Plan on batteries and circular economy

June 2021

- **Revision/proposal of all relevant legislation to support increased 2030 target (ETS, non-ETS, LULUCF, EED, RED2, CO2 emissions performance standards cars/van)**
- **Proposal for revision of energy taxation directive**

Zero pollution ambition
Mainstreaming sustainability
The EU as a global leader
Sustainable and smart mobility
Farm to Fork
Preserving and protecting biodiversity
Climate ambition
Clean, affordable and secure energy
Industrial strategy for a clean and circular economy
The European climate pact

Thüga Aktiengesellschaft

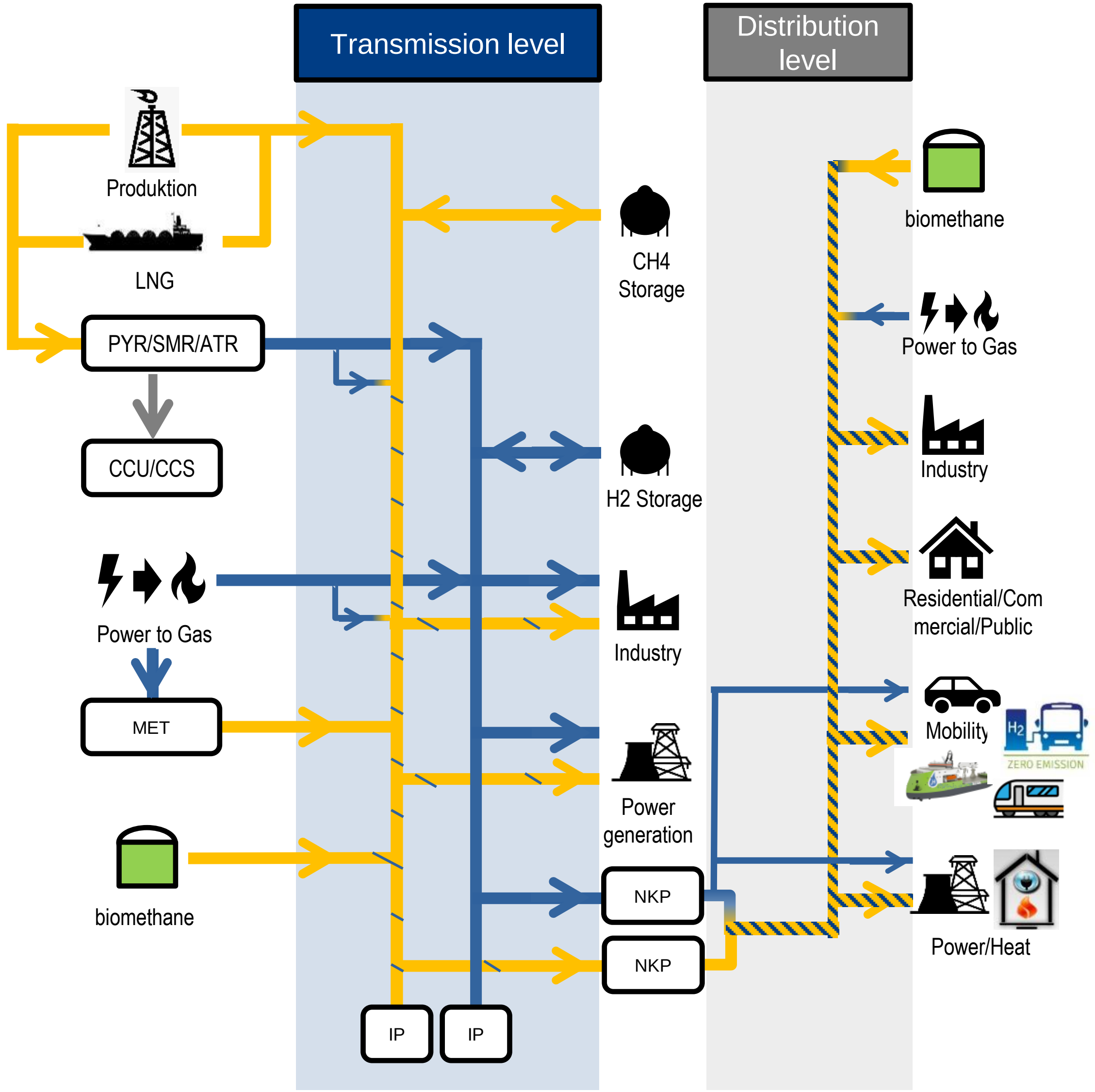
THE DRAFT (END APRIL!) ENERGY SYSTEM INTEGRATION STRATEGY IS DOMINATED BY PURE H2 IN TSO GRIDS FOR INDUSTRY AND LARGE VEHICLES. IT MIGHT HAVE CHANGED…….

- H2 in **the right place at the right time**. For the hardest to decarbonize sector which is presumed to be large industry and long haul transport
- Not technology neutral. Heating shall electrify 40 % in 2030, heat pumps are seen as much more efficient. The rest of heating shall be covered with district heating produced in CHP with large heat pumps or with waste heat. Only then hybrid heatings are mentioned.
- Local RES production is seen positive, pyrolysis not mentioned
- Biogas is seen as a positive local solution to use waste and residues.
- Resilience and seasonal storage is missing
- A lot about scaling up of electrolysers
- Concentrates on green hydrogen, blue hydrogen only if it meets the sustainability criteria
- Terminology and GO are needed
- Possibly a pure hydrogen regulation is planned
- Revise TEN-E, Revise TYNDP

*The case for blending hydrogen in the gas grid is less clear and will thus **deserve careful consideration** as regards its contribution to the decarbonisation of the energy system and its economic and technical implications. Blending hydrogen in the current gas grid to a limited degree[1] could enable decentralised hydrogen production and, to some extent, support the kick-start of renewable hydrogen in a transitional phase. **However**, blending hydrogen has intrinsic limitations which put this option at a disadvantage compared to other alternatives for supporting renewable hydrogen in the medium and long term. Blending reduces the value of hydrogen and prevents its use in higher-value industrial applications . In addition, beyond certain penetration levels, blending creates technical constraints at both injection and end-use appliances level which in turn would result into additional costs.*

[1]A blend of 5-20% by volume can be tolerated by most systems without the need for major infrastructure upgrades or end-use appliance retrofits or replacements (**BNEF, 2020**)➔ **this is the only reference! No projects, no Marcogaz, no GERG mentioned.**

TSO AND DSO DEPEND ON EACH OTHER. ONLY JOINT STRATEGIES IN EACH COUNTRY AND ON EU LEVEL CAN DELIVER A SUCCESSFUL HYDROGEN SYSTEM AND MARKET.



Possible developments on the transmission level

- Use of existing infrastructures
- Converting certain pipelines to 100 % **H2**
- Low H2 blending into the CH4 network. Level not harmful to large feedstock customers, storages, compressors, turbines
- Connect customers and DSO to **H2** and **CH4** grid according to their demand and individual situation

Distribution level

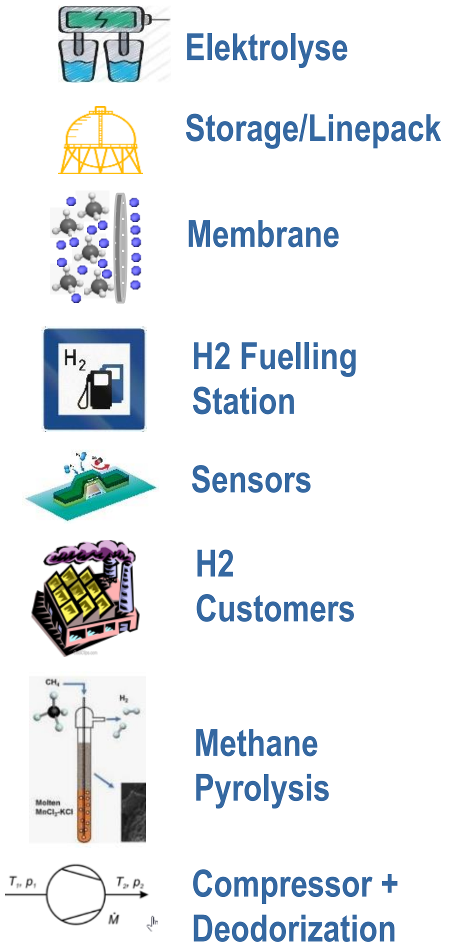
- **Use of existing infrastructure of the grid and the consumers**
- Individual solutions depending in the local situation possible as DSO are usually not interconnected
- Enables local injection of biomethane, hydrogen, blends, syngas
- Possibility for dedicated H2 delivery but also “deblending” with membranes for critical consumers

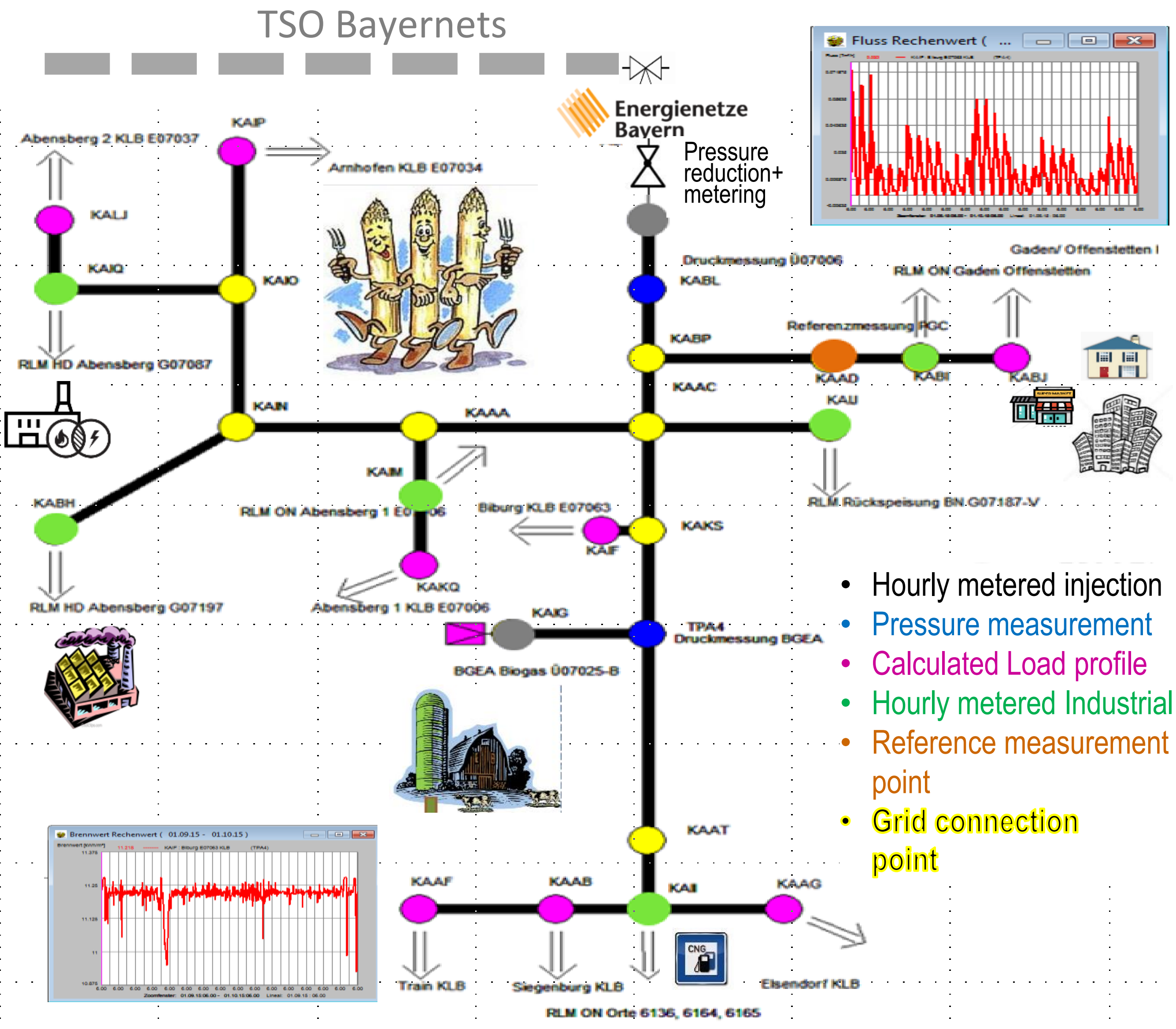
PYR = Pyrolysis	ATR=Autothermal Reformer
SMR = Steam Reformation	MET = Methanisation
CCU = Carbon Capture & Usage	IP = Interconnection point
CCS = Carbon Capture & Storage	NKP = TSO-DSO connection

THE TEN-E REVISION PROCESS IS VERY IMPORTANT TO PROMOT GAS DSO SMART GRID PROJECTS. SO FAR ONLY ELECTRICITY DSO WERE ELIGIBLE, BUT IT WAS COMPLICATED:

Today tracking systems enable the calculation of calorific value for accurate bills to the end consumer and monitor the injection of biomethane plants. Linepack is used in some grids to optimize the system capacity.

In the **future** new elements will be added to the system. For the safe operation more flow measurements and sensors have to be installed to monitor the grid e.g. H2 content, Wobbe Index and calorific value to ensure that appliances/applications work safely and efficiently and that bills are accurate. To increase the injection of R/D-Gas reverse flow from DSO to TSO, increase of line pack or local storages might be needed. Data communication between the various actors has to be developed.





SUSTAINABLE FINANCE IS NOT AGAINST H2 BUT EXPANSION OF THE GRID IS NOT CONIDERED SUSTAINABLE. NOT EVEN TO CONNECT BIOMETHANE OR H2 PLANTS:

4.14 Retrofit of Gas Transmission and Distribution Networks

Sector classification and activity	
Macro-Sector	Electricity, Gas, Steam and Air Conditioning Supply
NACE Level	4
Code	D35.21 H49.50
Description	Retrofit of gas networks for the distribution of gaseous fuels through a system of mains. Retrofit of gas networks for long-distance transportation of gases by pipelines. The **complete** system must have been in place and operating for a minimum of 5 years.

Mitigation criteria	
Principle	Significant GHG emissions reductions by reducing leakage and increasing the volume of hydrogen and other low-carbon gases used in the gas system
Metric & Threshold	Retrofit of gas transmission and distribution networks whose main purpose is the integration of hydrogen and other low-carbon gases is eligible: • Any gas transmission or distribution network activities which enable the network to increase the blend of hydrogen and/or other low carbon gasses in the gas system is eligible • The repair of existing gas pipelines for the reduction of methane leakage is eligible if the pipelines are hydrogen-ready and/or other low carbon gasses-ready. Retrofit of gas networks whose main purpose is the integration of captured CO2 is eligible, if the operation of the pipeline meets the criteria outlined for the transportation of captured CO2. **Gas network expansion is not eligible.**

Rationale

Electrification of the energy sector will not be sufficient to fulfil the EU's net-zero by 2050 target. Molecule-based energy will continue to have a role to play in the future energy supply. This is particularly pertinent to supporting the uptake of hydrogen but one with an enormous capacity to decarbonise the electricity, transport and manufacturing sectors.

Do no significant harm assessment

The main potential significant harm to other environmental objectives from retrofit and operation of existing gas distribution and supply networks that allow for the use of hydrogen and other low- carbon gas systems are associated with:

- Retrofitting phase of the network: all aspects have to be considered that are usually connected with construction like terrestrial habitat alteration, loss of valuable ecosystems, land consumption, overburden disposal, negative impacts on biodiversity, emissions of particles and NOx, noise and hazardous materials. For larger projects an ESIA should be done.
- Operation phase: Leakages should be kept at a minimum. Underground networks can have an impact on ground water systems and on local ecosystems.

(2) Adaptation	• Refer to the screening criteria for DNSH to climate change adaptation.
(3) Water	• Identify and manage risks related to water quality and/or water consumption at the appropriate level. Ensure that water use/conservation management plans, developed in consultation with relevant stakeholders, have been developed and implemented. • In the EU, fulfil the requirements of EU water legislation.
(4) Circular Economy	Ensure appropriate measures are in place to minimize and manage waste and material use in construction and decommission phases. Thresholds: European Directives 2018/850, 2018/851, 2018/852 and BREF document[264]
(5) Pollution	A minimum requirement is the implementation and adherence to a recognised environmental management system (ISO 14001, EMAS, or equivalent); Fans, compressors, pumps and other equipment, which is covered by the Ecodesign Directive and used must comply, where relevant, with the top class requirements of the energy label, and otherwise comply with the latest implementing measures of the Ecodesign Directive and represent the best available technology.
(6) Ecosystems	Ensure an Environmental Impact Assessment (EIA) has been completed in accordance with the EU Directives on Environmental Impact Assessment (2014/52/EU) and Strategic Environmental Assessment (2001/42/EC) or in the case of activities located in non-EU countries other equivalent national provisions or international standards for activities in non-EU countries (e.g. IFC Performance Standard 1: Assessment and Management of Environmental and Social Risks) – including ancillary services, e.g. transport infrastructure and operations). Ensure any required mitigation measures for protecting biodiversity/eco-systems have been implemented. For sites/operations located in or near to biodiversity-sensitive areas (including the Natura 2000 network of protected areas, UNESCO World Heritage sites and Key Biodiversity Areas (KBAs), as well as other protected areas), ensure that an appropriate assessment has been conducted in compliance with the provisions of the EU Biodiversity Strategy (COM (2011) 244), the Birds (2009/147/EC) and Habitats (92/43/EEC) Directives or in the case of activities located in non-EU countries, other equivalent national provisions or international standards (e.g. IFC Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources) – based on the conservation objectives of the protected area. For such sites/operations, ensure that: • a site-level biodiversity management plan exists and is implemented in alignment with the IFC Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources; • all necessary mitigation measures are in place to reduce the impacts on species and habitats; and • a robust, appropriately designed and long-term biodiversity monitoring and evaluation programme exists and is implemented.

THERE IS A LOT OF TALK ABOUT HYDROGEN. HUGE NUMBERS FLOATING AROUND. BUT THIS IS ONLY FOR A VERY SPECIFIC MARKET AND NOT FOR DSO.

We are still in very deep water and 2020 is the year to act as all important decisions are taken.

- Don´t give in and don´t be intimidated
- Know your numbers and voice them prominently
- Speak up, oppose loudly against fake news
- Make projects and promote them with TamTam
- Talk to your customers, support appliance and application tests
- Test material, Test sensors, test membranes, test tracking systems
- Share your knowledge within your country and Europe and the world
- Team up with others, use national and European funds
- Involve you local, regional and national politicians
- Develop a strategy and promote it
- Listen and learn from those who are against hydrogen at DSO level, meet with NGO
- Engage in the process of the sustainable finance regulation and the details of taxonomy
- Be present, attend events, give presentations, raise your voice, take part in consultations
- Send a clear message as a company, association and industry.

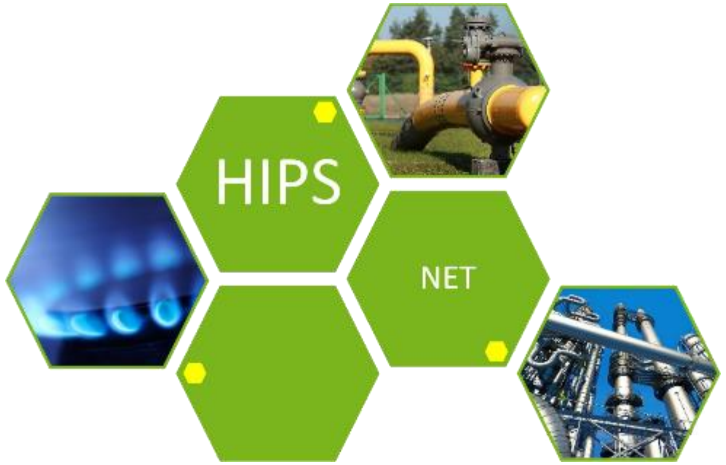
PRESENTATION 2: H_2 TRANSPORT IN THE NORTH SEA AND ON LAND: RECENT TNO PROJECTS

Néstor Díez González

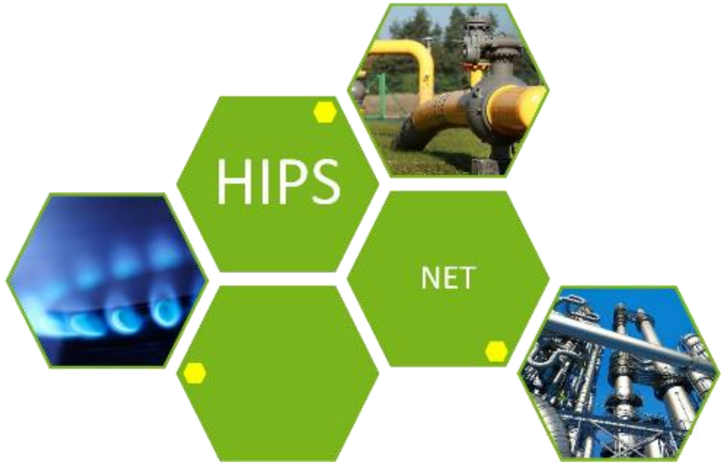
TNO

7th HIPS-NET Workshop

web conference, 3rd June 2020



OUTLOOK FOR TOMORROW & FEEDBACK 1ST DAY



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AGENDA – SECOND DAY

- Welcome and summary from 1st day

- Presentation

1	Hydrogen and integrity of existing natural gas networks	Alfons H. M. Krom, Gasunie

- Interactive part (introduction, discussion in groups, results)

- Presentations

2	Technical & economic conditions for injecting hydrogen into natural gas networks in France	William Rahain, Teréga
3	Organisational aspects HIPS-NET	Gert Müller-Syring, DBI

- Feedback & conclusions

GERG
THE EUROPEAN GAS RESEARCH GROUP

HIPS NET

Energy with Future.
Environment and Responsibility.
DBI

Welcome to our

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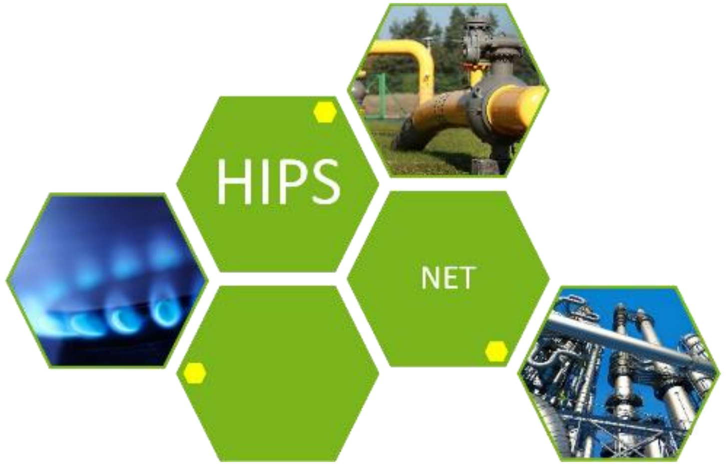
PRESENTATION 1:
HYDROGEN AND INTEGRITY OF EXISTING NATURAL GAS NETWORKS

Alfons H. M. Krom

Gasunie

7th HIPS-NET Workshop

web conference, 4th June 2020



4 June 2020

Hydrogen and Integrity of Existing Natural Gas Networks

HIPS-NET

Alfons Krom

Overview

- Hydrogen embrittlement (definition, factors, origin)
- Hydrogen concentration in steel from different sources
- Types & theories of hydrogen embrittlement
- Hydrogen effect in fracture mechanics tests of steel
- Approach of existing steel pipelines

Hydrogen embrittlement, definition (1/3)

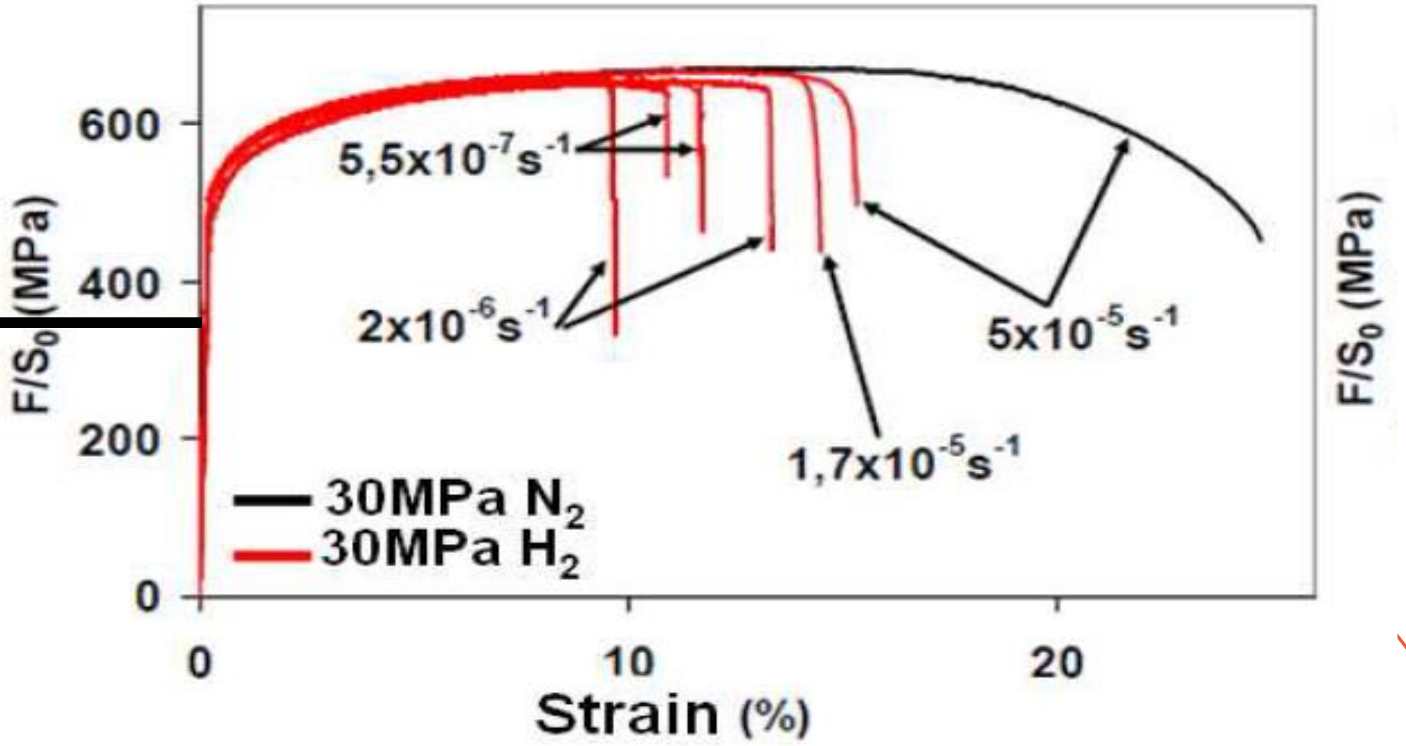
The interaction of hydrogen atoms and a metal may have a negative effect on the mechanical behaviour of the metal. The general term for this degrading effect is *hydrogen embrittlement.*

Hydrogen embrittlement of steel depends on (2/3)

1. the source of the absorbed hydrogen atoms:
   gas molecule H_2 or ion (H^+)
2. the steel strength and microstructure
3. the stress level and temperature
4. the mechanical loading conditions: static, variable, dynamic
5. the occurrence of continuous plastic straining
6. the presence of crack-like defects
7. the presence of oxide layer (H_2 gas only)
8. …

Origin of the term hydrogen embrittlement (3/3)

decrease in ductility in the tensile test with decreasing strain rate



design stress
level in pipeline

L. Briottet, I. Moro, P. Lemoine, Quantifying the hydrogen embrittlement of pipe steels for safety considerations, International Conference on Hydrogen Safety, 4th, San Francisco, 2011

Hydrogen concentration in steel
Hydrogen gas loading, no oxide layer present

- Chemical equation: $H_2 \rightleftarrows 2[H]_{Fe}$
- Sieverts' law: $C_H = k\sqrt{p_{H_2}}$
- k: solubility depends on steel and temperature
- Hydrogen pressure 81 bar / 8,1 MPa (a)

temperature [°C]	steel [atomic ppm]
5	0,15
20	0,25

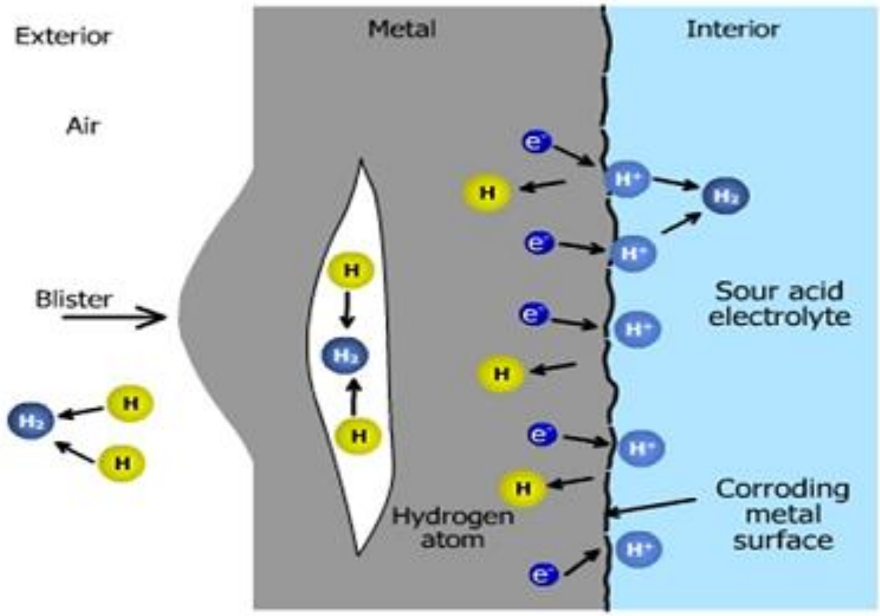
0,25 atomic parts per million = 1 H-atom per 4 million Fe-atoms

Estimated hydrogen concentration in steel
source of H: *H_2S corrosion, welding, cathodic protection and charging*

H source	H concentration [mass ppm]	H concentration [atomic ppm]	equivalent pressure [bar (a)]
81 bar H_2	**0,0045**	**0,25**	**81**
wet 0,01 bar H_2S [a]	0,26	14	7062
active cathodic protection [c]	1,0	56	11438
3 ml H_2/100 g weld consumable	2,7	150	14519
cathodic charging [b]	12	650	19897

a) K. van Gelder et al., Hydrogen-induced cracking: determination of maximum allowed H_2S partial pressures, Corrosion, vol 42, no 1, 36-43 1986
b) M. Tröger et al., Investigations on hydrogen assisted cracking of welded high-strength pipes in gaseous hydrogen, Steely Hydrogen Conference proceedings 2014
c) D.X. He et l., Effect of cathodic potential on hydrogen content in a pipeline steel exposed to NS4 near-neutral pH soil solution, Corrosion, 778-786 2004

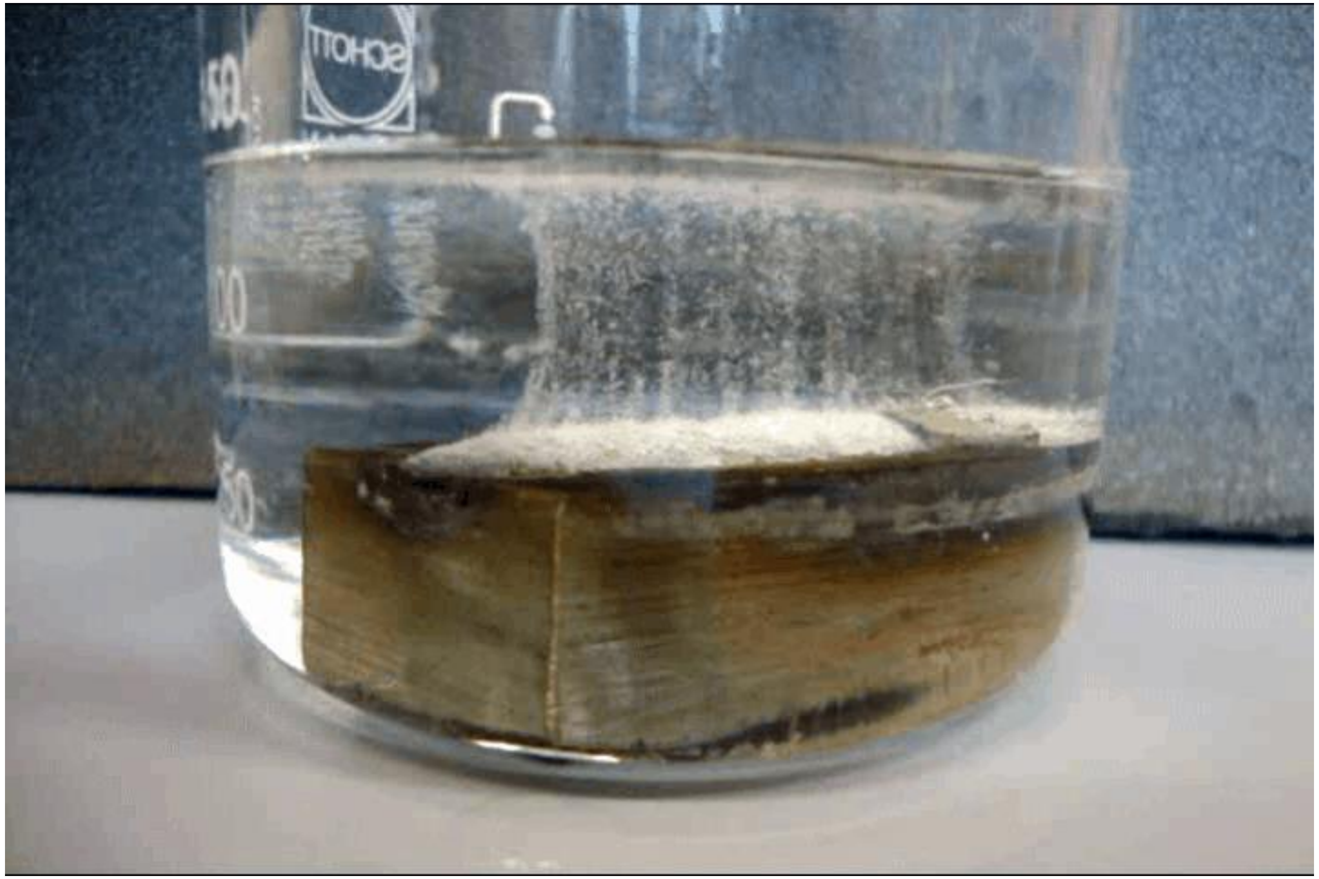
wet H_2S corrosion -> Hydrogen-induced cracking recombination of H-atoms in defects in the steel wall



blister

Pipelines: no HIC because hydrogen gas pressure is significantly lower.

Escaping hydrogen gas from weld with high hydrogen content in the weld electrode

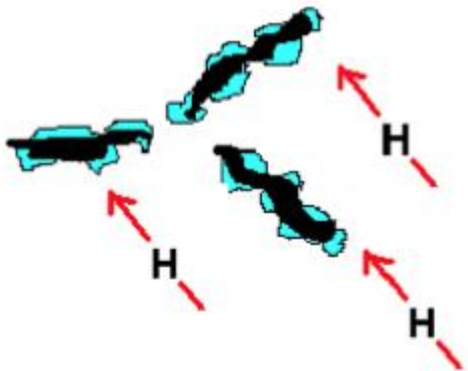


Hydride formation

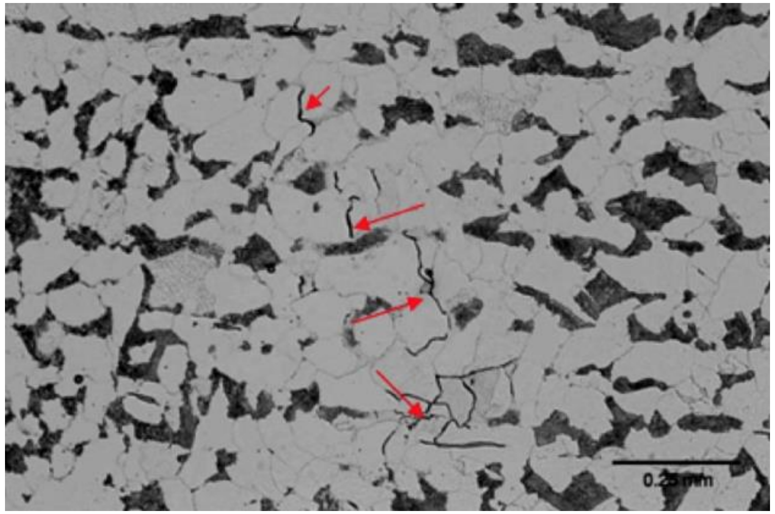
https://www.youtube.com/watch?v=0OivtRfarVQ

Hydrogen attack (1/2)

CH4 gas pockets (blue)

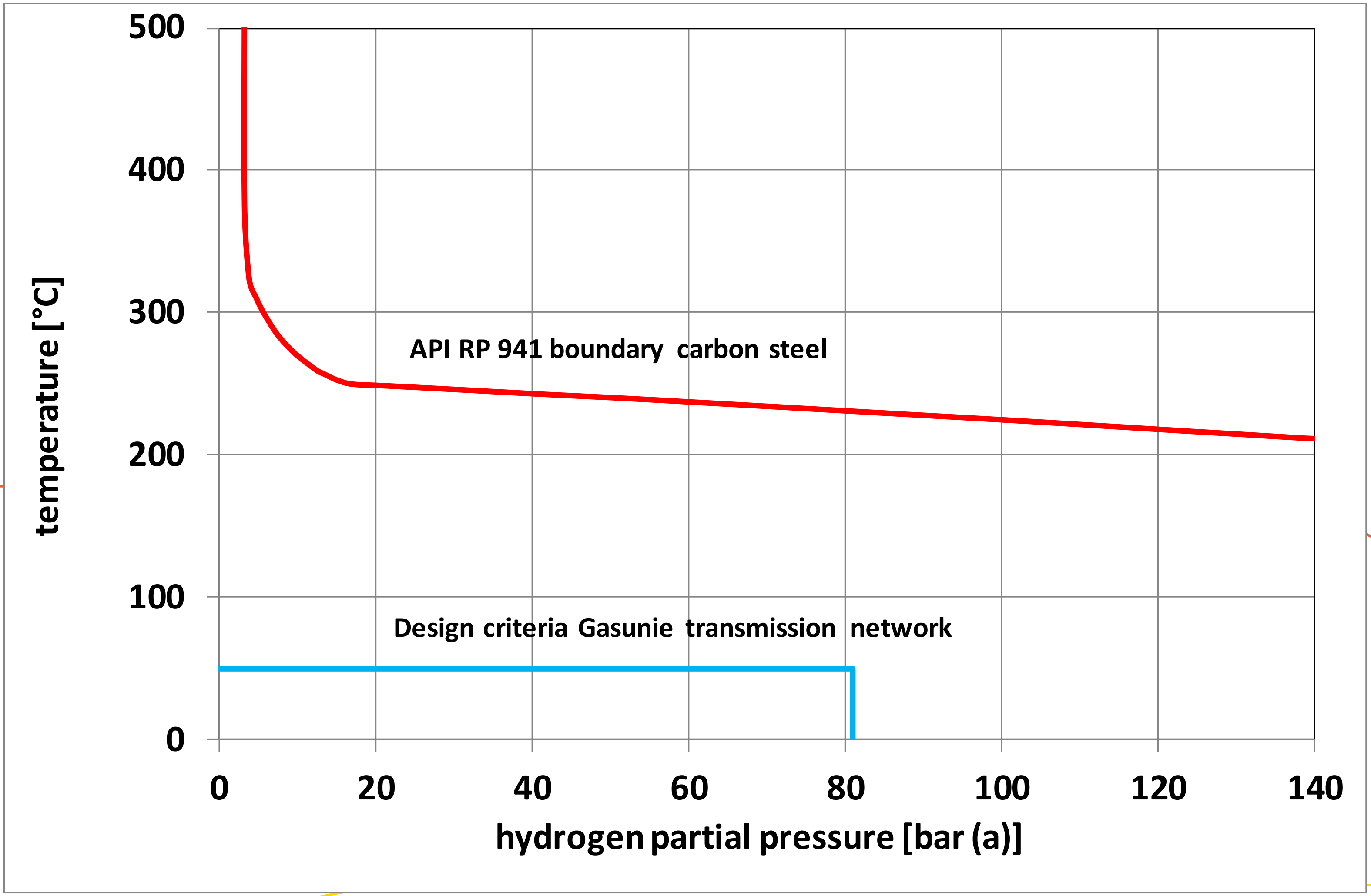


H is driven into the steel by heat & pressure, and reacts with the Fe3C to form CH4 gas



https://www.csb.gov/csb-releases-new-computer-animation-of-2010-explosion-and-fire-that-killed-seven-workers-at-the-tesoro-refinery-in-anacortes-washington/

Hydrogen attack: use of steel (2/2)

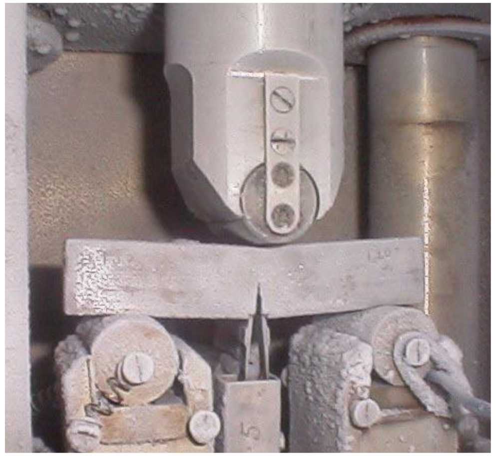


hydrogen embrittlement theory	description
hydrogen pressure / hydrogen induced cracking (HIC)*	pressure built up at internal defects
hydrogen hydride forming*	forming of brittle compound (does not occur with iron)
hydrogen attack*	hydrogen reacts with carbon to form methane, temperature >200 °C
hydrogen enhanced decohesion (HEDE)	hydrogen atoms influence the bond between metal atoms
hydrogen enhanced local plasticity (HELP)	hydrogen enhances the movement of dislocations

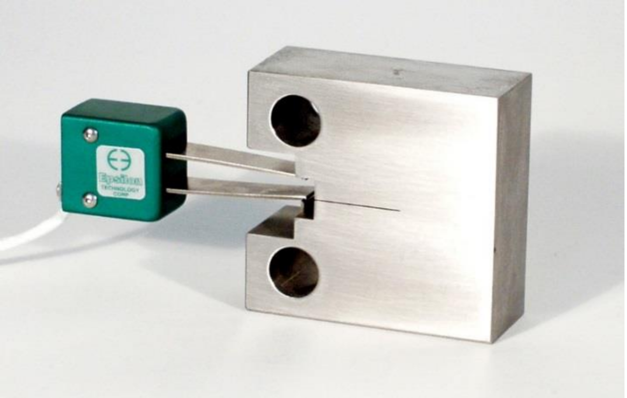
* not relevant for existing steel pipelines for natural gas

Fracture toughness & fatigue crack growth testing

- specimen with a pre-fatigued crack (most critical defect)
- specimen is loaded increasingly until failure or loaded repeatedly (fatigue) after an amount of crack growth
- load versus crack mouth opening measured
- because of plastic deformation the oxide layer is broken
- fracture toughness and crack growth derived from the measurements
- depends on loading rate / frequency
- crack driving force $K=\sigma\sqrt{\pi a}$ or $\Delta K=\Delta\sigma\sqrt{\pi a}$

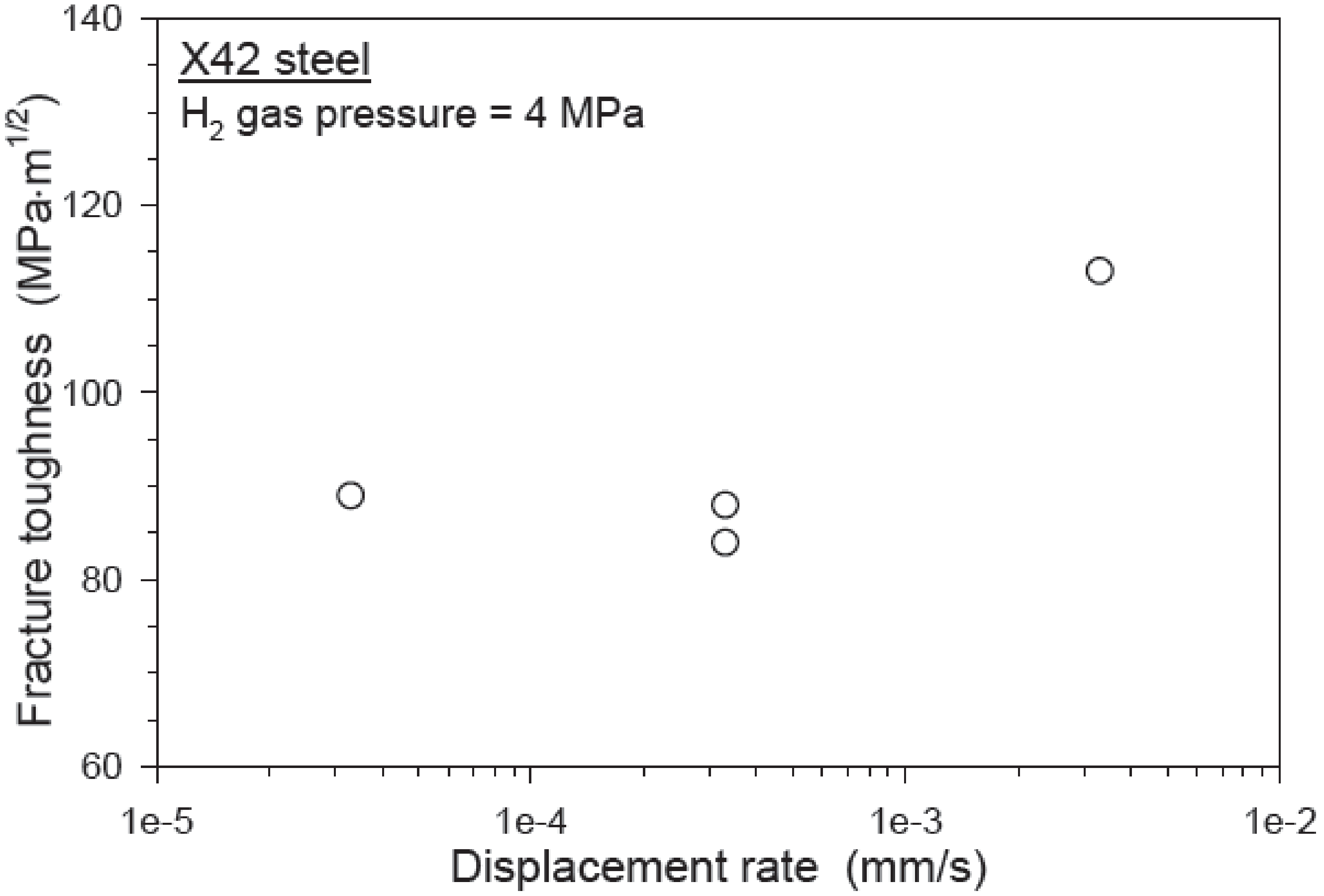


single edge notch bend specimen



compact tension specimen

Fracture toughness in 40 bar H_2
effect of loading rate

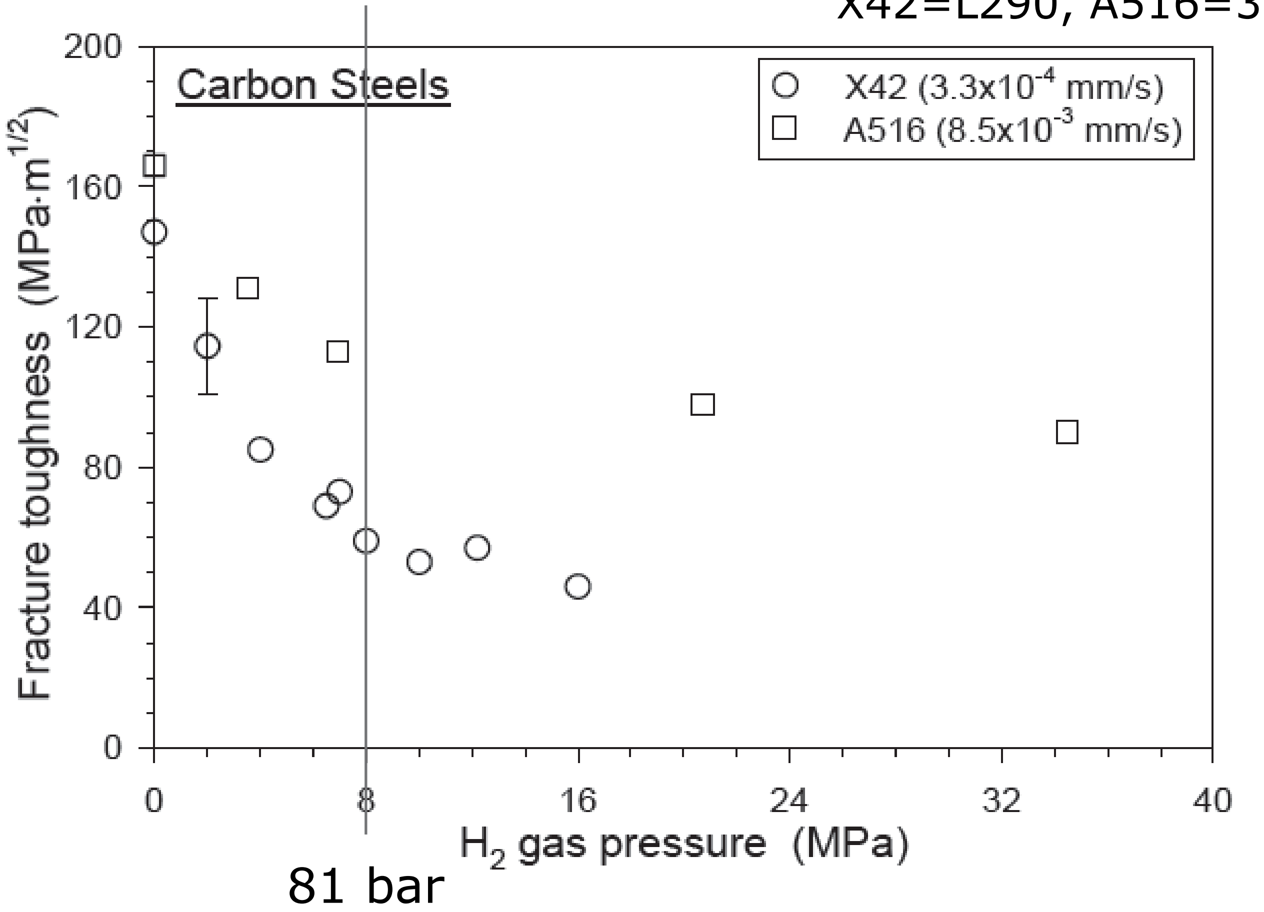


X42=L290 MPa

C. San Marchi, B.P. Somerday, Technical Reference for Hydrogen Compatibility of Materials, Sandia National Laboratories report SAND2012-7321, September 2012

Fracture toughness
effect of H_2-pressure

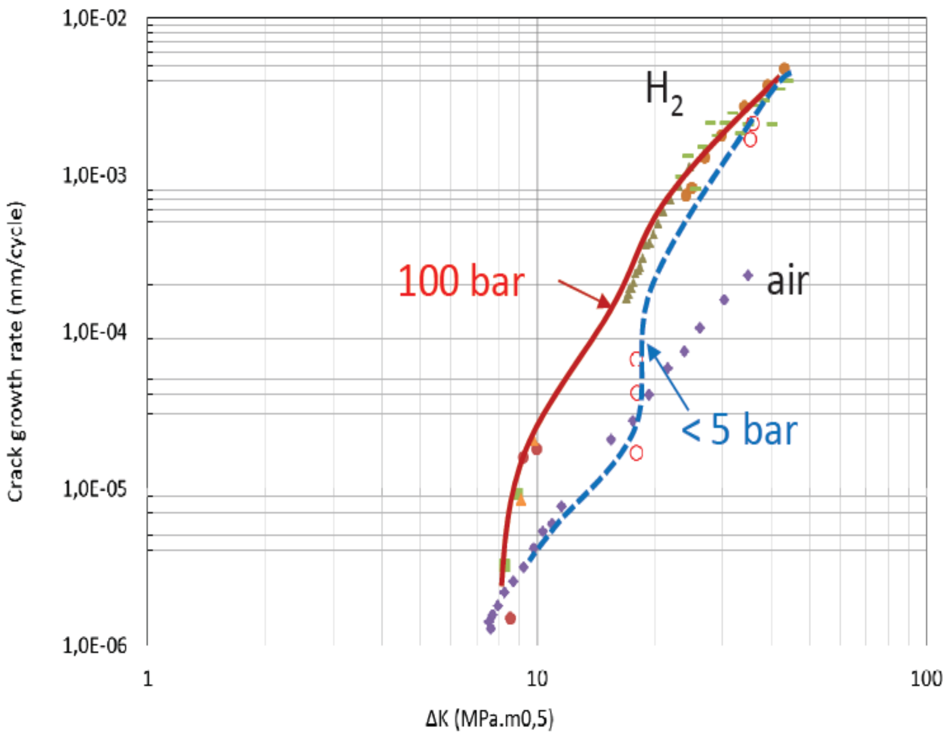
X42=L290, A516=335 MPa



C. San Marchi, B.P. Somerday, Technical Reference for Hydrogen Compatibility of Materials, Sandia National Laboratories rapport SAND2012-7321, September 2012

Fatigue crack growth in H_2
effect of pressure

0,01 μm/cycle



- R=0,1
- f=0,5Hz
- Air or 100bar H_2
- Constant load amplitude test
- CT and SENT specimen

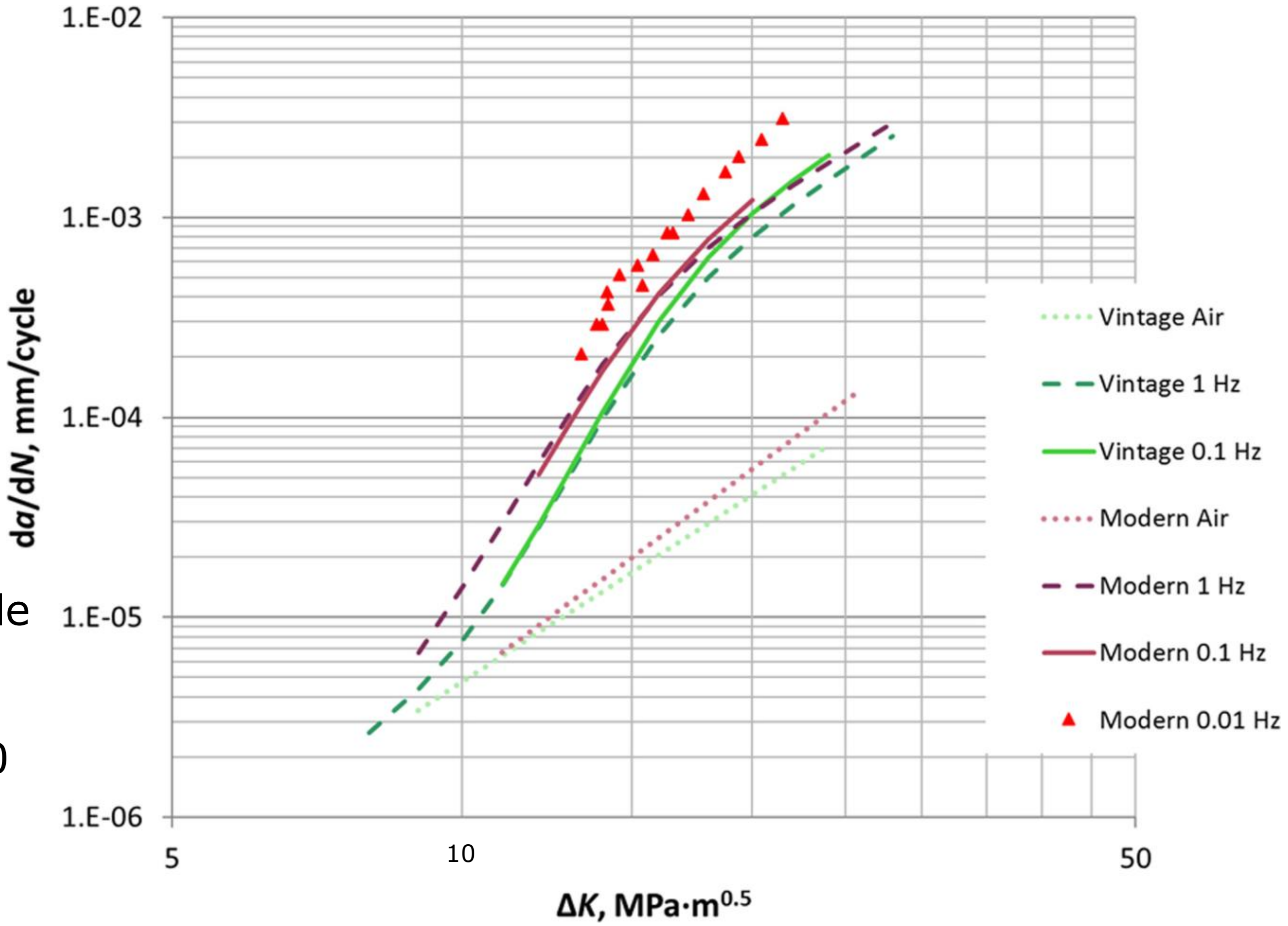
H_2 gas bottle Re=630 MPa 25CrMo4

J. Solin, N. de Miguel, Labscale – Full scale experimental comparison - Mechanisms, Modeling, Experiments and Pressure Vessel Design, Mathryce dissemination workshop, Paris, September 18, 2015

Fatigue crack growth in H_2
effect of frequency and vintage vs. new pipe

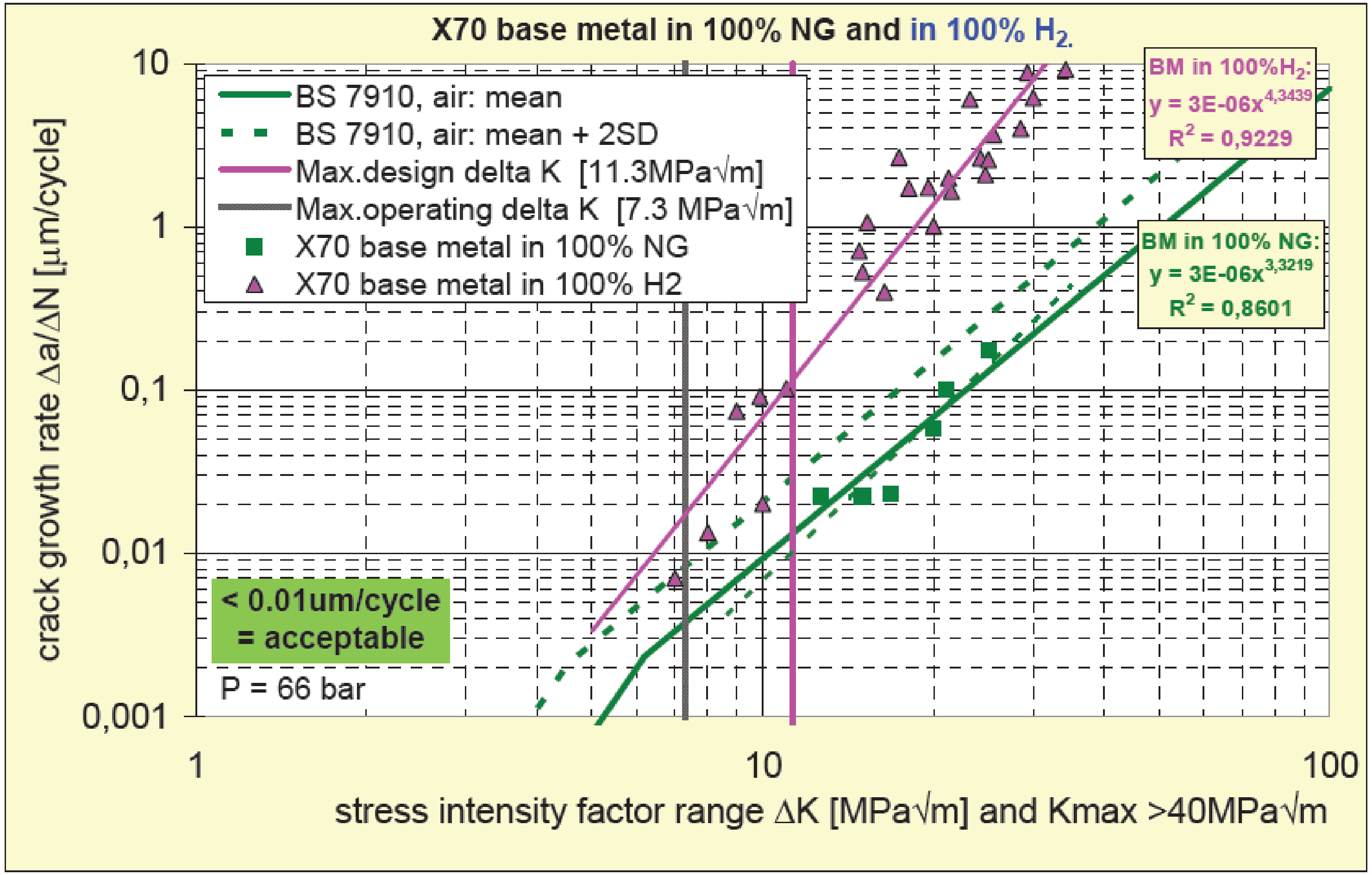
0,01 μm/cycle

X52=L360



A.J. Slifka, Fatigue Measurement of Pipeline Steels for the Application of Transporting Gaseous Hydrogen, Journal of Pressure Vessel Technology (2018)

Fatigue crack growth Naturalhy



0,01 μm/cycle, 100 year 1 cycle per day = 0,37 mm crack growth in air

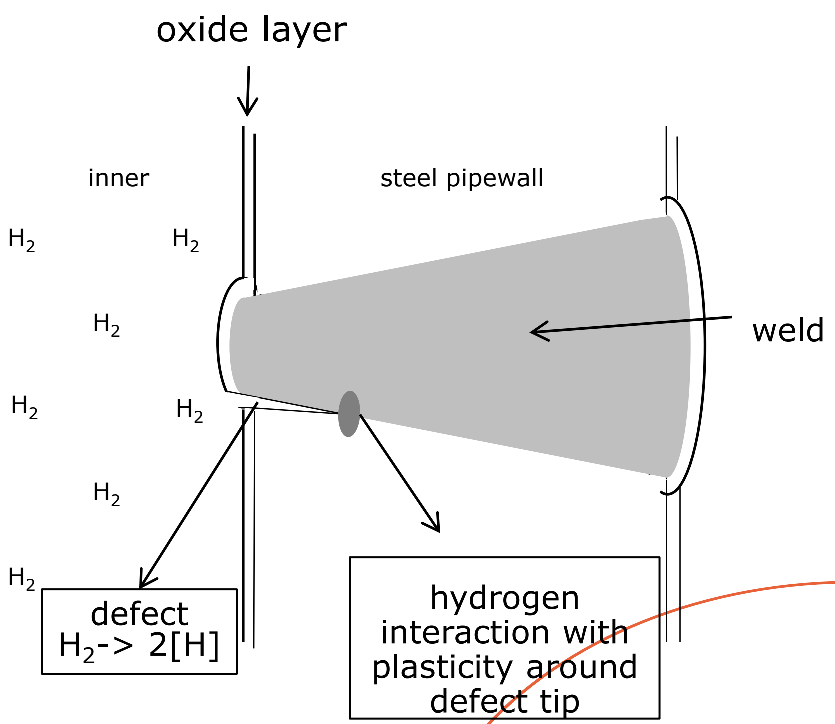
Mechanical tests and its impact on pipeline behaviour

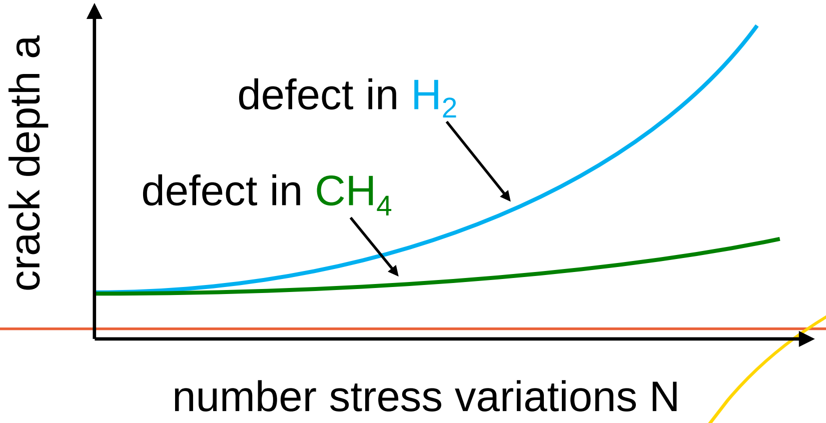
test	H_2	impact pipeline
tensile	decrease of fracture strain	no*
fracture toughness	decrease in toughness	no*
fatigue	increase in crack growth rate	yes**

* pipelines are not continuously stressed in the plastic region
** pipelines may experience fatigue loading (pressure variations, vibrations (offshore), traffic load) & crack-like defects may be present

gaseous hydrogen embrittlement only at newly created plastic deformation during slowly increasing load or cyclic load

Scenario for hydrogen-enhanced fatigue crack growth





The approach for dealing with hydrogen-enhanced fatigue of existing natural gas pipelines

	description	example
1	choice of a assumed crack-like defect in the pipeline	weld defect typically: 3 mm high and 50 mm long
2	the stress intensity factor ΔK of the assumed defect (“crack force”)	see next slide
3	the fatigue load (stress range and number of cycles)	daily pressure variation of 10% of internal pressure
4	the required lifetime of the pipeline	100 year
5	the fatigue crack growth rate at ΔK of the assumed defect in H_2 gas	see next slide
6	the lifetime of the assumed defect	see next slide

Step 2 & 3 crack force ΔK and stress range Δσ assumed defect is 3 by 50 mm in longitudinal pipe weld or girth weld in 14,1 mm, 48”, 66 bar

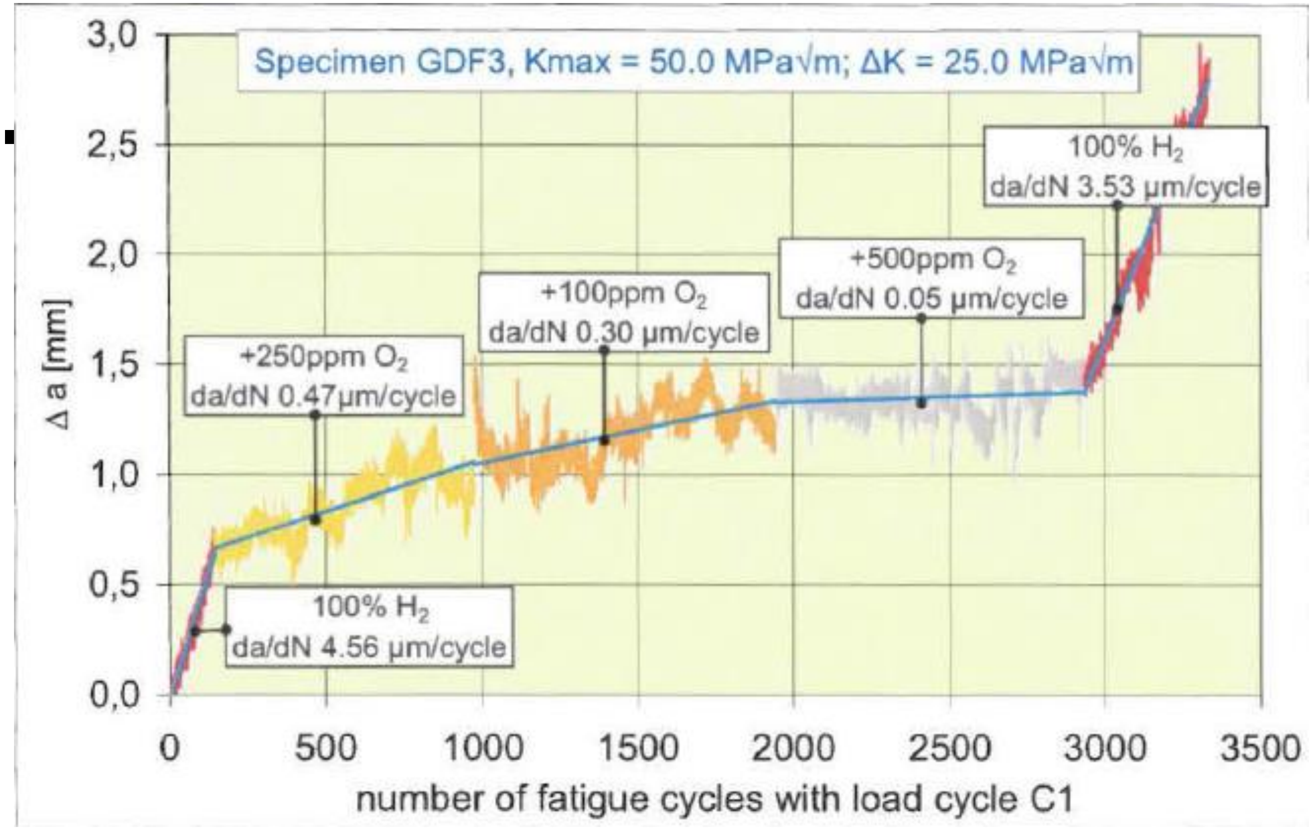
pressure cycle		crack orientation in weld	stress [MPa]	stress range Δσ [MPa]	crack force variation ΔK [MPa√m]
[%]	[bar]				
10	6,6	longitudinal	292	29	**3,4**
		girth	150	15	**1,7**

Step 5 & 6 ΔK of the assumed defect in H_2 gas and the crack growth over 100 year

pressure cycle [bar]	crack orientation in weld	crack force variation ΔK [MPa√m]	crack growth rate [mm/cycle]	crack growth 100 year [mm]
6,6	longitudinal	3,4	$6{,}1.10^{-7}$	0,022
6,6	girth	1,7	$3{,}0.10^{-8}$	0,001

Crack growth is so small over a period of 100 year, 100% H_2 at 66 bar does not impose an integrity risk.

Fatigue crack growth in the presence with O_2



frequency 0,00164 s^{-1}, 66 bar H_2, steel X52=L360

Conclusion (1/3)

Where hydrogen gas is being transported in pipelines at ambient temperatures and moderate pressures, the relevant hydrogen degradation mechanism is hydrogen-enhanced fatigue crack growth. When taking this degradation mechanism into account, 100% hydrogen gas up to the design pressure can be transported in existing natural gas pipelines without affecting the integrity of the pipeline during its lifetime.

But ….

Conclusion (2/3)

Though the integrity may not be affected by the hydrogen, it does not mean that hydrogen can actually be transported in the existing pipeline. Hydrogen is a smaller molecule than the methane molecule and the ignition energy is much lower.

Conclusion (3/3)

So before hydrogen can be transported in an existing pipeline the following has to be considered:

- is the leak tightness of existing valves (internal and external) sufficient?
- is the leak tightness of existing flanges sufficient?
- do the risk contours of the pipeline become larger because the risk assessment for hydrogen is different?
- can operational and maintenance activities be performed in a safe manner?
- is welding on a live pipeline possible?

Nothing new

"*The major technical problem with transmission of hydrogen gas at high pressure is the possibility of slow fatigue crack growth from existing cracks or crack-like defects in the pipe body or weld*."

E. Anderson et al. Geneva Research Centre in "Analysis of the potential transmission of hydrogen by pipeline in Switzerland"

Proceedings of the 2nd World Hydrogen Energy Conference, Zurich, Switzerland, 21-24 August **1978**

Interactive Part

Background and goal:

- get in touch with 6-7 participants
- allow for (technical) exchange
- summary of the results of your discussions
- publication (upon your consent) in an article and dissemination

Timeframe:

10:10	10:25	Interactive Part – introduction
10:25	10:45	Interactive Part – discussion in smaller groups
10:45	11:00	Interactive Part – getting together ... sharing results

QUESTIONS | GROUPS + GROUP LEADER

Group	Question	Remarks	Group Leader
1	**What are the 3 most urgent steps in my country (or Europe) to launch H2/NG blends in the gas network?**	• Which of the steps are within my company's influence? • Please name other stakeholders that need to take action urgently to realise the three steps.	Robert
2	**H2/NG blends in the gas network – what is already working well in my country?**	• Please name examples, solutions ... whatever - according to your impression - can be stimulating as example / precedent (for further activities or (external) stakeholders)	Adriaan
3	**Which H2-tolerance is technically feasible in my country until 2025, 2030, 2040, 2050?**	• We are asking your opinion here. You may think about ambitious, well-balanced (using renewal cycles of technologies) scenarios.	Gert
4	**What is in the focus of the political discussions in your Country regarding transmission and distribution of "green gases"?**	• Pure hydrogen networks vs. blends of NG/H2? • Building new networks for green gases especially H2?	Guilhem
5	**What are acceptable hydrogen sources in your perception**	• Hydrogen from renewable sources only? • Hydrogen from carbon neutral/low carbon sources acceptable? • Are compromises for the transition period conceivable?	Alexandra
6	**How will the transition natural gas/H2 mix to 100% H2 go technically?**	• Do we need full flexible appliances (from 0 to 100% H2)? • ?	Elbert/Micha
7	**Will there be enough hydrogen for the gas networks or will absorb the industry and transport absorb most of the future hydrogen production?**	We expect that the demand of renewable electricity will be higher than the production in Europe. Energy import is needed also in the future. Will the hydrogen production be sufficient to serve the demand or will there be a shortage. In case of hydrogen shortage, maybe sectors like industry and heavy-duty transport will first receive hydrogen and the other sectors are second. With this picture – whether we like it or not – will there be a gas network in the future for hydrogen transport? Which role have ammonia, NH3 and other hydrogen carrier technologies?	Jean

please enter

scrumblr.ca/hips-net

Sharing results!

Summary – our **most important points** are:

120 seconds. ;-) Please keep it BRIEF.

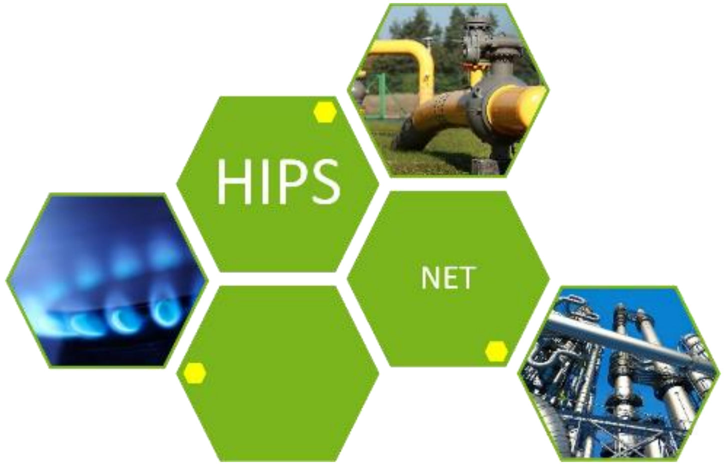
PRESENTATION 2:
TECHNICAL & ECONOMIC CONDITIONS FOR INJECTING HYDROGEN INTO NATURAL GAS NETWORKS

William Rahain

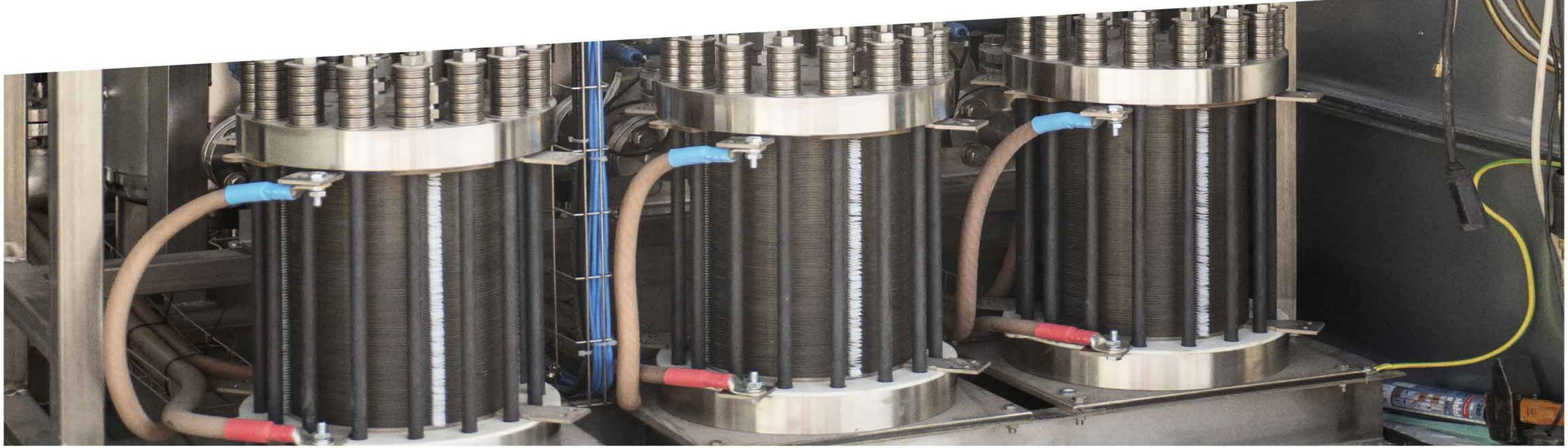
Teréga

7th HIPS-NET Workshop

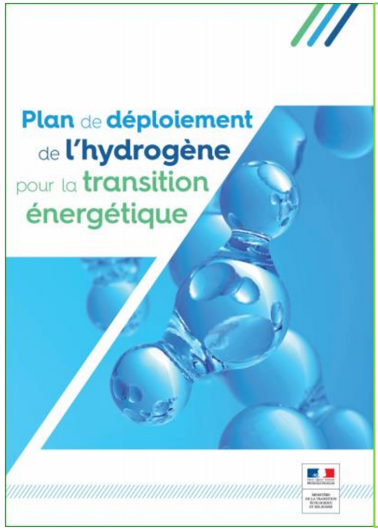
web conference, 4th June 2020



- Technical and economic conditions for injecting hydrogen into natural gas networks



- A coordinated effort by the French gas industry, led by GRTgaz, within the framework of France's Hydrogen Plan



France's Hydrogen Plan
- Measure 7

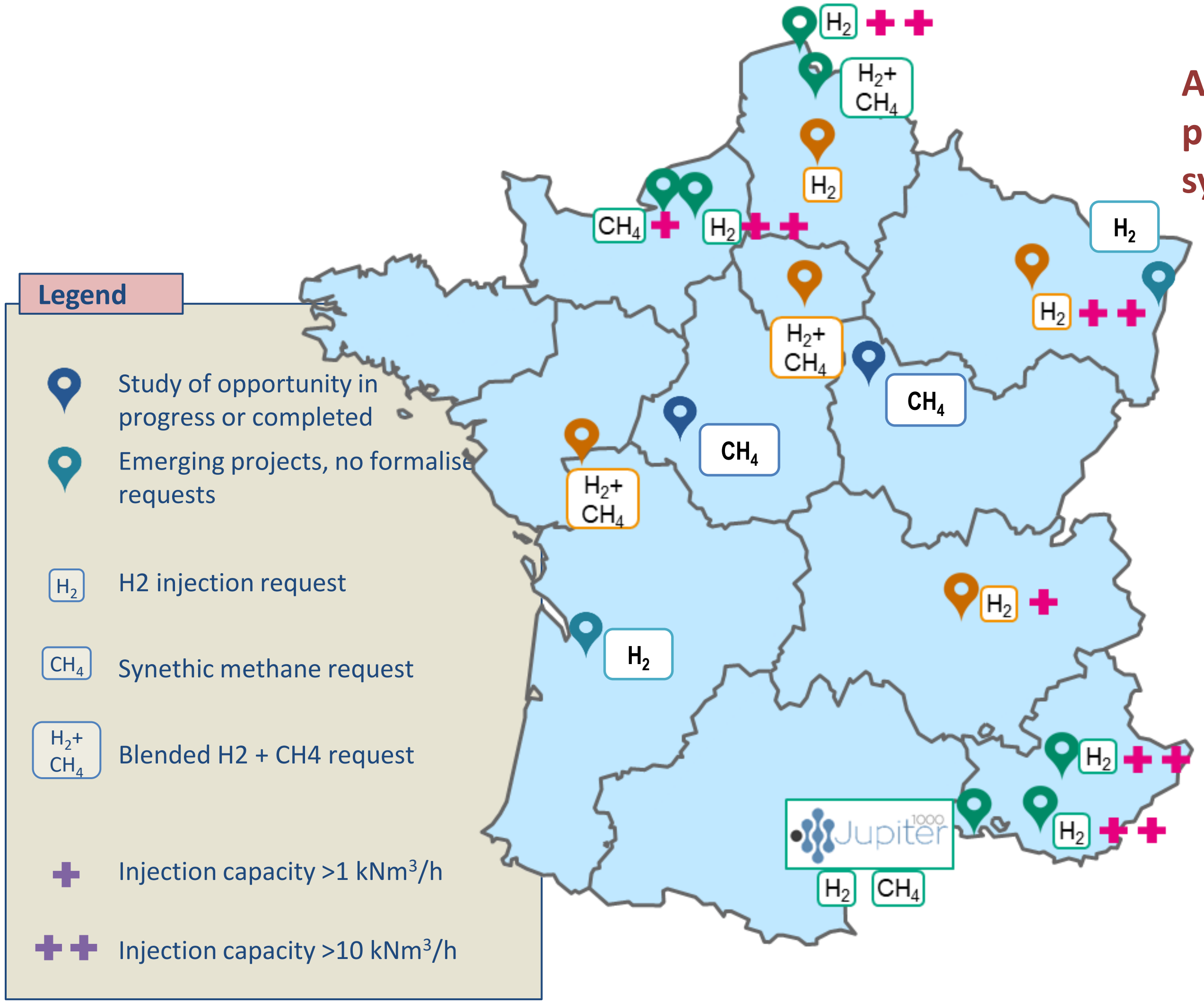
"In order to prepare for the arrival of power to gas, gas transporters and distributors will have to determine the technical and economical conditions for hydrogen injection into the grid that are: acceptable for the networks, for the installations connected to it and for end-uses (including gas mobility), in collaboration with manufacturers."

Coordinated report from the French gas operators:

- **TSOs** – GRTgaz & Teréga (representativeness: 100%)
- **DSOs** – GRDF, R-GDS, REGAS & SPEGNN association (100%)
- **SSOs** – Geométhane, Storengy, & Teréga (100%)
- **LSOs** – Elengy (75%)

Report publicly disclosed November the 15th: download link

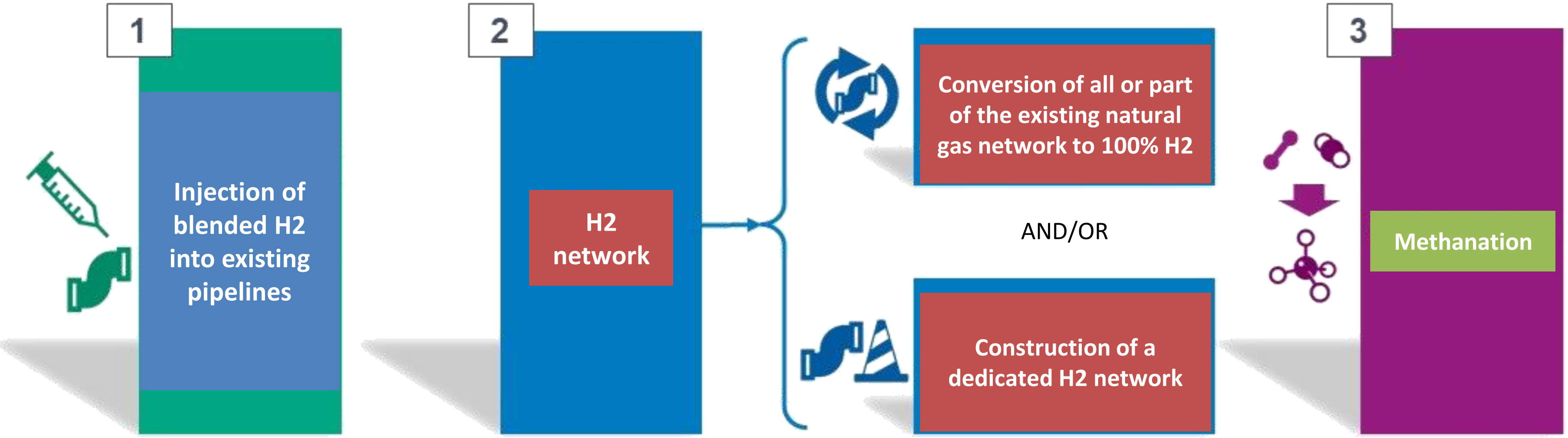
- In addition to France’s Hydrogen Plan, H2 & Syngas injection already under examination by gas operators



Applications for the connection of projects of different nature, from synthetic gas to pure hydrogen

- **Power-to-gas** from 1 to 200 MW (total injection or surplus)
- **H_2 byproduct** (chlorine industry)
- **Pyrogasification** (biomasse, wood waste or RDF) CH_4/H_2 blend or pure H_2

- Complementary ways of integrating H_2
- into the gas system



Complementary routes, consistent with a differentiated development of hydrogen in the territories, dependent in particular on:

- **Mode of production** : centralised/decentralised, base load/variable,
- **Concerned area** : characteristics of the network, gas flows
- **Temporality of projects**: gradual adaptations, « jumps » towards 100% H2 clusters

- Main barriers related to blending, technical locks and solutions envisaged to remove them

TRANSPORT	STORAGE	DISTRIBUTION	END USES

STEEL PIPES: Tolerance of steel pipes at H2 levels, depending on their grade and the pressures used (pb integrity)

Laying a coating replacement or conservation as appropriate

NETWORK EQUIPMENT: Integrity and good operation of network equipment at high H2 rates (**Transport**: Compressors, turbines; **Storage**: Compressors, meters and desulpharisation / dehydration; **Distribution**: Regulators, Customer counters)

Retrofit or replacement of all / part of equipment according to H2 rates

AQUIFERS: Tolerance to elevated H2 levels

Separation of H2/CH4 in certain cases

END USE EQUIPMENT AND GAS SUPPLY LINE Tolerance of end-use equipment (boilers, ovens, hobs...) at high and variable H2 levels

Separation of H2/CH4 for certain uses (NGV stations...)

Replacement of end use equipment with dual fuel equipment

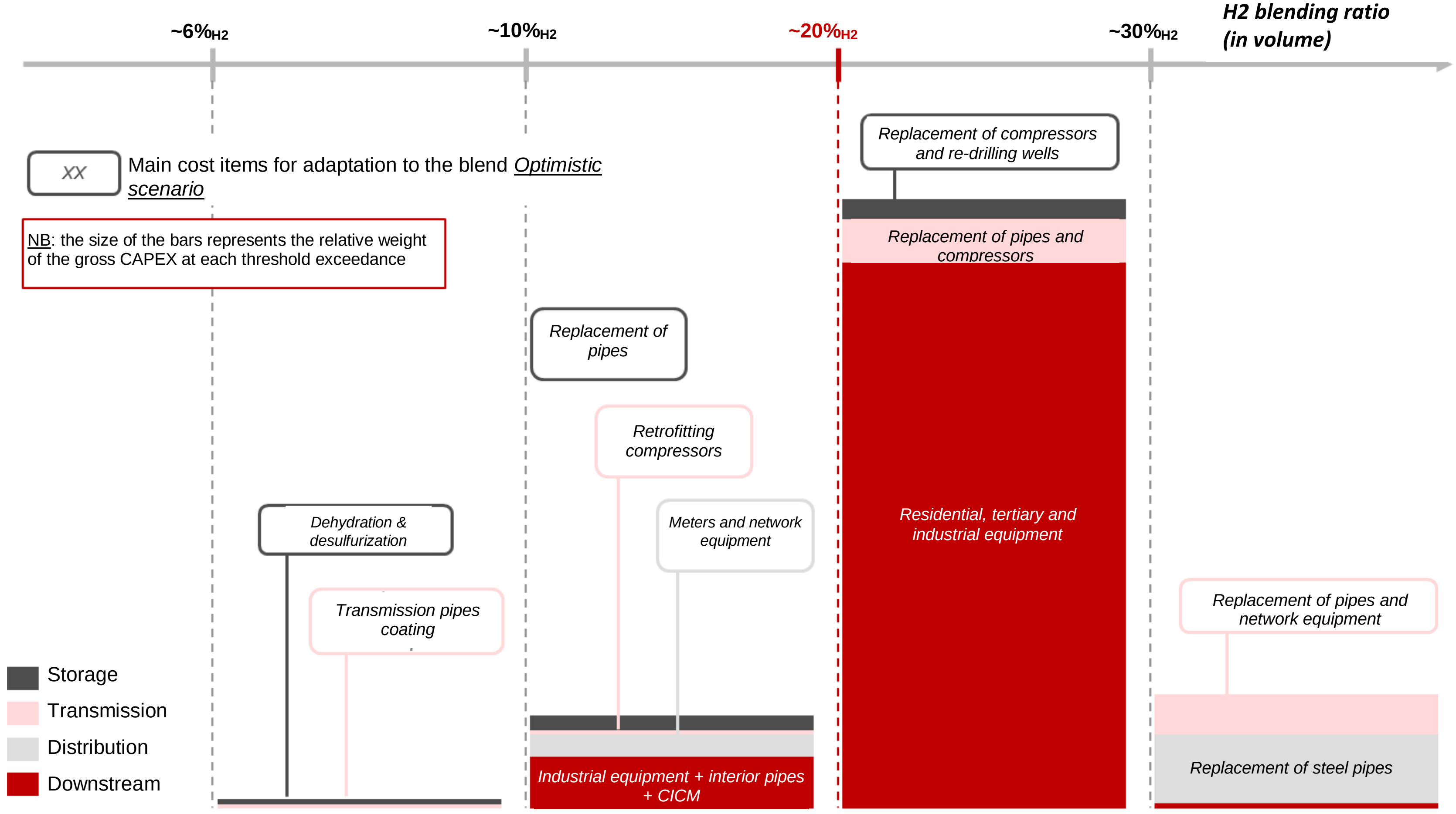
Replacement of gas suppl line and other critical parts (joints, connectors...)

Barrier

Envisaged solution

• Investments : limited to adapt to 20% blending, but unreasonable beyond

Summary of adaptation costs (CAPEX) at different hydrogen levels [adaptation costs relative to the volume of equipment concerned]

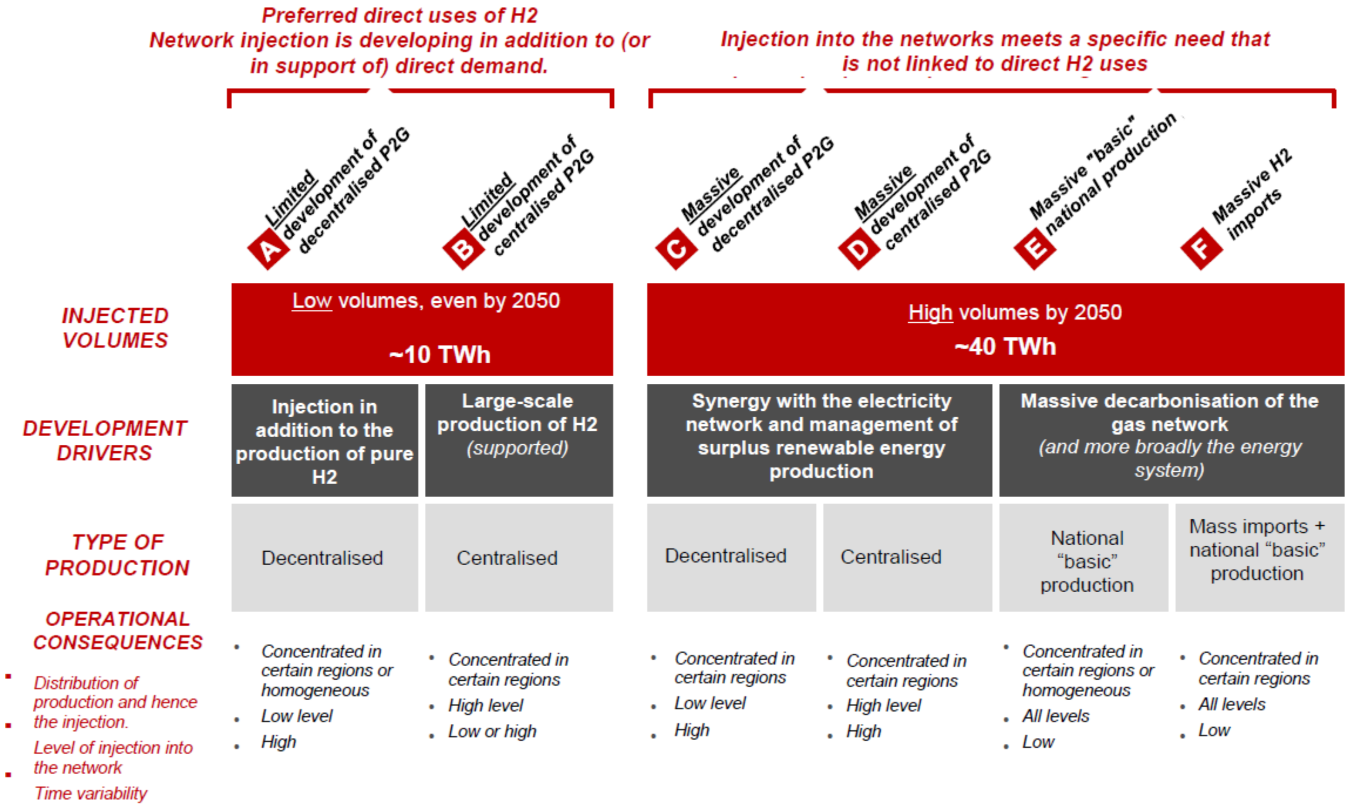


Note: the operating costs of H2/CH4 separation upstream of NGV stations or groundwater aquifiers take effect from 1%H2

Source: E-CUBE Strategy Consultants analysis, Gas operators WG

NB: the graphic view above is maximising as it represents the financial volumes corresponding to the cost of adapting 100% of the fleet at a given time, with no anticipation effect (gradual replacement of equipment by other compatible equipment over time)

- H_2 development case studies modelized by 2050
- to identify cost otpimized integration solutions



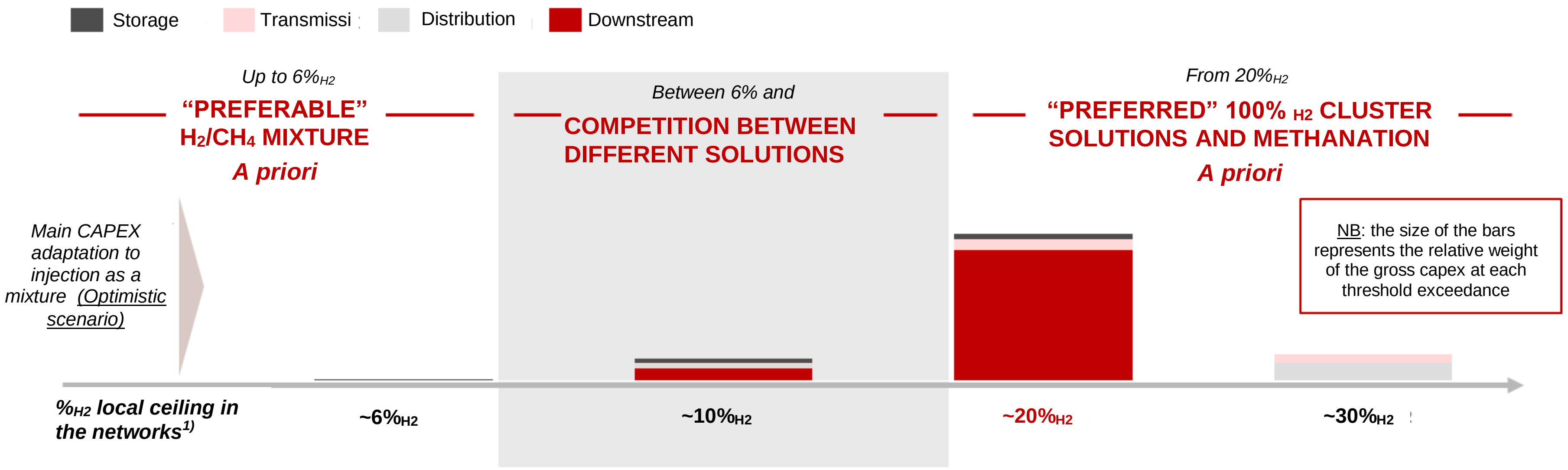
Source: E-CUBE Strategy Consultants Analysis

Figure 5 : Differentiated case studies used by operators for their cost modelling

Simplified model of the French gas system: 1 national transmission network, 300 regional subzones and 3,300 distribution zones

• Areas of competitiveness of the different hydrogen integration solutions in gas networks

Competitive advantages of the different H_2 integration solutions in the networks according to the hydrogen level



1) H2 rate by volume

Source: E-CUBE Strategy Consultants analysis, Gas operators WG

Results of modeling: **possible to integrate hydrogen for infrastructure adaptation costs from € 1 / MWh to € 8 / MWh by 2050** depending on the scenarios studied

Conclusion on acceptable hydrogen levels in mixture

Conclusions of the work carried out by the French operators::

- **Possibility of integrating a significant volume of hydrogen into the 2050 gas mix with limited infrastructure adaptation costs.**
- Need to mobilize in a coordinated way **solutions for blending, methanation and deployment of 100% hydrogen clusters** on certain meshes by conversion of structures or creation of new networks.

In the short term, blending of 6% in terms of volumes of hydrogen is feasible in most networks, except for cases where there are sensitive structures or installations at the customer level. **Pre-identification of suitable areas** to guide projects makes it possible to integrate the first volumes of H2 with adaptation costs reduced to the strict minimum

By 2030, recommendation to set a capacity target for integrating blended hydrogen into networks: 10% and then 20% beyond, in order to anticipate equipment adaptation, particularly at end-user level.

• Priority levers identified

Identify suitable areas in which the 6% blending level is applicable. When conditions are met, adapt the gas specifications to inject first 10%, then 20%.

Set a specification of 10% blended hydrogen as a sector-wide target by 2030. The aim is to mobilise equipment manufacturers and downstream users, and to manage operator investments on a case-by-case basis.

Invite operators to coordinate and share R&D efforts for all the technical injection routes. Ensure that the corresponding costs are covered in their regulated economic models under the existing processes.

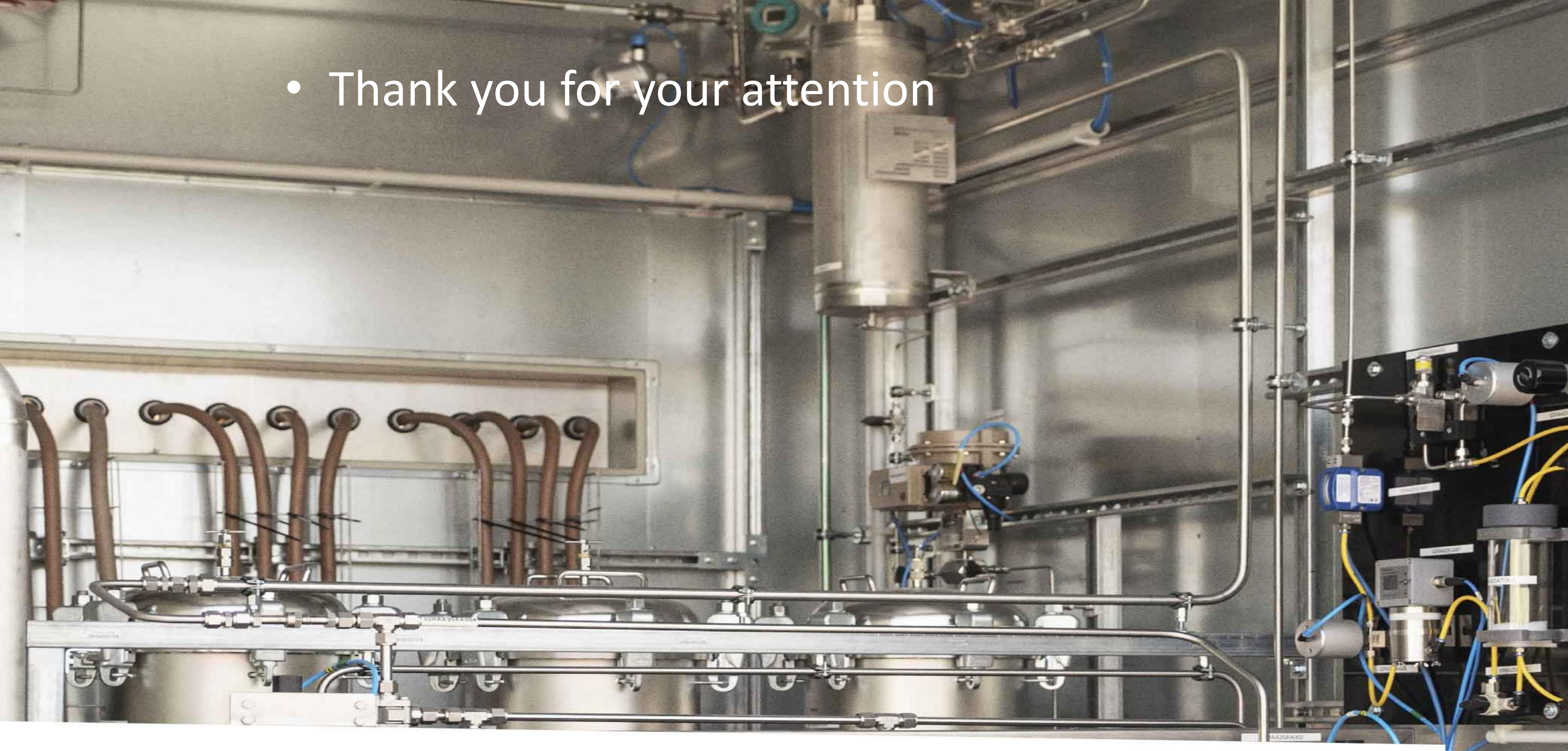
Carry out an **assessment of the externalities of injecting hydrogen into the networks and of methanation**, including a life cycle analysis of these sectors.

Integrate the role of gas infrastructures in the development of hydrogen into energy mix forecasting and implement a specific work programme on the coupling of gas and electricity networks.

Define and implement a favourable framework for experimenting with the development and operation of the first 100% hydrogen clusters.

Create a framework for the development of power-to-gas in the event of market failure.

- Thank you for your attention



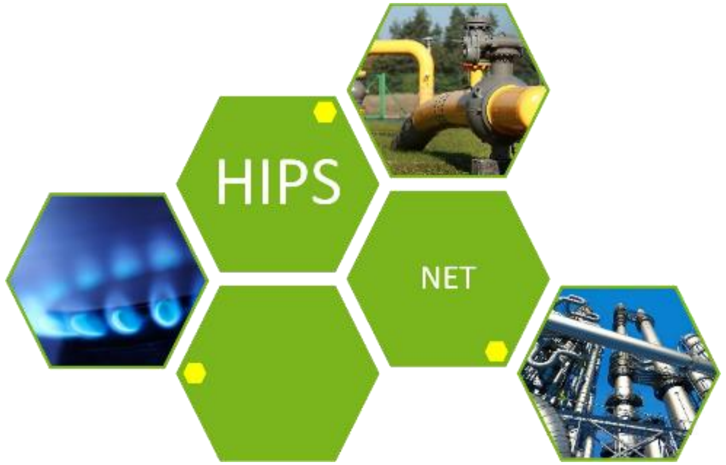
PRESENTATION 3:
ORGANISATIONAL ASPECTS HIPS-NET

Gert Müller-Syring

DBI Gas- und Umwelttechnik GmbH

7th HIPS-NET Workshop

web conference, 4th June 2020



AGENDA

- Review Working Plan Year 7
- Working Plan Year 8
- HIPS-NET Status (Partner, Core Topics, Status Report)
- Partner Feedback

Review Working Plan Year 7

Mandatory scope based on HIPS-NET agreement

- Issuing (quarterly) newsletter - running - (✓)
- Annual workshop - still running - ✓
- Addressing open R&D subjects and communication e.g. to the EC ✓
- Preparing a short status report - running - (✓)

Additional scope (providing additional budget):

- Maintaining HIPS-NET website ✓
- Maintaining contact to CEN/CENELEC ✓
- Updating Power-to-Gas map (✓ July)

Working Plan Year 8

Working Plan Year 8

Mandatory scope based on HIPS-NET agreement

- Issuing newsletter every 2 month
- Annual workshop – 16^{th}/17^{th} June 2021?
- Addressing open R&D subjects and communication e.g. to the EC
- Preparing a short status report

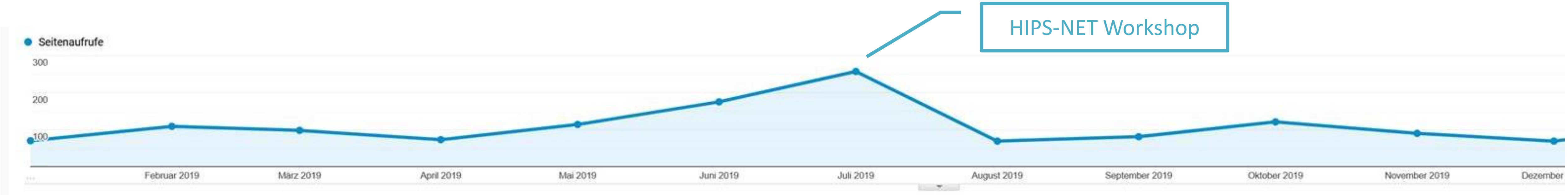
Additional scope (depending on available budget)

- Maintaining/renewal of Layout HIPS-NET website
- Continuous updating Power-to-Gas map
- Maintaining the cooperation with SFEM WG Hydrogen/TC6

Do you have requests / ideas for additional activities?

Status of HIPS-NET website

- Site views direct on HIPS-NET website: 1,355 (Google Analytics)
- Site views redirected from DBI website to HIPS-NET: around 3,500 (Google Analytics)
- How to achieve additional views?
  - through tweets on Twitter
  - through extended input on the public area



New Ideas for the Website - Overview

Members Area:

1) List with links of studies (low)

Ideas for **Public Area** of the Website (and expected effort/costs):

1) Update of (dusty) design (high)
2) Group photo from workshop (low)
3) Picture with origin (country) of the members (low)
4) More general information about our core topics (medium)
5) For each core topic: short description of current technological knowledge (i.e. studies) (medium)
6) Publication: 1-2 old newsletters (2018) to attract new members (low)
7) Links to partners (i.e. by clicking on company logos) (medium)
8) Proposal to our partners: links from partners to HIPS-NET
9) Twitter („Follow #HIPSNET on Twitter“) (low)

HIPS-NET STATUS

HIPS-NET Partners

- The network initially had the target to attract 30 partners.
- The number of HIPS-NET paying partners increased to **40 organisations** in the 7th year.
- TNO joined the group in 2020.

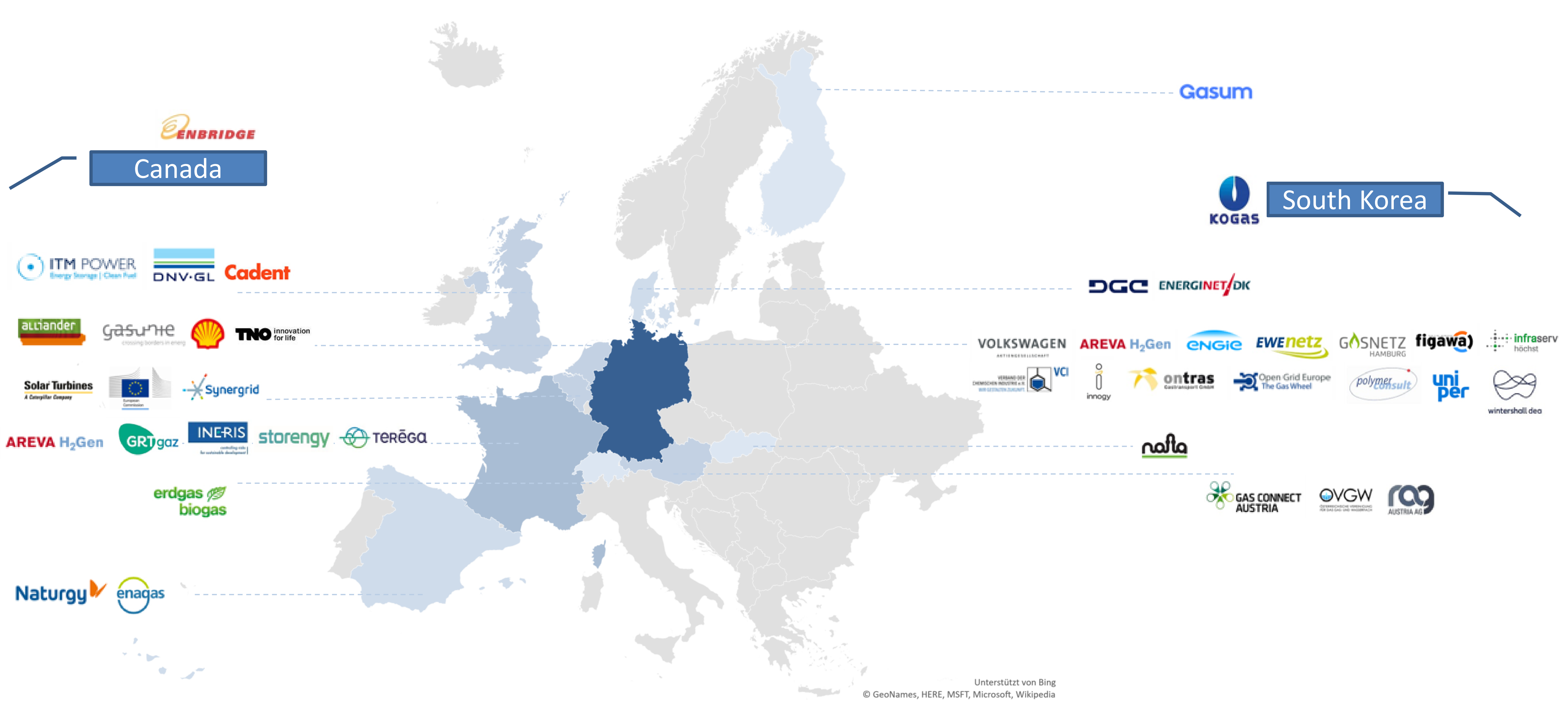
→ Moderate, growing base for the network is ensured.

HIPS-NET STATUS
HIPS-NET PARTNERS | JUNE 2020

1	Alliander, Netherlands
2	AREVA H_2Gen, France + Germany
3	Cadent, United Kingdom
4	DEA Deutsche Erdoel, Germany
5	DGC, Denmark
6	DNV GL, United Kingdom
7	Enagás, Spain
8	Enbridge, Canada
9	Energinet.dk, Denmark
10	ENGIE, Germany
11	EWE Netz, Germany
12	Gas Connect Austria, Austria
13	Gasnetz Hamburg, Germany
14	Gasum OY, Finland

15	Gasunie, Netherlands
16	GRTgaz, France
17	grzi e.V. (figawa), Germany
18	INERIS, France
19	Infraserv Höchst, Germany
20	Innogy SE, Germany
21	ITM Power, United Kingdom
22	Joint Research Centre (JRC), EC
23	KOGAS, South Korea
24	NAFTA, Slovakia
25	Naturgy (Gas Natural Fenosa), Spain
26	ONTRAS (Germany)
27	Open Grid Europe, Germany

28	ÖVGW, Austria
29	Polymer Consult Buchner, Germany
30	RAG Rohöl-Aufsuchung, Austria
31	Shell, Netherlands
32	Solar Turbines Europe, Belgium
33	Storengy, France
34	SVGW, Switzerland
35	Synergrid, Belgium
36	Teréga (TIGF), France
37	TNO, Netherlands
38	Uniper Energy Storage, Germany
39	VCI, Germany
40	Volkswagen, Germany


Enbridge
Canada
Gasum
KOGAS
South Korea
ITM POWER
Energy Storage | Clean Fuel
DNV·GL
Cadent
DGC
ENERGINET/DK
alliander
gasunie
TNO innovation for life
VOLKSWAGEN
AREVA H2Gen
ENGIE
EWE netz
GASNETZ HAMBURG
figawa
infraserv höchst
Solar Turbines
A Caterpillar Company
European Commission
Synergrid
VCI
innogy
ontras
Open Grid Europe
The Gas Wheel
polymer consult
uniper
wintershall dea
AREVA H2Gen
GRTgaz
INERIS
storengy
Teréga
nafta
erdgas biogas
GAS CONNECT AUSTRIA
ÖVGW
rag AUSTRIA AG
Naturgy
enagas
Unterstützt von Bing
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- Aim is a growing network with well selected and active partners
- Partner target for project year 7 is 41-43
- DBI will try to attract new partner by using its network and is in contact with
  - EuStream
  - Gas Networks Ireland
  - Mannesmann Line Pipe GmbH
  - Northern Gas Networks
  - Salzgitter AG
  - Snam

Are there companies/institutions, we should try to attract?

HIPS-NET STATUS

Status Report Year 6 (2018/19)

HIPS-NET - Overview of Budget Spending

Including Outlook

Category	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	*running 2019/20*	*planned 2020/21*
Income								
Partner	30	30	32	35	36	36	*39*	*40*
Membership Fee	2.000 €	2.000 €	2.000 €	2.000 €	2.000 €	2.000 €	*2.000 €*	*2.000 €*
Annual Budget	**60.000 €**	**60.000 €**	**64.000 €**	**70.000 €**	**72.000 €**	**72.000 €**	***78.000 €***	***80.000 €***
Expenses								
Administration	9.094 €	6.465 €	3.705 €	2.635 €	2.125 €	1.550 €	*1.600 €*	*1.600 €*
Promotion	4.400 €	4.480 €	4.560 €	4.640 €	4.800 €	4.880 €	*5.040 €*	*5.040 €*
Website	- €	- €	11.120 €	2.900 €	3.000 €	3.050 €	*3.150 €*	*3.150 €*
Editorial Work	45.100 €	45.920 €	46.740 €	47.560 €	49.200 €	52.765 €	*54.810 €*	*54.810 €*
Workshop	13.077 €	13.072 €	12.315 €	13.111 €	14.000 €	14.195 €	*14.885 €*	*14.885 €*
Final Report	1.650 €	1.680 €	570 €	580 €	600 €	610 €	*630 €*	*630 €*
Subcontracting	14.480 €	10.437 €	- €	- €	- €	- €	*- €*	*- €*
Total Expenses	**87.801 €**	**82.053 €**	**79.010 €**	**71.426 €**	**73.725 €**	**77.050 €**	***80.115 €***	***80.115 €***
Result	**-27.801 €**	**-22.053 €**	**-15.010 €**	**-1.426 €**	**-1.725 €**	**-5.050 €**	***-2.115 €***	***-115 €***

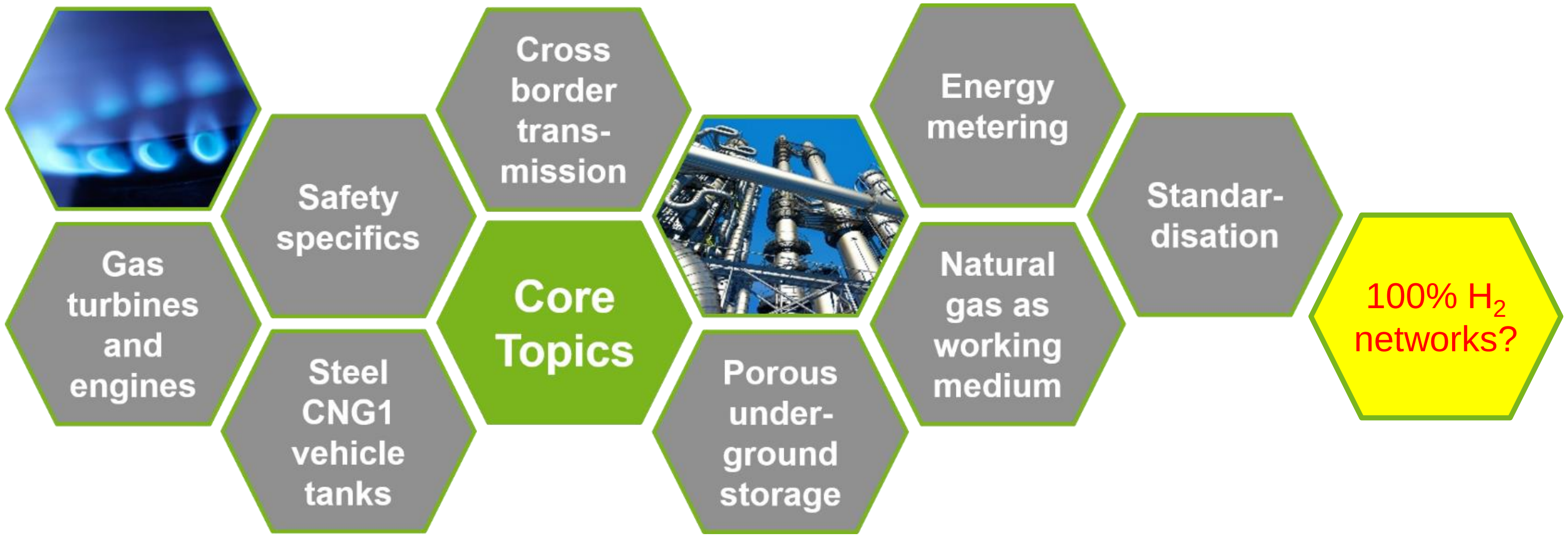
(income-expenses)

HIPS-NET Status

HIPS-NET Objectives and Core Topics

HIPS-NET Status
Objectives and Core Topics

- We gather and disseminate the latest available knowledge to improve the understanding of hydrogen/natural gas blends in pipeline systems to path the way for a successful energy transition. Our core topics are:



- We additionally keep a minor focus on:
  - the general development of power-to-gas, hydrogen networks, and further topics around the utilisation of (renewable) hydrogen.
  - Power-to-X or electricity based gases

Partner Feedback
- ORGANISATIONAL ASPECTS-

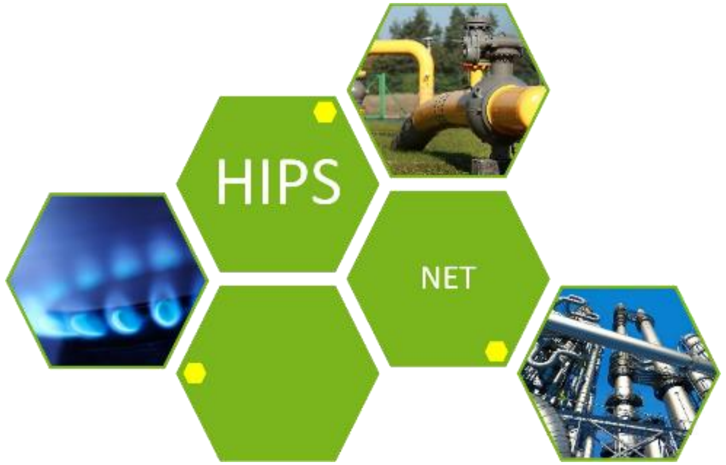
Do you have further questions?

Do you have additional wishes concerning HIPS-NET?

Do you know companies who might be interested?

Do you have general feedback?

Conclusions & Feedback



FEEDBACK 2ND DAY

1. Please take your smartphone or the laptop browser
2. Open the browser
3. Search menti.com
4. Enter the code

Mentimeter

Energy with Future.
Environment and Responsibility.

THANK YOU FOR YOUR ATTENTION!

Your contact partner

Gert Müller-Syring

managing director

DBI Gas- und Umwelttechnik GmbH
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