THyGA Workshop

December 15th 2021

Testing **Hy**drogen admixture for **G**as **A**pplications

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No. 874983. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Agenda

13h30	Welcome, Introduction and rules to the webinar	Alexandra Kostereva / Patrick Milin
13h40-14h25	Experience sharing: GRHYD, Higgs, HyDeploy	Isabelle Alliat Javier Sanchez Lainez Adam Madgett
14h25-14h30	THyGA - Objectives of the project	Patrick Milin
14h30-14h50	THyGA - Theory on the impact of H2 admixture in NG on combustion aspects	Jörg Leicher
14h50-16h15	THyGA - Interim test results • Focus on some specific results (flashback, ionization current, adjustment, etc.) • Q/A session between each thematic session • GERG PNR project and link with on-going work	Jean Schweitzer
16h15-16h30	Experience sharing: HyDelta	Julio C. Garcia-Navarro
16h30	THyGA - Next steps and end of the Workshop	Patrick Milin

GRHYD

Isabelle ALLIAT (ENGIE Lab CRIGEN)

GRHYD : a successfull demonstration for the new gas H2NG

Isabelle ALLIAT (ENGIE Lab CRIGEN)

THyGA webinar, June 15, 2021

GRHYD
Let's renew our energies

The GRHYD project

Grid management by Hydrogen injection for Decarbonizing the energies

Context and aim

The 1st Power-to-Gas H2 demonstror in France :

- Part of the French Program 'Investment for the Future' : Hydrogen for a Sustainable City
- Valorize, through the production of H2, renewable overcapacity and promote a new energy in urban areas to decarbonise the networks and uses of natural gas!

✓ Evaluate in real conditions the new H2NG energy in the usual uses of gas at home and in transport, on technical, environmental, regulatory and societal aspects

Two pilots based on Hydrogen to assess the relevance of H2NG chain for sustainable cities

- **GRHYD objective : produce H2 from renewable electricity, inject this H2 into the gas distribution grid and consume the new H2-NG gas locally** (heating, cooking, hot water, CHP, and mobility)

A NEW GAS : H2NG

SUSTAINABLE MOBILITY

A new kind of gas for homes

A new 100-home district and the boiler of a health center, are supplied with a new type of gas H2-NG.
The H2 content fluctuates but doesn't exceed 20% vol.

From feasibility demonstration to commercialisation

A new fuel for urban buses

Through a **pre-commercial** demonstration, NGV station and 30 urban buses will be adapted to **Hythane® fuel** (5% and 20% H2 vol)

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The main results of the new gas H2NG demonstration

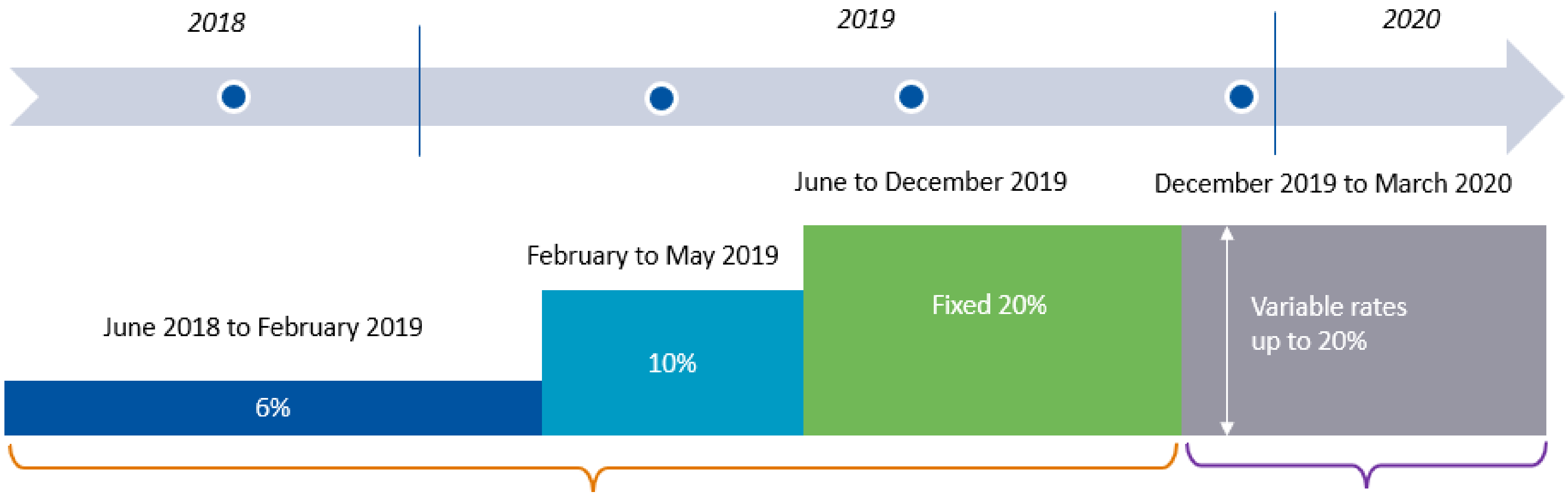
Good social acceptability among user residents

- A priori favorable experimentation area: a population accustomed to an industrial environment
- An information system combining public meetings with future residents, targeted communications, posters in housing buildings

Feedback from sociological studies carried out with residents (focus group, interviews):

- ➢ Confidence in the project partners to manage the industrial safety issue
- ➢ Their main concern: impact on the energy bill (neutral in the context of the project)

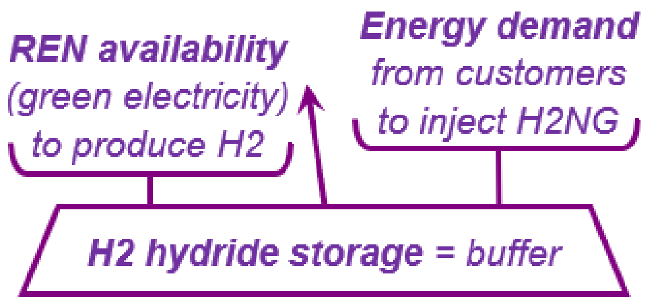
The demonstration lasted 22 months, and applied the fluctuating H_2 content in gas during the winter 2019-2020



Checking process:

- ✓ Grid exploitation & safety procedures
- ✓ H2 electrolysis, storage, injection: exploitation
- ✓ Societal acceptance: habitants enquiries
- ✓ Domestic boilers, cookers: efficiency, combustion
- ✓ Central heating boilers: efficiency, combustion

Strategy for driving H2 equipment:



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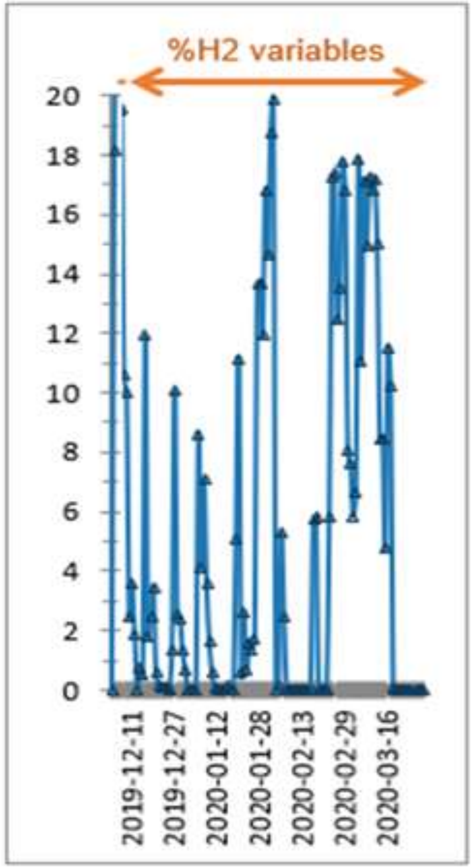
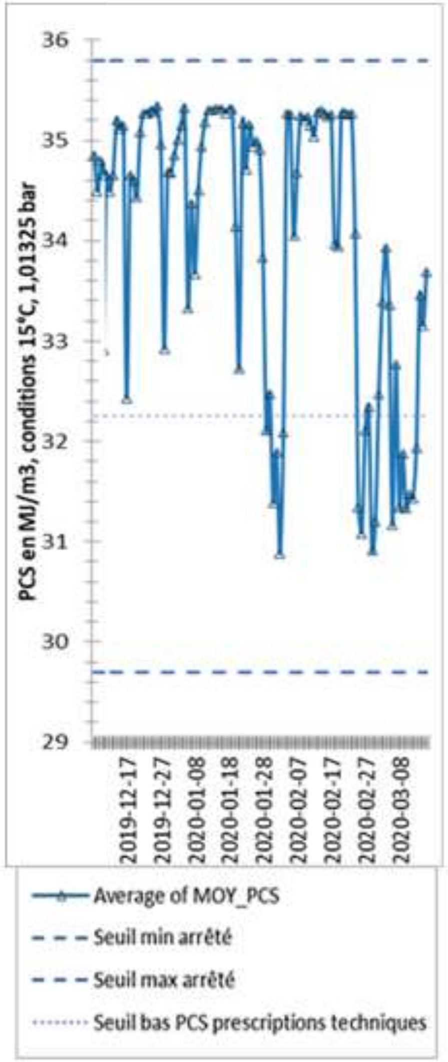
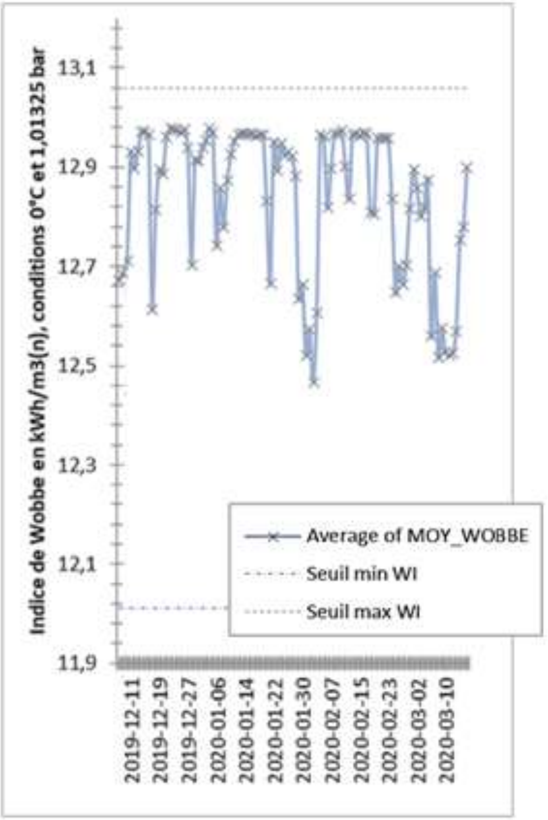
H2NG gas quality

- The fluctuating H2 % run during the winter times (Dec-March)





- The delivered H2NG fulfilled the DSO requirements in France (L-gas), except:
  - Content of H2 above 6% in NG
  - Calorific value:
    - GCV is out of the legal range above 12% H2 in L-gas
    - i.e. below 12% H2 in L-gas, GCV is in the legal range
- Large fluctuations will lead to the development of the Smart Gas Grid (billing purpose)
- The Wobbe index shows rapid instantaneous variations which may impact some sensitive end-uses, other than domestic gas appliances



Test results on domestic boilers

CETIAT
ensemble, innover et valider

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Tested domestic gas appliances

	In the lab (CETIAT)	On-site (residents)
Domestic boilers	2 new boilers (*Saunier, Chappée)* 3 old boilers*(Frisquet, Chaffoteaux, Saunier)* 0, 10, 15, 20, 25 and 30 %vol. H2	3 new boilers (*Saunier*) 6, 10 and 20 %vol. H2
Cookers and ovens	1 new 1 old 0, 10, 15 and 25 %vol. H2	1 old (6 and 10 %vol. H2) 1 new (6 and 10 %vol. H2) 1 new at 20 %vol. H2

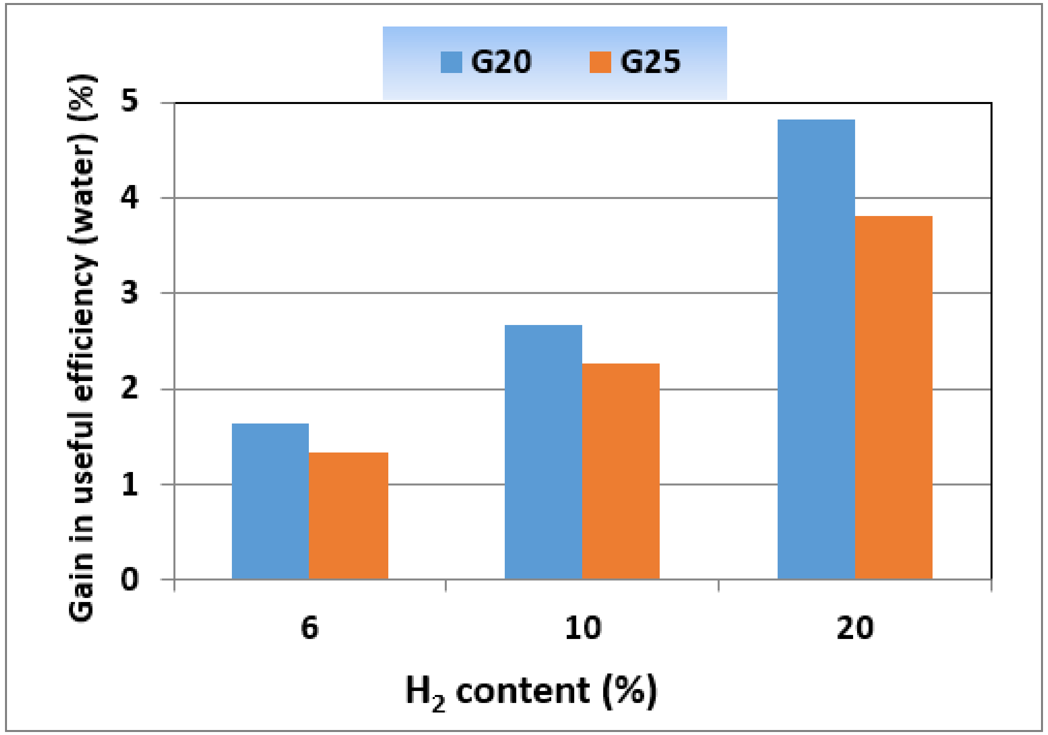
Tests in laboratory

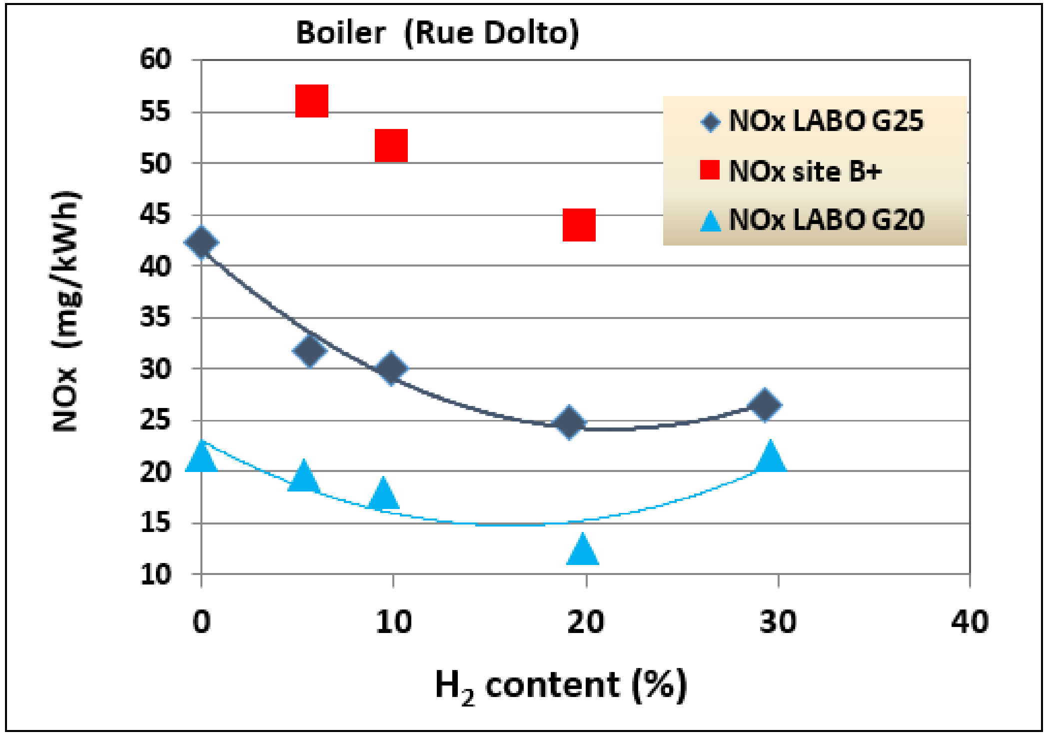
Measures on site

Results in lab and on-site (Saunier boiler)

- ✓ **Useful efficiency (water) increases with the H2 content (lab tests)**
  - ✓ Higher values with G20 reference gas

- ✓ **Reduction of NO_X emissions with H2 content (lab and on-site)**
  - ✓ On-site with L-gas («B+») gives higher values versus G25 in lab





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Conclusions of tests on domestic boilers

- ✓ **These results are specific to the boilers tested, they confirm the literature, but they cannot be directly extrapolated to other boiler models**
  - ✓ Reduction of the useful power and the heat output
  - ✓ Maintain of combustion efficiency and **increase of useful efficiency**
  - ✓ **Reduction of emissions : CO_2, CO and NO_X**
  - ✓ No problems relating to safety, noise, shutdown, securing, declared during technical inspections on site

For future deployment

- **Long-term impact of hydrogen (aging, endurance)** is to be verified in future projects
- There is a need for large-scale test campaigns **to adapt the standards to the new H2NG gas**

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On-site test results on the tertiary boilers

ENGIE Lab CRIGEN

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The tested tertiairy boilers

- The care center (EPSM of Flandes) has 2 boiler rooms, equipped with:
  - 1 old Guillot boiler
  - 2 recent Viessmann boilers

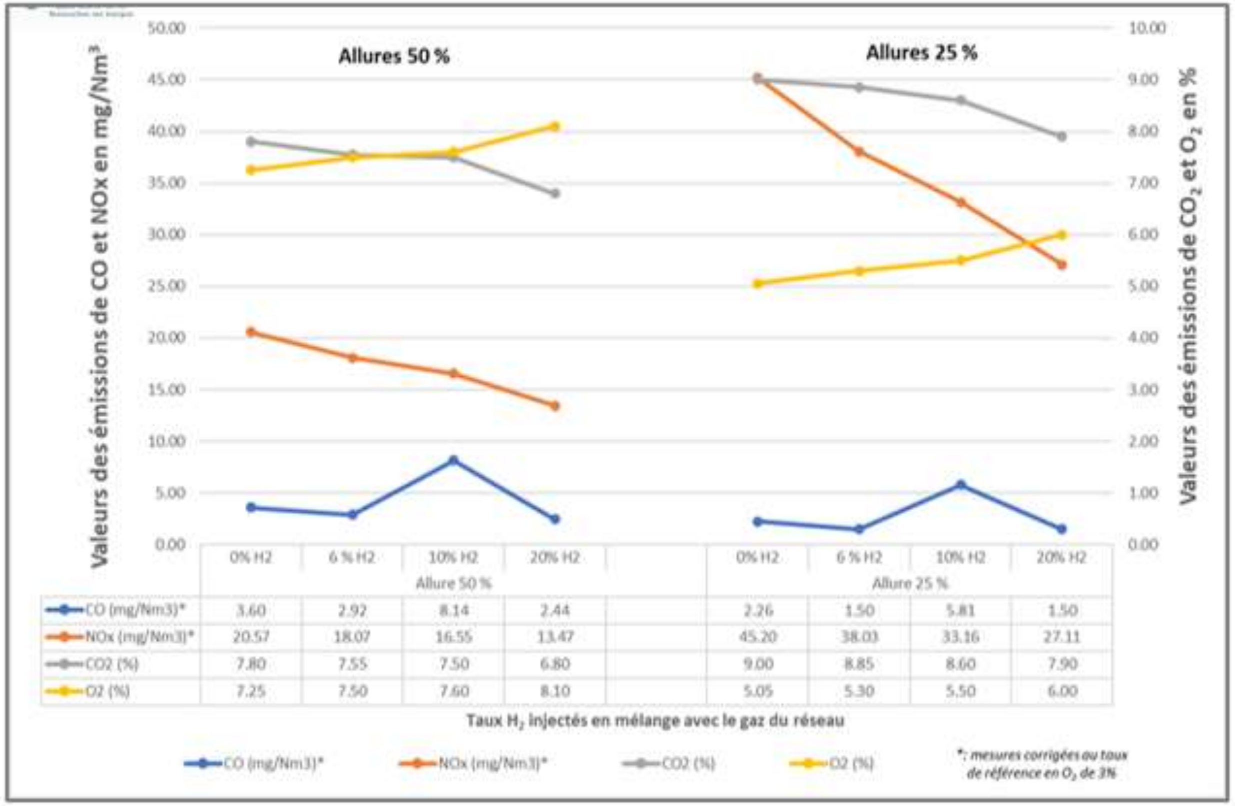
- The interesting parameters to measure are:
  - ➢ The polluant emissions
  - ➢ The useful efficiency
    - But it was impossible to measure it
  - ➢ The combustion efficiency

The Viessmann boilers show better performances

- Operation with H2NG complies with current regulations
- No dysfunction was observed

- The presence of 20 %vol. H2 in the natural gas decreases :
  - ➢ the CO2 emissions by 12%
  - ➢ the NOx emissions by 57%
  - ➢ the CO emissions by 20%

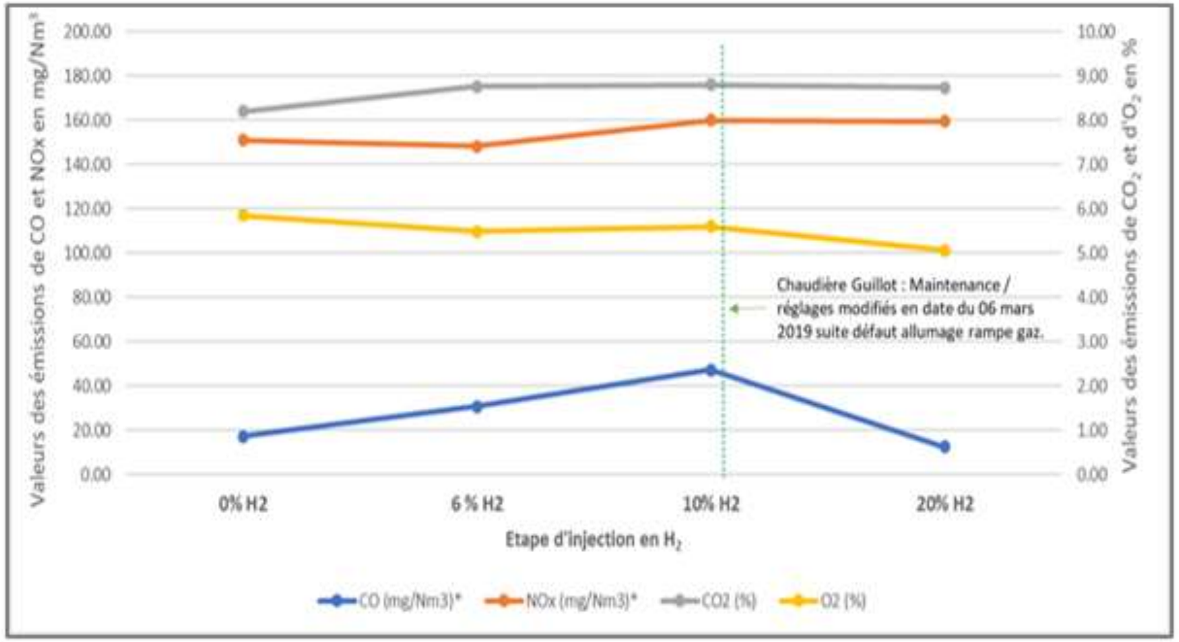
- Combustion efficiency:
  - ➢ Slight increase with 6% H2 and 10% H2



	0% H2	6 % H2	10% H2	20% H2		0% H2	6 % H2	10% H2	20% H2
	Allure 50 %					Allure 25 %			
CO (mg/Nm3)*	3.60	2.92	8.14	2.44		2.26	1.50	5.81	1.50
NOx (mg/Nm3)*	20.57	18.07	16.55	13.47		45.20	38.03	33.16	27.11
CO2 (%)	7.80	7.55	7.50	6.80		9.00	8.85	8.60	7.90
O2 (%)	7.25	7.50	7.60	8.10		5.05	5.30	5.50	6.00

No negative impact on the old boiler Guillot

- The Guillot boiler is an old model without the possibility of regulation (operation in "All or Nothing" mode)
- Therefore, it was not possible to perform relevant performance measurements
- The emissions measured at the various levels of H2 in the gas comply with current regulations



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Conclusion of the new gas H2NG demonstration

A demonstrator that guides future work

Continue to optimize the Power-to-Gas chain by relying on improved solutions for operation and monitoring of the equipment

Work on European regulations, standardization & certification with consideration of hydrogen in gas infrastructures and gas uses to prepare for industrial deployment (network equipment, gas analyzer and meter, equipment and installations downstream meters, gas appliances, etc.)

Develop equipment and operation-maintenance procedures adapted to the new composition of the gas supplied (inspection method and frequency, leak detectors adapted to the mixture, etc.)

Extend the compatibility analysis of the natural gas chain by carrying out tests **on the existing devices** (distribution network, indoor installations, downstream meter equipment in the residential, tertiary and industrial sectors)

Continue R&D work on **protection solutions for sensitive network installations or customers** (e.g. membranes separating H2 from natural gas)

As a conclusion

- **In France, Territorial Communities have an interest in this new green gas**
- **The GRHYD project is preparing the ground for the pre-industrialization and deployment of the new H2NG gas: the next project will increase in size!**

Hythane®
as fuel
for urban buses

A pre-commercial demonstration

Conclusion on Hythane® demonstration

Where we are as GRHYD close out:

- **An interest in Hythane® fuel, as H2-CNG and H2-bio-CNG blend**
- **A parallel rise of the H2 mobility market during the GRHYD project lifetime**
- **But an overall cost analysis (TCO) showing the competitivity of the Hythane® fuel vs CNG and FC**
- Questions raised by the GRHYD project are current hot topics due to Power-to-Gas H2 projects development
  - **Adaptation of the European or International regulation to Hythane® fuel & vehicles**
  - **Potential interesting synergies between H2 and Hythane® due to the development of Power-to-Gas projects on the French grid, assuming environmental and economical performance of Hythane® are confirmed**

OPÉRATION RÉALISÉE AVEC LE CONCOURS DES INVESTISSEMENTS D'AVENIR ET DE L'ÉTAT CONFIÉS À L'ADEME

En partenariat avec :

Ville pilote :

THANKS FOR YOUR ATTENTION

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GRHYD
Let’s renew our energies

THyGA

HIGGS

Dr. Javier Sánchez-Laínez

FUNDACIÓN PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

THyGA

HIGGS

Hydrogen in Gas Grids

Injection of hydrogen in high-pressure gas grids: presentation of HIGGS project

15th December 2021

Dr. Javier Sánchez-Laínez

Aragon Hydrogen Foundation (FHa), SPAIN

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875091 'HIGGS'. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

HIGGS – Hydrogen In Gas GridS

HIGGS
Hydrogen in Gas Grids

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH JU) under grant agreement no. 875091. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

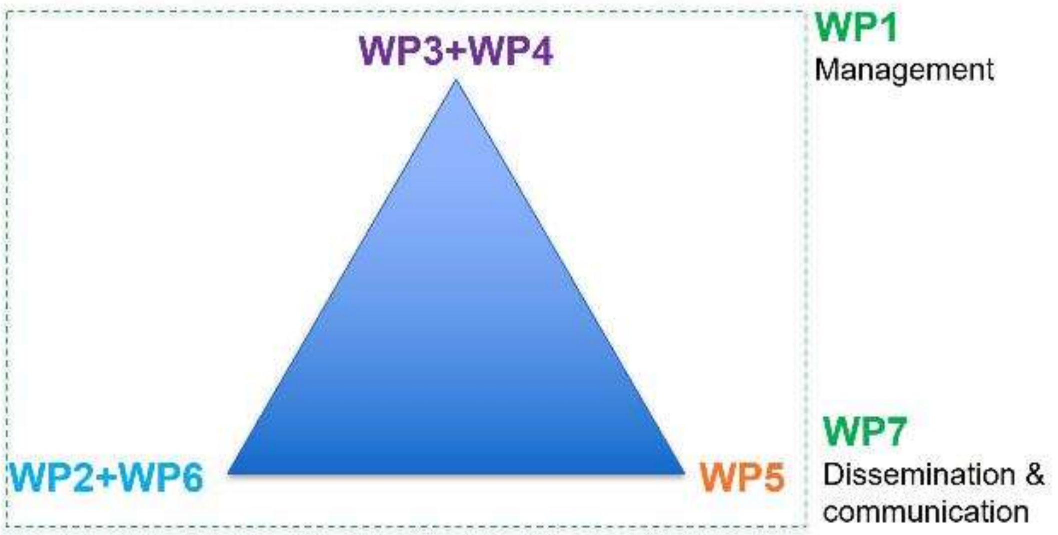
- **Duration:** 36 months **Start:** 01.01.2020
- **Funding:** 2,107,672.50 €

Goal

HIGGS project aims to pave the way to **decarbonisation of the gas grid** and its usage, by **covering the gaps of knowledge of the impact** that high levels **of hydrogen** could have **on the gas infrastructure**, its components and its management.

How?

- Mapping of technical, legal and regulatory barriers and enablers ➔ **survey of state of art**
- Testing and validation of systems and innovation ➔ **building a testing facility**
- Techno-economic modelling to develop operation strategies



➔ Defining a set of conclusions as a pathway towards enabling the injection of hydrogen in <u>high-pressure gas grids</u> ➔

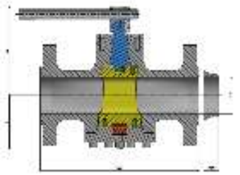
Legal, regulatory and technical aspects (WP2)

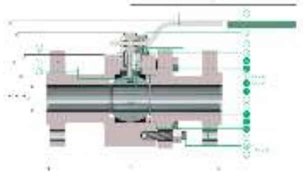
Specific objectives

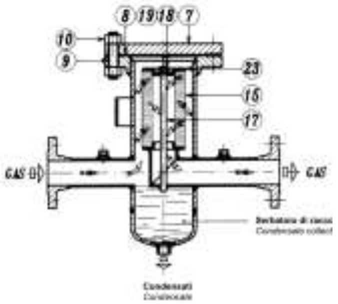
1. **Investigation** on the present regulations, standarizations and certifications (**RSC**) of the EU for **most critical bottlenecks**
   a) on limitations with respect to **hydrogen concentrations in the gas system**,
   b) on the corresponding **standards**.
2. Provide updated information on **equipment and infrastructure** of the **existing high-pressure NG grid in EU**, to identify the most representative facilities➔detailed survey on pipelines, facilities, installations and equipment
3. Setup of **mitigation measures** for existing gas appliances and gas system.

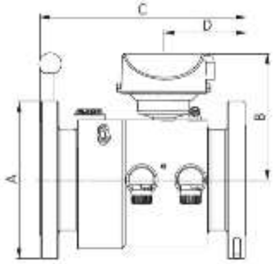
Infrastructure analysis results: Target elements to be tested in the platform

- Predominant **pipeline's steel grades**: API 5L Gr. B, **X42**, **X52**, **X60** and **X70**.
- **Most common facilities: valve nodes**, **metering** and **pressure reduction stats**.
  - Composed of **pipes**, **valves**, **filters**, **regulators**, **meters** and **instrumentation**.
  - Installed by **welding** or using **flanged joints**.







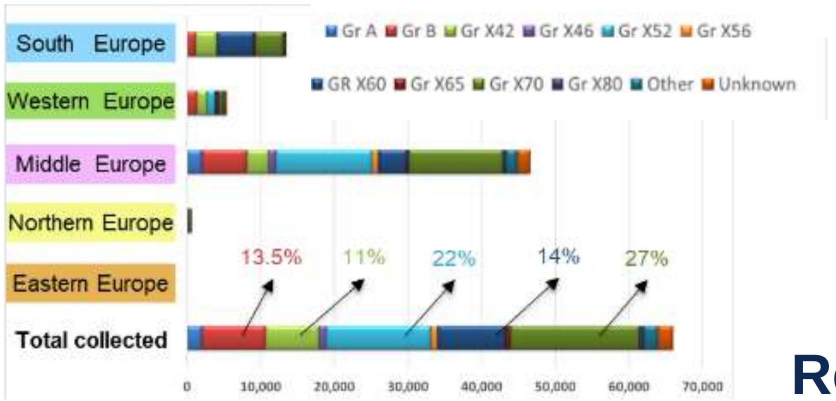


➔ Transfer to R&D platform design in WP3

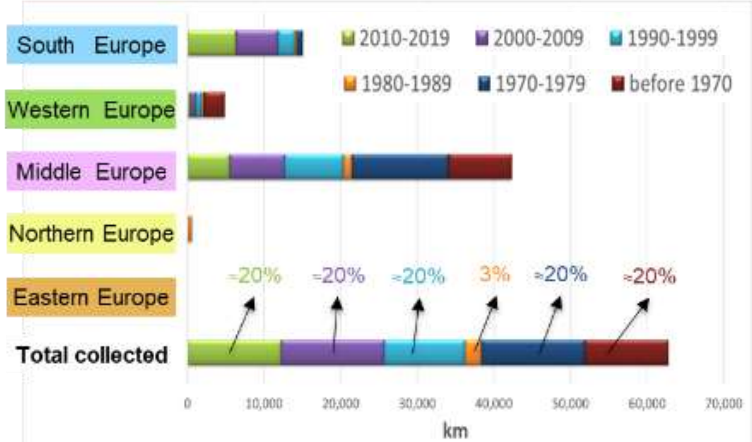
All the Legal, regulatory and technical information is on HIGGS Project public deliverable D2.3. Available soon on the HIGGS Project website (https://www.higgsproject.eu/)

Infrastructure analysis: pipelines

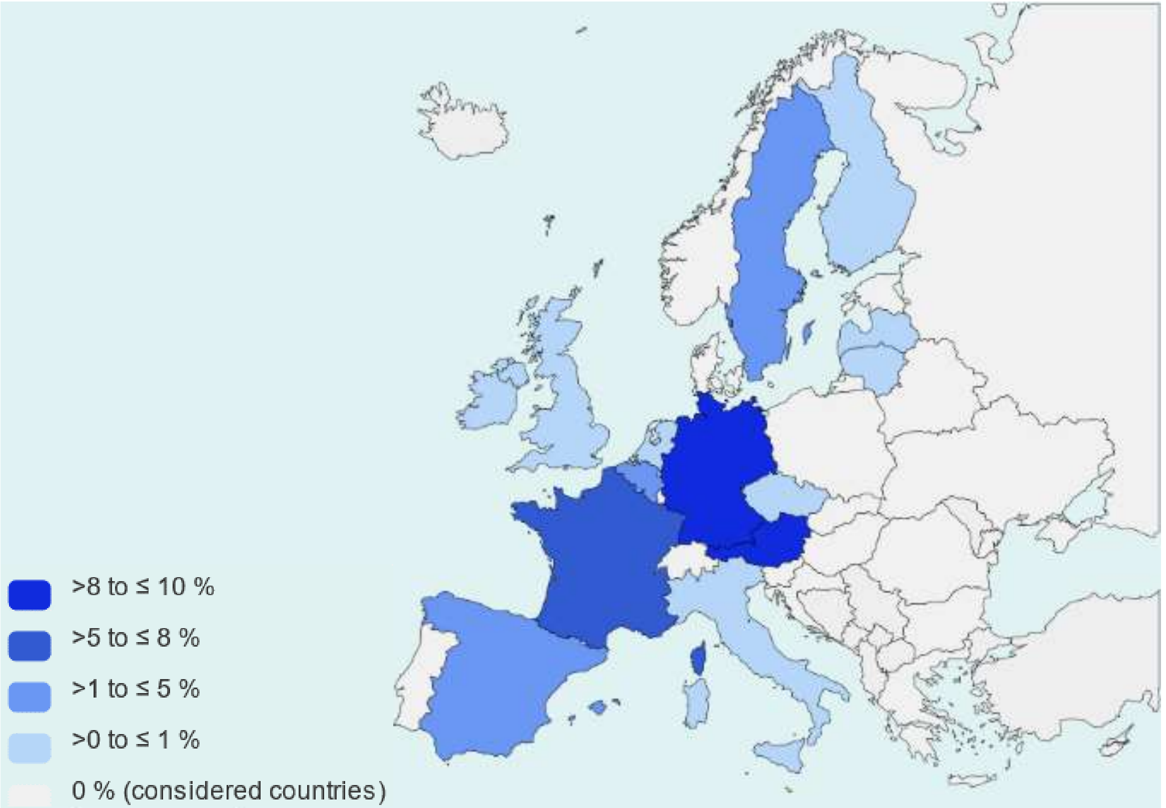
Materials



Renewal time



RSC analysis: Allowed H_2 concentration in NG



Design, preparation and commissioning of testing facilities (WP3)

Overview of the R&D platform

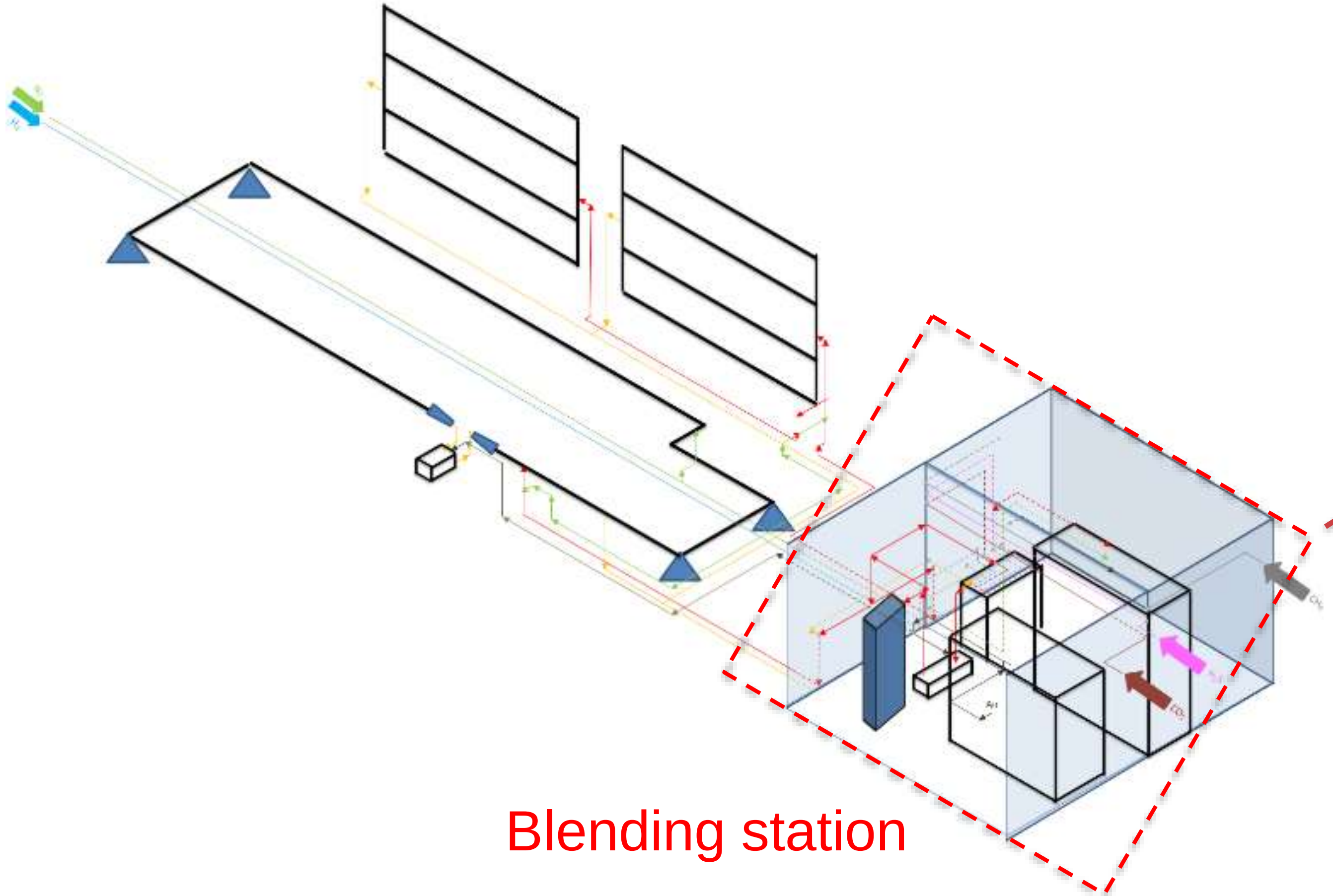
- It recrates the injection of hydrogen in transmission natural gas grids
- Key elements in the experimental platform
  - Admixture system
  - Testing platform
  - Purification prototype

- Design to work at 80 barg

- Several levels of blending possible (0-100 %vol H2)

Design, preparation and commissioning of testing facilities (WP3)

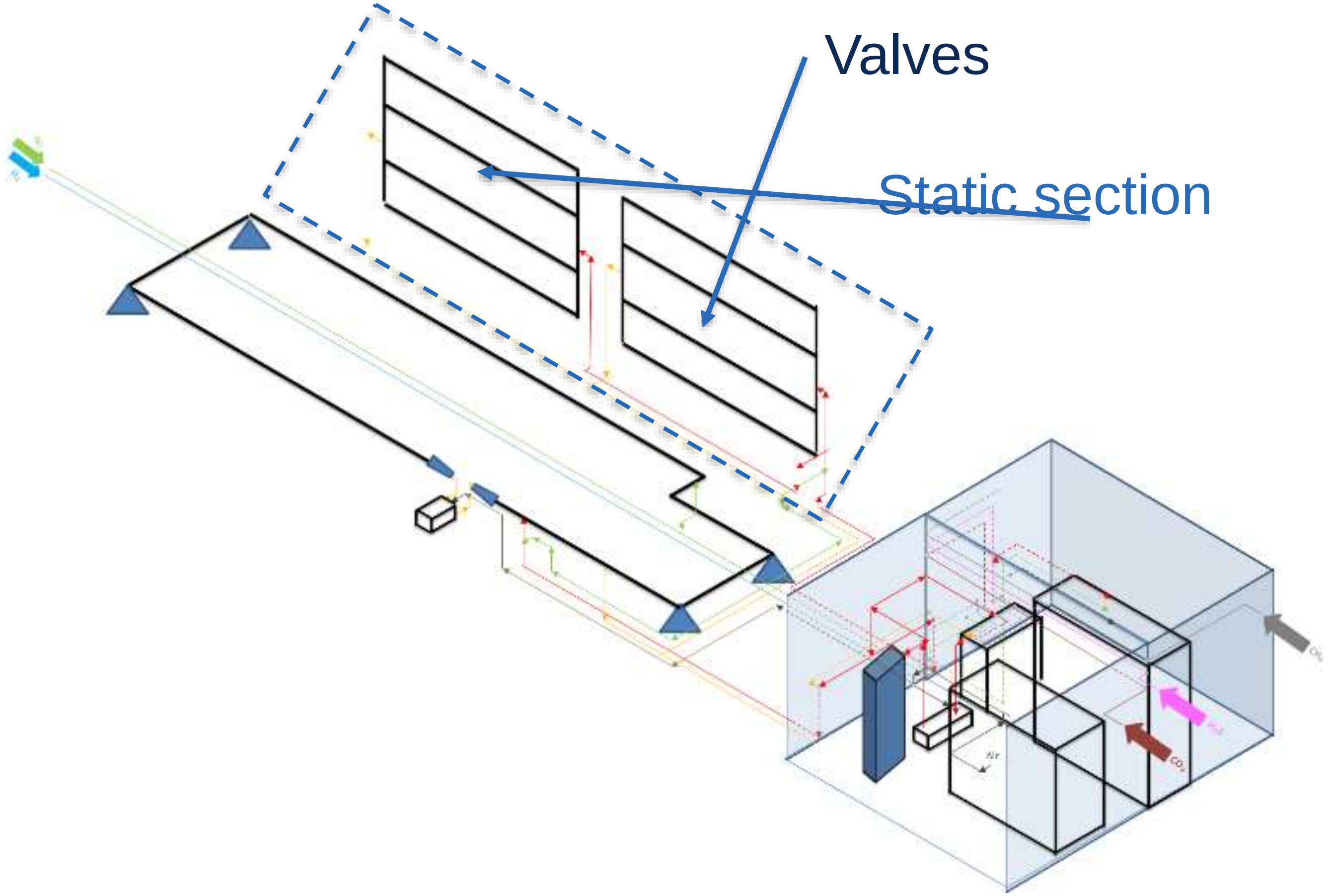
It recreates the **injection of electrolytic H_2 into a "simplified" natural gas** (CH_4+H_2S+CO_2).



Blending station

Design, preparation and commissioning of testing facilities (WP3)

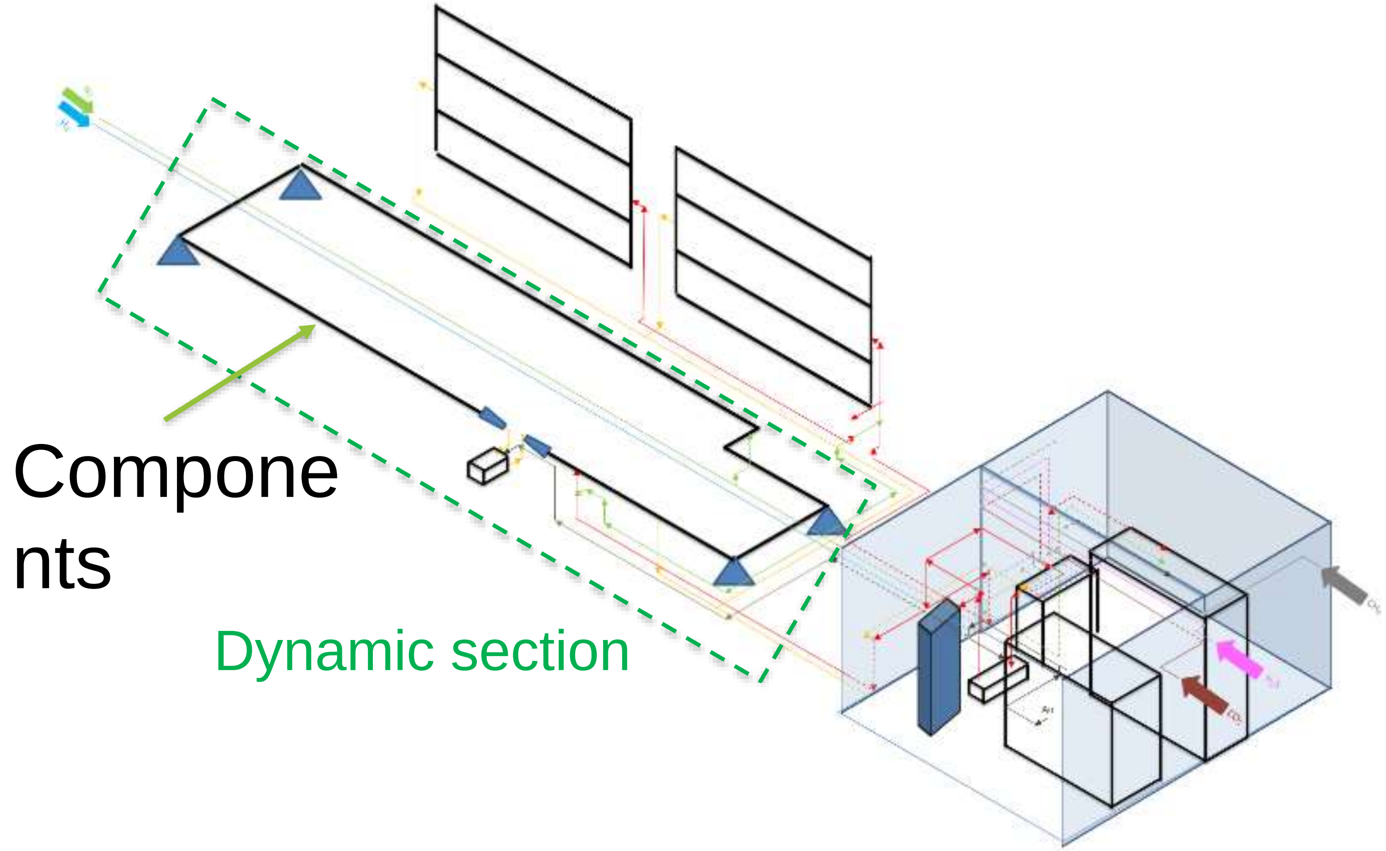
- No Flow: lines filled and pressure mantained during the tests
- Leackeage tests



Component	Tests conditions
Ball Valve	Static
Butterfly Valve	
Plug valve	
Needle valve + screw cap (purge)	
Ball valve + screw cap (purge)	

Design, preparation and commissioning of testing facilities (WP3)

- Constant flow of gas at high pressure in closed loop
- Degradation issues (e.g. hydrogen embrittlement)

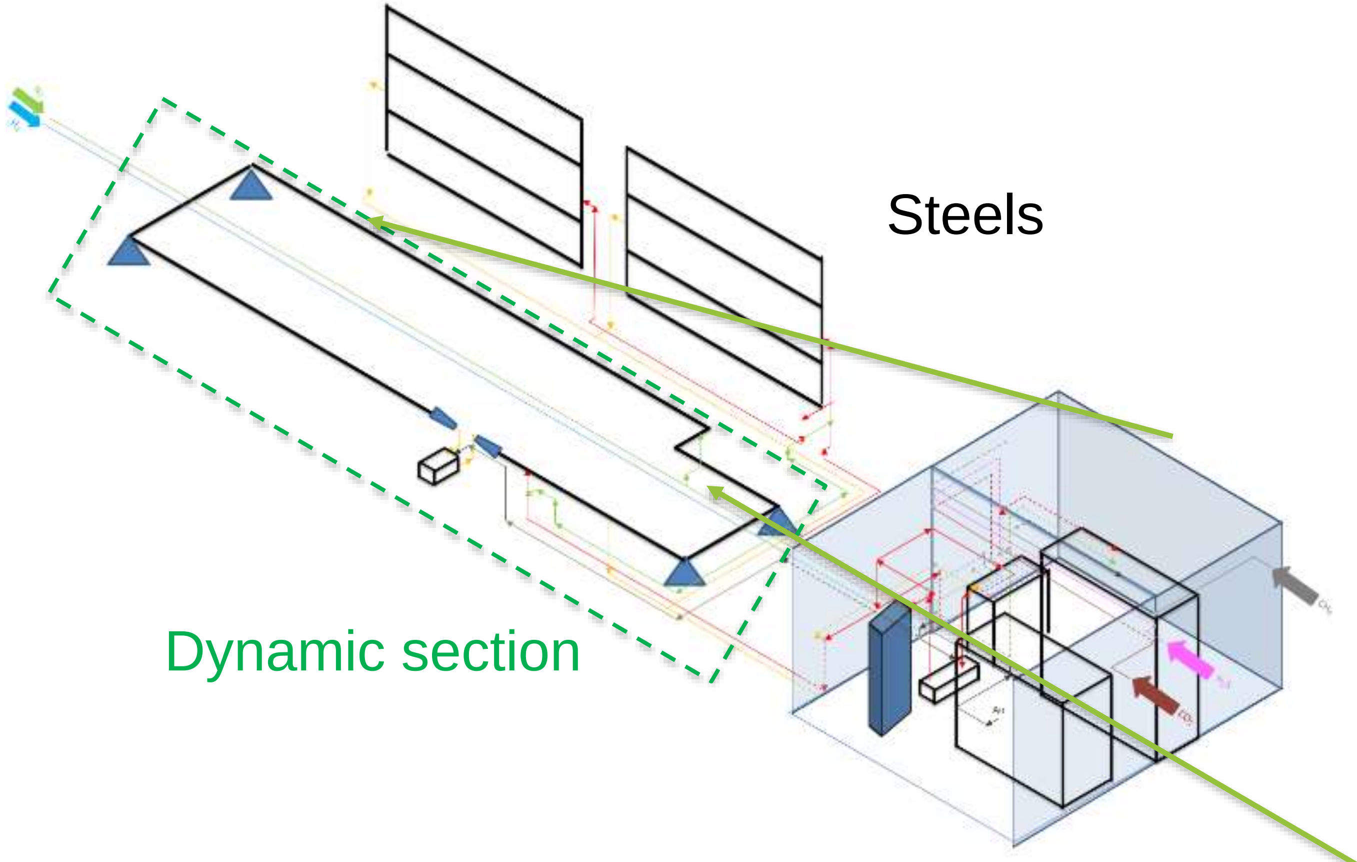


Component	Tests conditions
Pressure regulator	Dynamic
Filter	
Flow meter	
Pressure switch	
Pressure transducer	
Temperature transducer	

Design, preparation and commissioning of testing facilities (WP3)

- Constant flow of gas at high pressure in closed loop
- Degradation issues (e.g. hydrogen embrittlement)

API 5L steel grade	Tests conditions
B	Dynamic
X42	
X52	
X60	
X70	

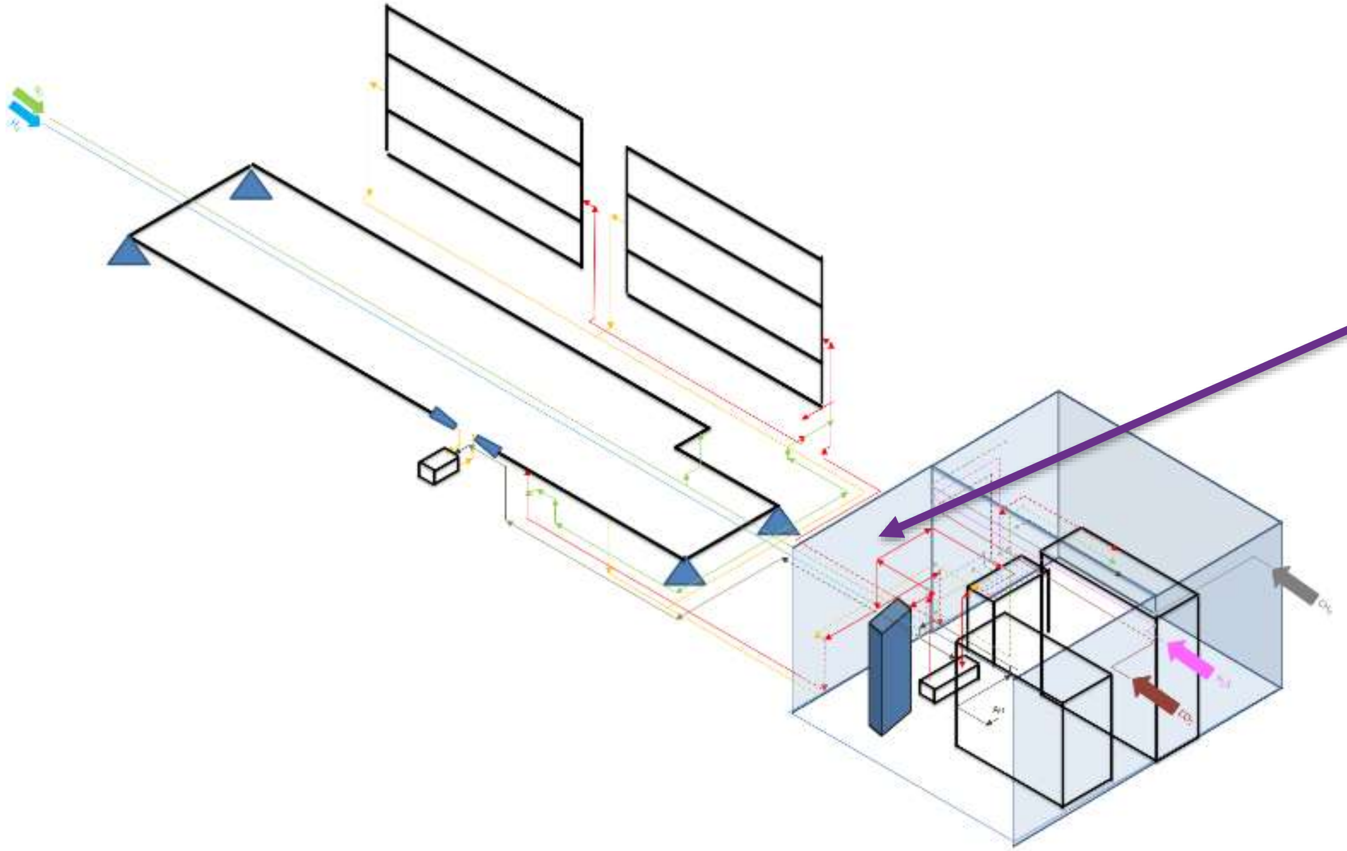


Pig trap

- ➢ C-ring specimens
- ➢ 4-point bend specimens
- ➢ Precracked fatigue compact tension (CT) specimens

Design, preparation and commissioning of testing facilities (WP3)

- Gas separation tests with membrane technology



MEMBRANE PROTOTYPE

Test campaign conditions (WP4)

HIGGS Hydrogen in Gas Grids

- At least 3 conditions: i) 20 %vol H_2 in CH_4, ii) 20 %vol H_2 in CH_4+H_2S+CO_2 and 100%vol H_2
- 4 months gas exposure @ 80 bar

Results validation

DYNAMIC SECTION

- Characterization of materials after exposure: visual inspection for crack detection, metallographic and mechanical investigation

STATIC SECTION

- Monitoring H_2 leakeages (pressure control & chromatography)

MEMBRANE PROTOTYPE

- Analysis of composition of gas permeate by gas chromatography

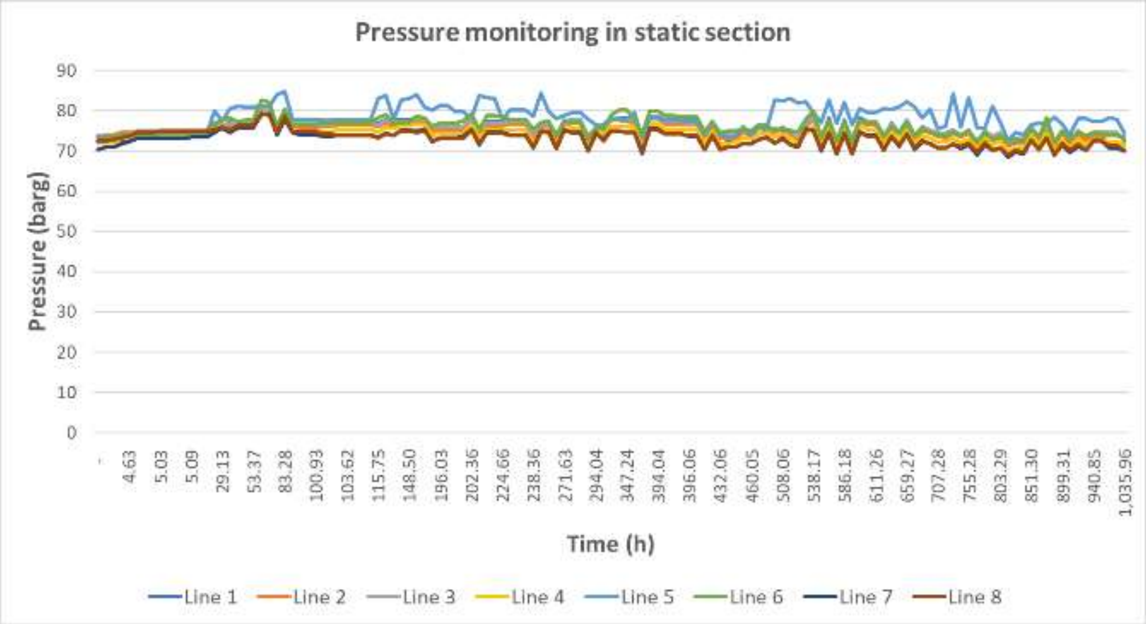
Test campaign conditions (WP4)

Test ongoing: 20 %vol H_2 in CH_4

Preliminary results:

➔ Over 1000 h operation right now

➔ No significant change in the gas composition



Tecno-economic modelling (WP5)

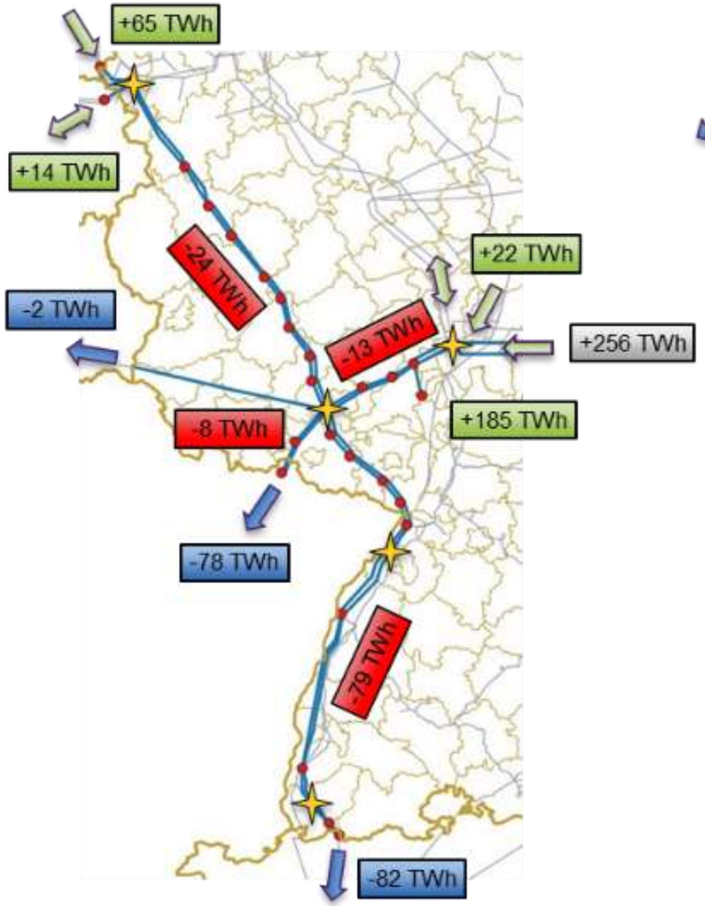
Network modelling of TENP/MEGAL pipeline sections

- <u>Modelling scope</u>: Pipelines, compressors, regulator stations

- To be analyzed: **10, 20, 30, 60, 100 (H_2 vol.-%)**
  - <u>Not</u> considering future gas separation technologies
  - <u>Including</u> technology innovations needed

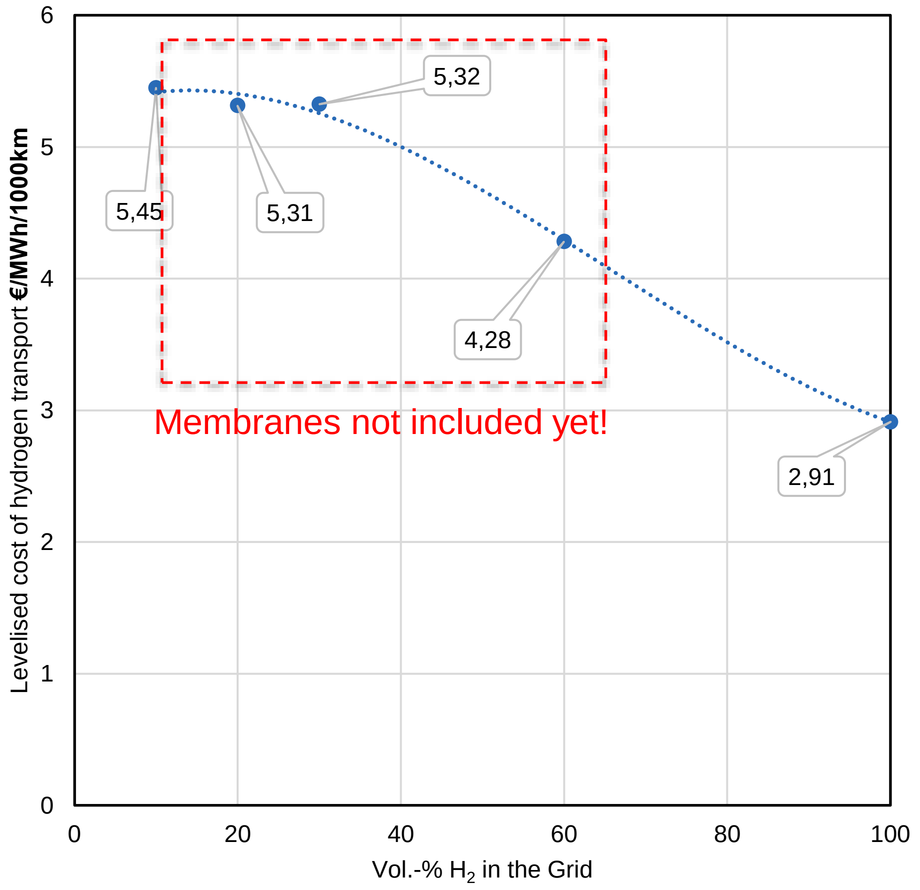
- **<u>Target parameters:</u>**
  - Fixed OPEX:
    - Maintenance and operation cost for transport systems
  - Variable OPEX:
    - Compression work for gas transport
    - Energy expenses for preheating at regulator stations
  - CAPEX for system retrofit

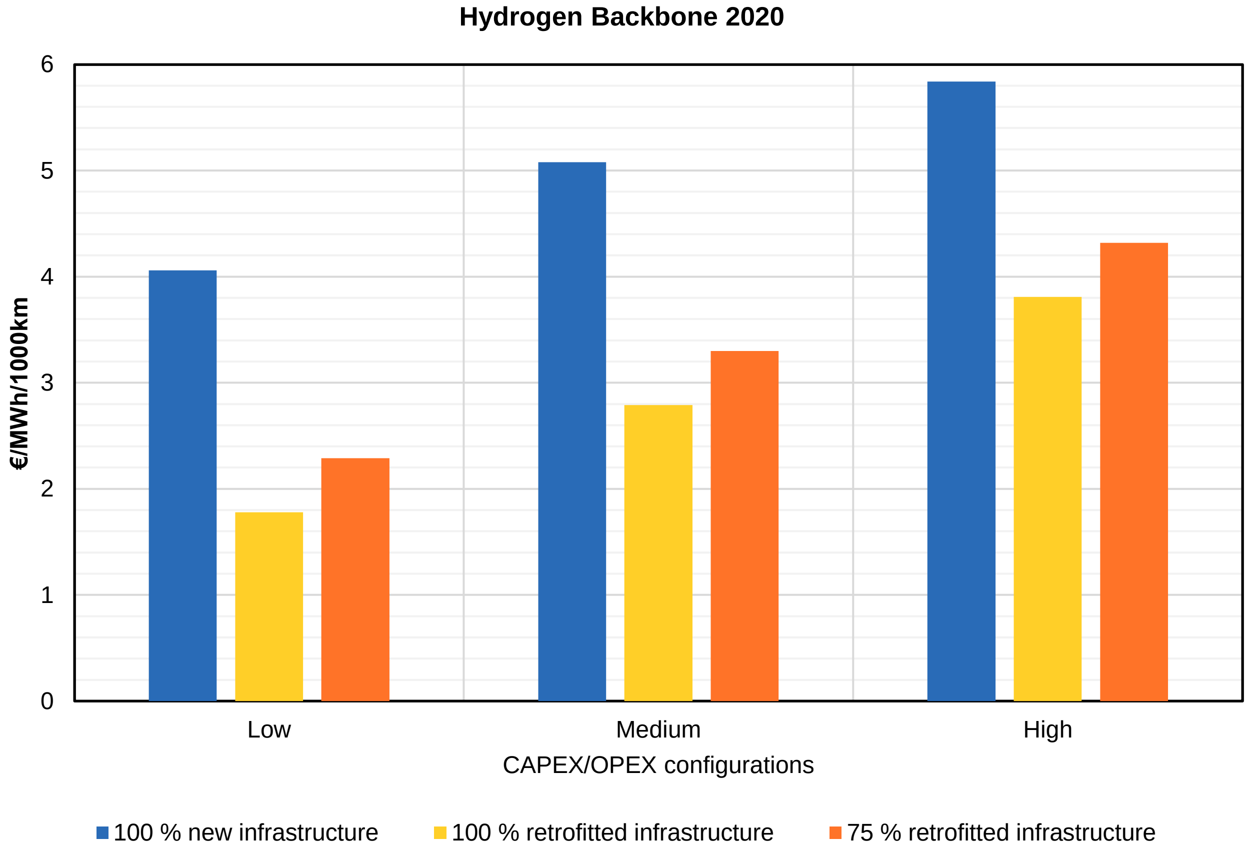
Pure natural gas



Premixed gases at model inlet nodes

Preliminary results: Simulations ongoing…





Summary

Legal, regulatory and technical aspects

- There is a quite diverse picture on the current status of national legal and technical framework in regards of hydrogen implementation in Europe.
- The analysis of the European NG transmission network has made it possible to:
  - Identify the most representative steels and facilities.
  - Identify the main components and characteristics of these facilities.

Establishing those to be tested

Experimental platform

- Tests with blends and pure hydrogen condition @ high pressure.
- Hydrogen embrittlement + leackeage issues.
- Designed to be updated and support future needs and trends.

Tecno-economic modelling

- Ongoing network modelling of TENP and MEGAL pipeline sections

THANKS FOR YOUR ATTENTION!

Dr. Javier Sánchez Laínez
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HyDeploy$_2$

Adam Madgett

HyDeploy$_2$ – NE trial Winlaton

Adam Madgett – Northern Gas Networks

Project Leads and Partners

Supported by

And many contributors and supporters from the industry

Stage 2 Project Objective

To enable a hydrogen supplier to apply for an exemption and inject up to 20% hydrogen into the gas network just as biomethane can today.

Project Funded under OFGEM's Network Innovation Programme

Overall Timeline

Pathway to Deployment

Safety Case

- Building on the work from Keele the exemption for Winlaton needed to gather wider evidence on;
- Appliances
  - The safety case based on representative GB appliances,
  - No safety or performance issues identified
  - Use of hydrogen blended gas resulted in lower levels of CO in flue and substantially lower CO produced during fault conditions
- Gas Characteristics
  - Extensive modelling and experimental showed that potential leaks of blended gas within buildings will produce practically identical gas concentrations to NG
- Materials
  - Extension the materials assessment from Keele to address materials on the public network
- Operational Procedures
  - Embodiment of the procedural requirements into NGN operations
- QRA
  - The updated QRA continues to support the premise that safety is not prejudiced by the use of a blend.

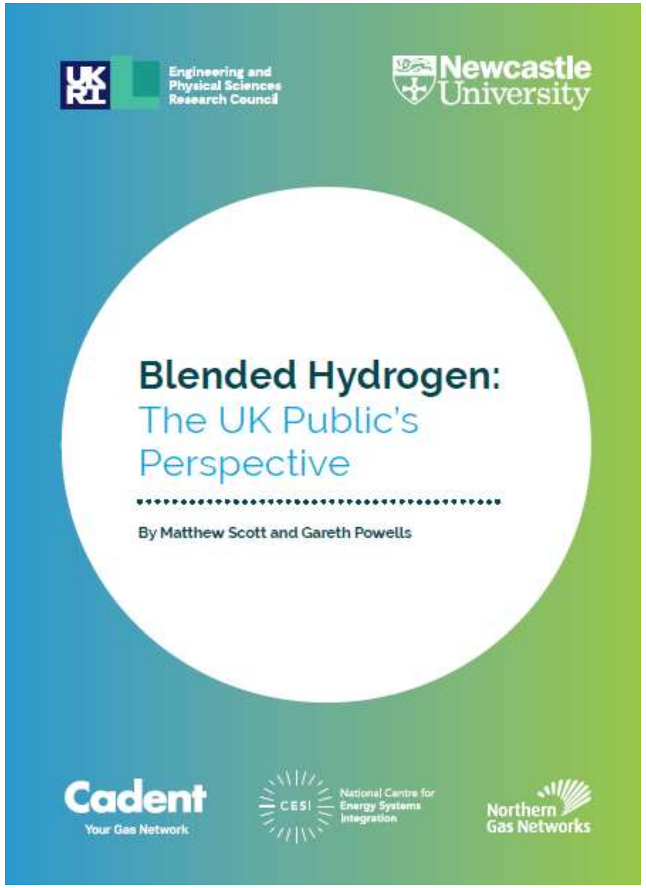
NGN Trial Area

- Located in the North East outside Gateshead.
- Isolated network for injection
- 668 Trial properties
  - Including a church and School.
- Wide spread of materials

NGN Low Thornley Site for Hydrogen compound

Customer perceptions

- Online and face to face survey 802 people surveyed
- Key findings
  - Reasonably high overall support around active participation in a trial
  - Support contingent on customers prior hydrogen knowledge and reassurances regarding the perceived impact on safety, home appliances, cost, and environmental benefits
  - Two thirds of participants unwilling or unable to pay more for hydrogen
- Helped inform customer engagement for 1st public trial



Customer engagement

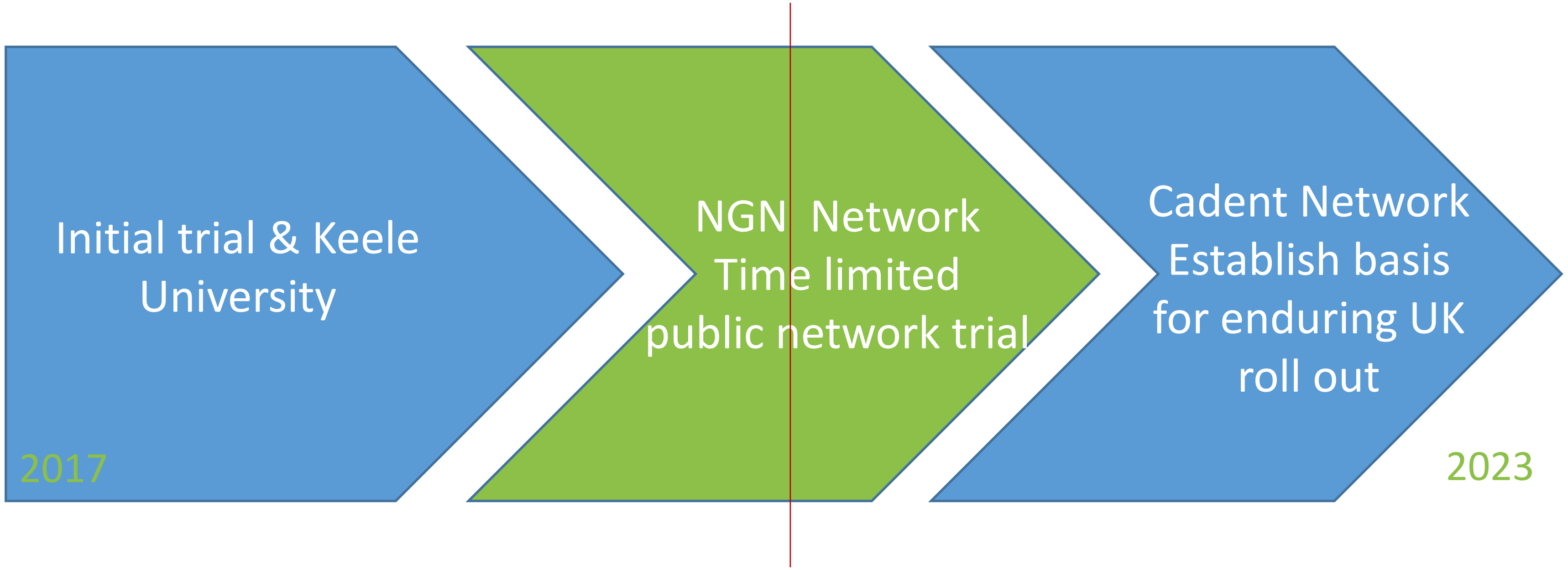
- Early engagement was required to explain the scope of the project and offer any support.
- To support the exemption and develop our learning with regards appliances the project had to gain access to as many properties as possible.
- A dedicated customer officer was put in place to support customers if required.
- The team developed a strategy to gain access to as many properties as possible.
- We acquired data on nearly 90% of the trial area properties.

Physical works

- New mains and district governor installed.
- Network isolations carried out to ensure the blend is only distributed to those in the trial area.
- Hydrogen compound construction complete.
- New Hydrogen Grid Entry Unit (HGEU).

Hydrogen compound

Overall Timeline



Pathway to Deployment

Key Differences from Keele

- ↑ Household number & appliance diversity
- ↑ Supply chain & regulatory engagement
- ↓ Intervention
- + Roll out evidence gap

HyDeploy

HyDeploy

Delivering safe and non-disruptive carbon reduction for gas customers

THyGA Workshop

Presentation of the project

December 15th 2021

Patrick Milin, ENGIE

Testing **Hy**drogen admixture for **G**as **A**pplications

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No. 874983. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

THyGA project: some reminders

Context: Hydrogen in the gas grid to decarbonise the European energy system

Hydrogen, along with green electricity from wind and solar power, is currently being discussed as a pathway to decarbonise the European energy systems. In this way, the CO_2 footprint of gas utilisation would be reduced, contributing to an overall reduction of greenhouse gas emissions.

INJECT HYDROGEN IN THE GAS GRID

One way to use hydrogen as an energy vector is to **inject it directly into the existing natural gas grids.**

INCREASE LEVELS OF HYDROGEN

End-use equipment across all sectors need to deal with higher levels of hydrogen in natural gas in a **safe, efficient and environmentally friendly way.**

NEW CHALLENGE FOR END-USE EQUIPMENT

Hydrogen is not part of natural gas compositions, i.e. **equipment was never designed with hydrogen in mind.**

200 MILLION GAS APPLIANCES

There are **an estimated 200 million gas appliances installed in the European residential sector** alone

THyGA project: some reminders

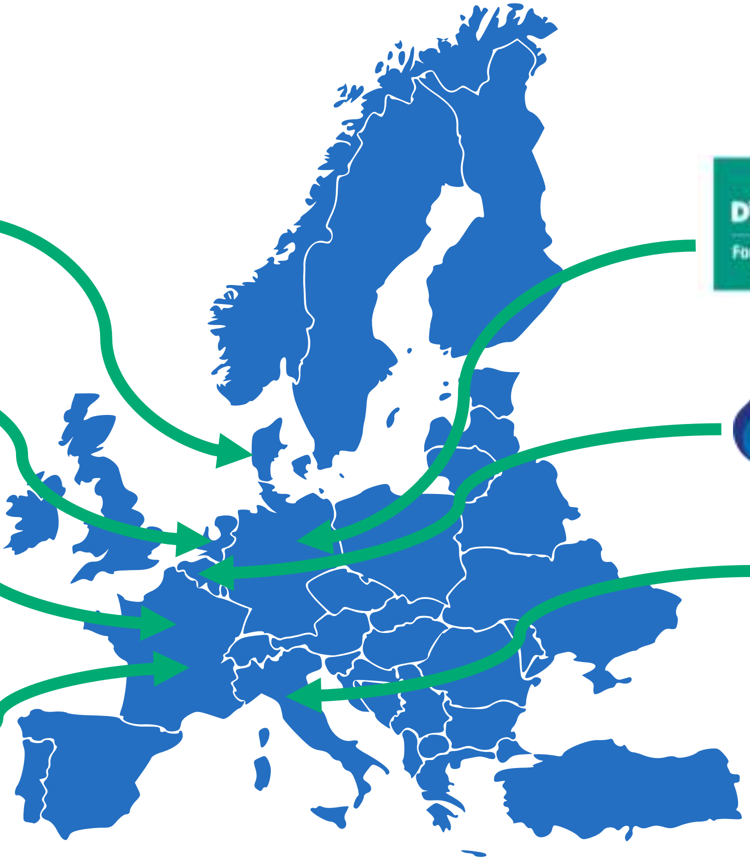
Project consortium: 9 partners in response to the Horizon 2020 call FCH-04-3-2019

DGC

BDR THERMEA GROUP

ENGIE

cea



DVGW Forschungsstelle ebi gwi

GERG THE EUROPEAN GAS RESEARCH GROUP

gas.be

Electrolux

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No (No. 874983). This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

THyGA project: some reminders

Expected results

CLOSING KNOWLEDGE GAPS

Closing knowledge gaps regarding technical impacts on residential and commercial gas appliances.

IDENTIFYING ADAPTATION OF STANDARDS

Identify standards that should be modified or adapted to answer the needs for new appliances and proposals on test gases.

CLARIFYING THE ACCEPTABLE HYDROGEN PERCENTAGE

Clarify the acceptable hydrogen percentage that wouldn’t compromise safety and performance.

THyGA project: some reminders

Work Packages

WP1
Project management
- General coordination
- WP coordination
- Relation to FCH JU

WP2
Status of gas utilisation technologies
- Impact of H2 on combustion
- Segmentation and selection of technologies
- Test program

WP3
Experimental work
What happens on the field with H2 injection?
- Test protocol
- Tests on various appliances (~100)

WP4
Standardisation
How can we certify an appliance according to H2 rate in NG?
- Current framework of standards
- Test procedures development
- Validation tests

WP5
Recommendation for mitigation measures
How can we increase the acceptable H2 rate?
- Identification of mitigation measures
- Validation tests

WP6
Communication dissemination exploitation
- Dissemination
- Workshops
- Green H2 roadmap from the end-user point of view

Advisory Panel group
Challenge of the processed results and support through wide dissemination

Appliances, burners, controls, sensors manufacturers

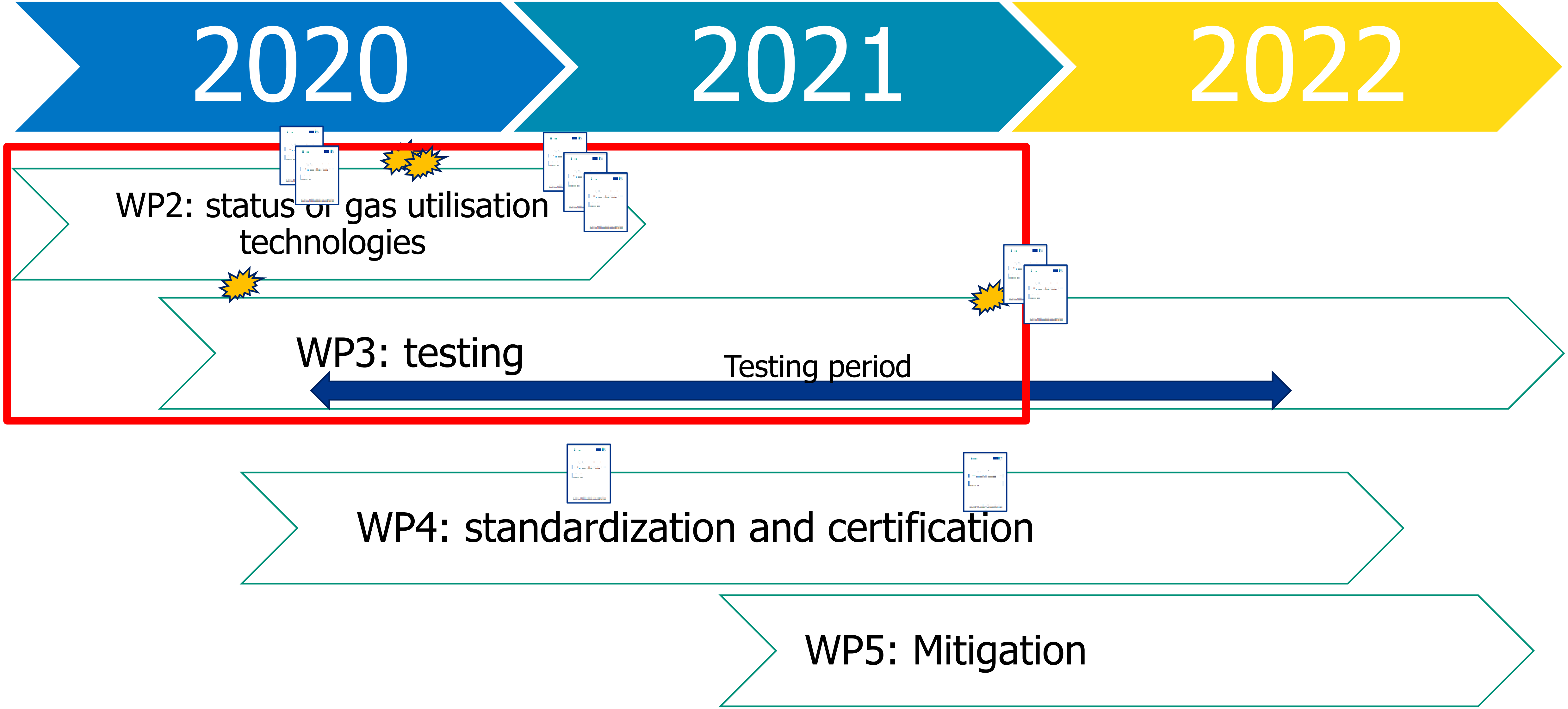
Associations, DSO, research centers

THyGA project: some reminders

Planning: several works on-going

Public deliverables

Public events: slides and replays available on the website



Any questions?

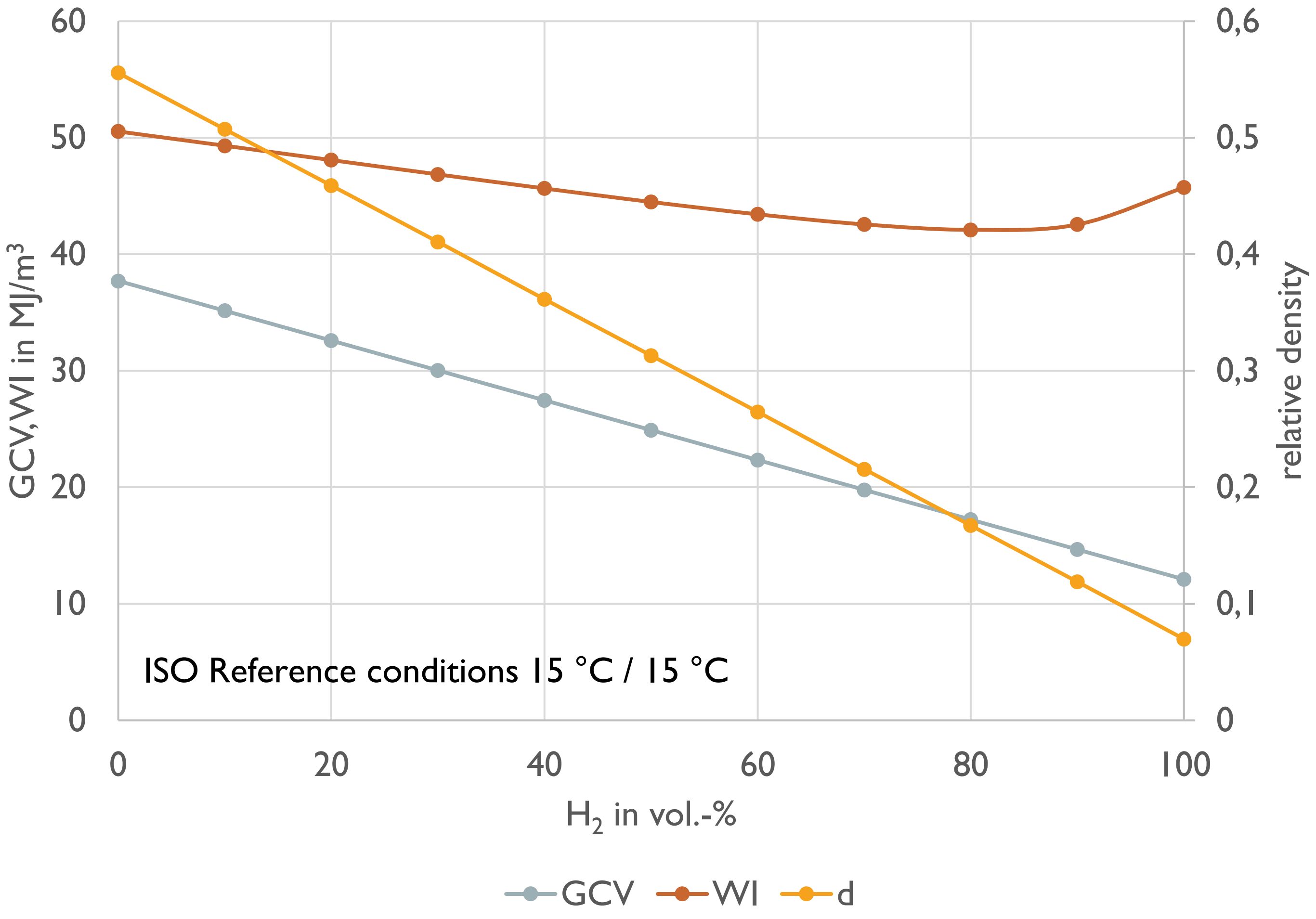
Workshop WP3: Input from combustion theory

December 15th 2021 Jörg Leicher, GWI

Testing **Hy**drogen admixture for **G**as **A**pplications

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No. 874983. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

H_2 admixture and gas quality

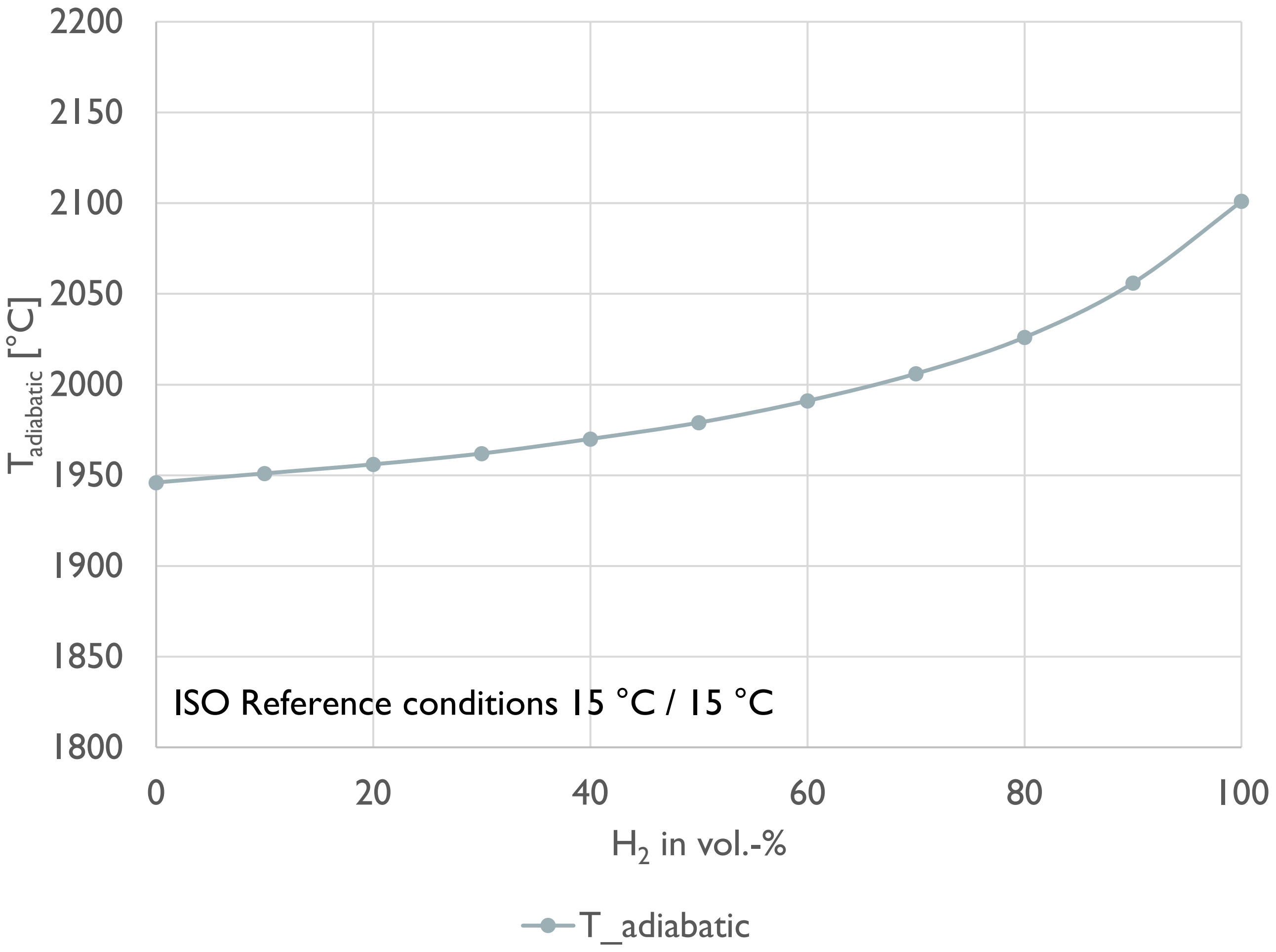


- **Relative density**: $d = \frac{\rho_{n,fuel}}{\rho_{n,air}}$
- **GCV**: gross calorific value (the energy content of a fuel gas in volumetric terms)
- (superior) **Wobbe Index**:

$$\mathrm{WI} = \frac{GCV}{\sqrt{d}}$$

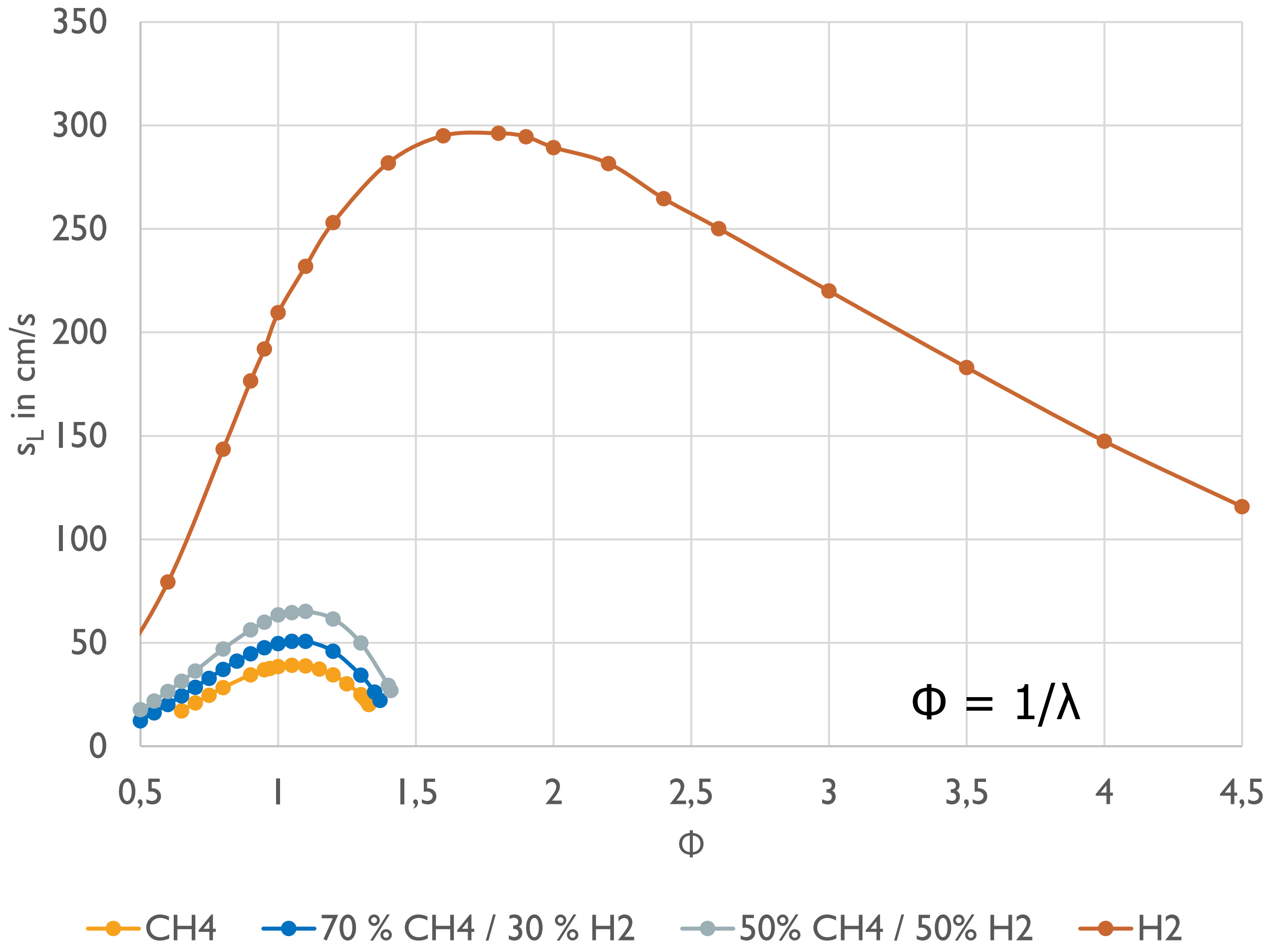
- H_2 vs. CH_4:
  Δd ≈ -88 %
  ΔGCV ≈ -68 %
  ΔWI ≈ -9.5 %

Other aspects: temperature

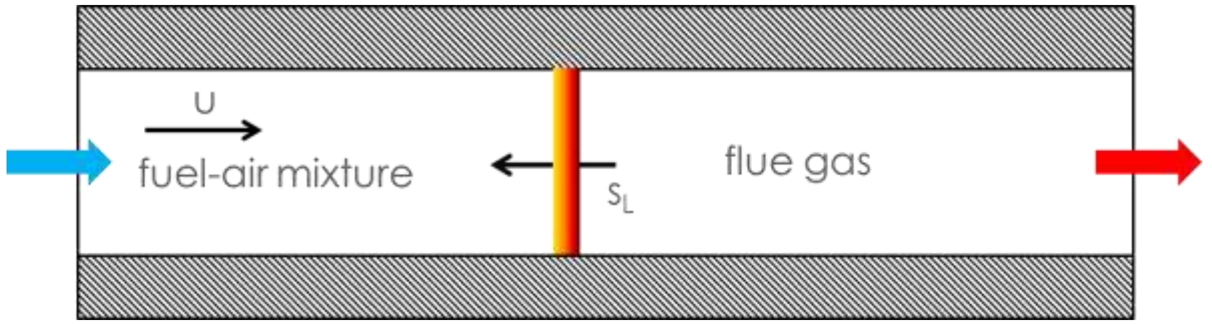


- To assess the impact of a fuel change on the temperatures, it is often useful to look at the **adiabatic combustion temperature** $T_{adiabatic}$.
- The adiabatic combustion temperature is the **theoretical maximum temperature** that can occur in a combustion process.
- It is assumed that the entire thermal energy that is released is used to heat the flue gas, i. e. there are **no heat losses**.
- $T_{adiabatic}$ is only dependent on the **compositions** of **fuel** and oxidizer, their temperatures, the system pressure and the **air excess ratio λ**.
- $\Delta T_{adiabatic} \approx 150$ °C

Other aspects: combustion velocity



- The **laminar combustion velocity** s_L indicates how fast a flame front will propagate into a resting fuel-air mixture.
- It is therefore crucial for **flame stabilization**, especially for premixed burner systems.
- s_L is dependent on the **compositions** of **fuel** and oxidizer, their temperatures, the system pressure and the **air excess ratio λ**.



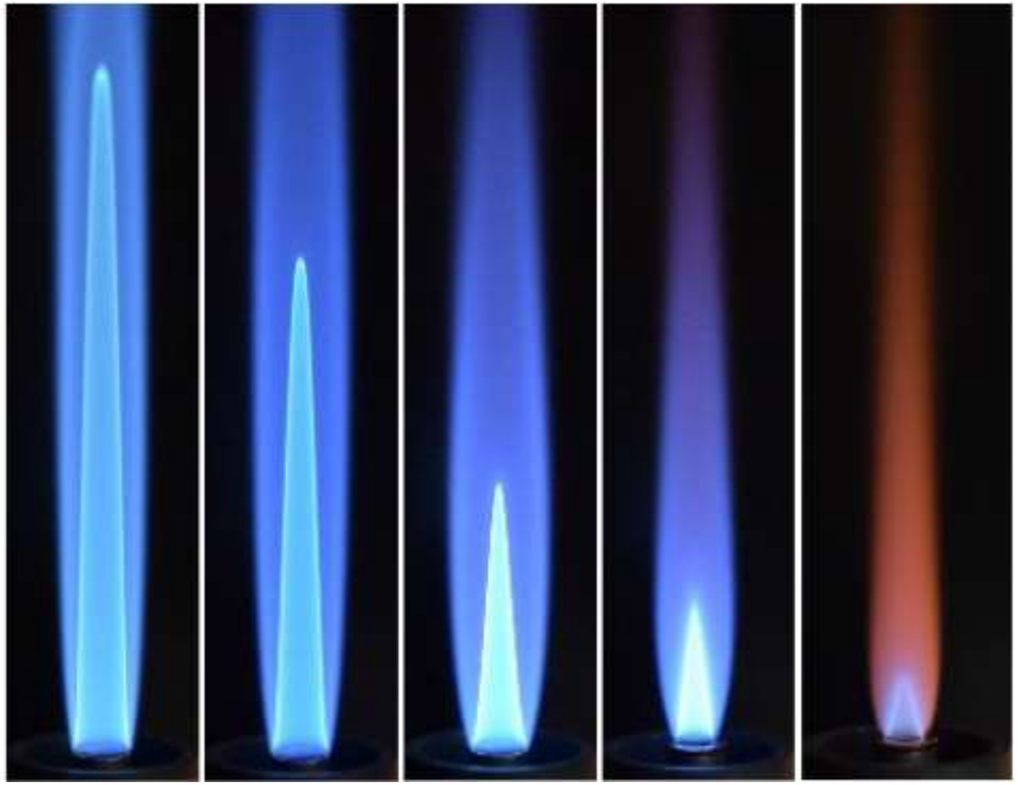
Gas quality in the context of H_2

	Unit	100 % CH_4 (G20)	94 % CH_4 / 6 % CO_2	92 % CH_4 / 8 % N_2	100 % H_2	80 % CH_4/ 20 % H_2
WI	MJ/m^3	50.64	45.28	45.27	45.78	48.17
NCV	MJ/m^3	34.06	32.02	31.34	10.24	29.30
GCV	MJ/m^3	37.80	35.53	34.78	12.1	32.66
d	-	0.5571	0.6157	0.5901	0.0698	0.592
Air_{min}	m^3/m^3	9.524	8.952	8.762	2.381	8.095
T_{ad} ($\lambda = 1$)	°C	1982	1971	1974	2096	1990
s_L ($\lambda = 1$)	cm/s	38.57	36.79	37.52	209	46.67
MN	-	100	105	99	0	80

Impact of H_2 admixture on laminar premixed flames (P, λ constant)

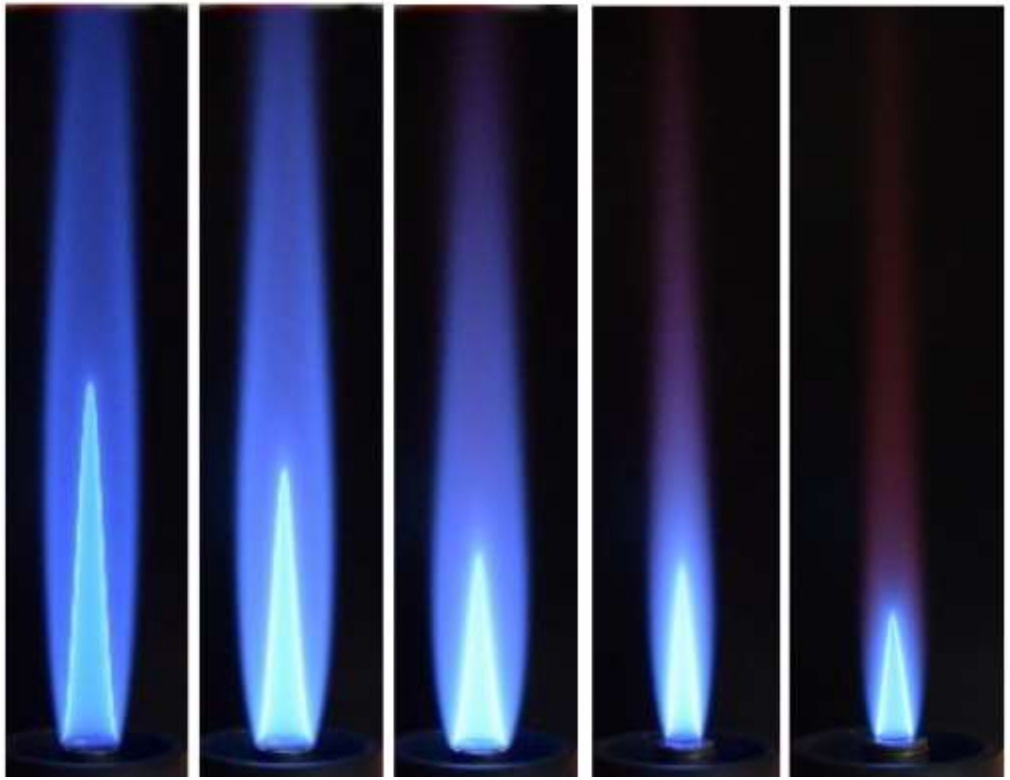
Source: University of Duisburg-Essen, Germany

P = 750 W, λ = 1



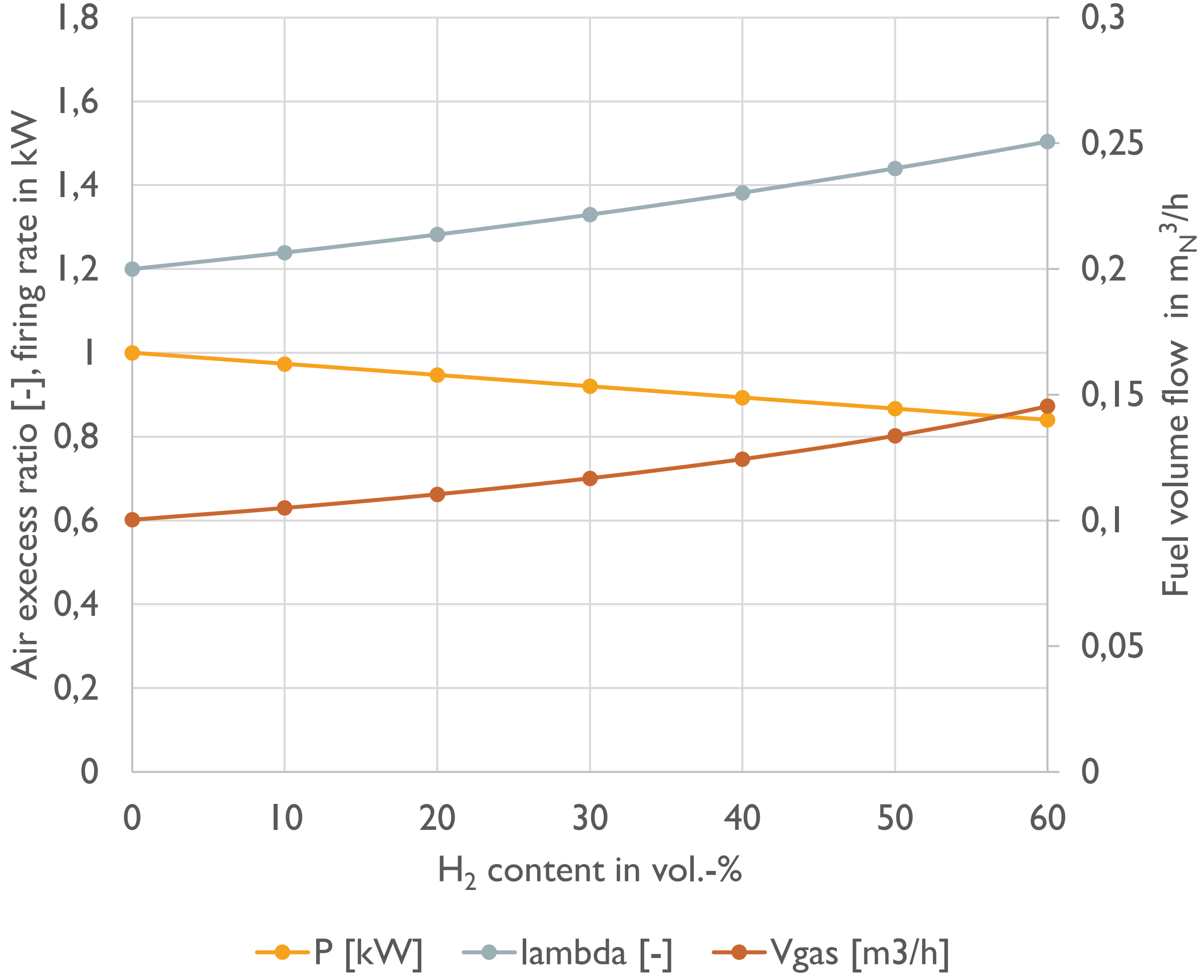
Natural gas H | 25 % H2 | 50 % H2 | 75 % H2 | 100 % H2

P = 750 W, λ = 1.2



Natural gas H | 25 % H2 | 50 % H2 | 75 % H2 | 90 % H2

Impact on process parameters – no combustion control

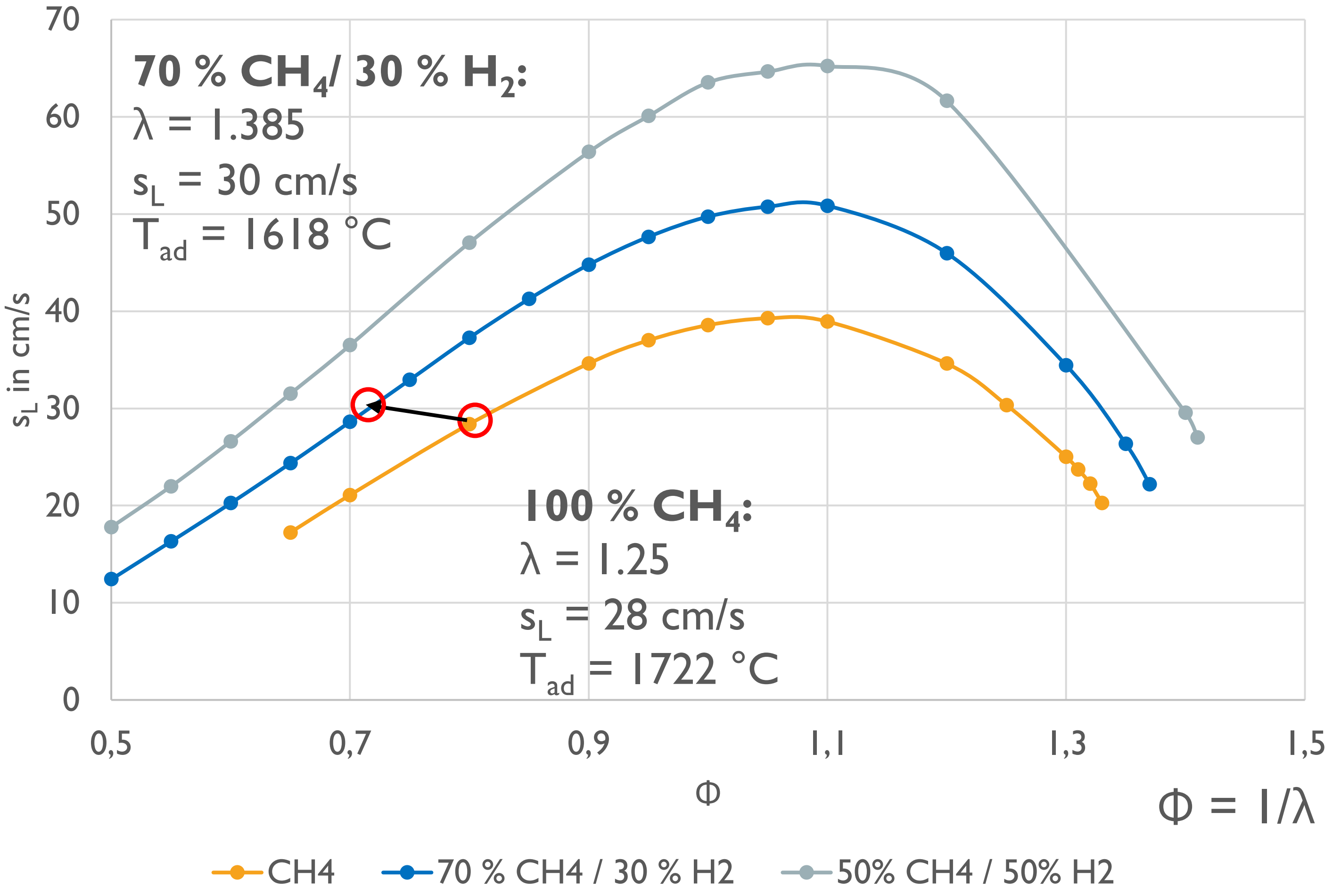


- Firing rate: $\frac{P_2}{P_1} = \frac{W_{i,2}}{W_{i,1}}$
- Fuel volume flow: $\dot{V}_{Gas} = \frac{P}{H_i}$
- Air excess ratio: $\frac{\lambda_2}{\lambda_1} = \frac{CARI_1}{CARI_2} \approx \frac{W_{i,1}}{W_{i,2}}$

- In the case of H_2 admixture, the firing rate of the burner decreases with higher levels of H_2, while the fuel volume flow increases.

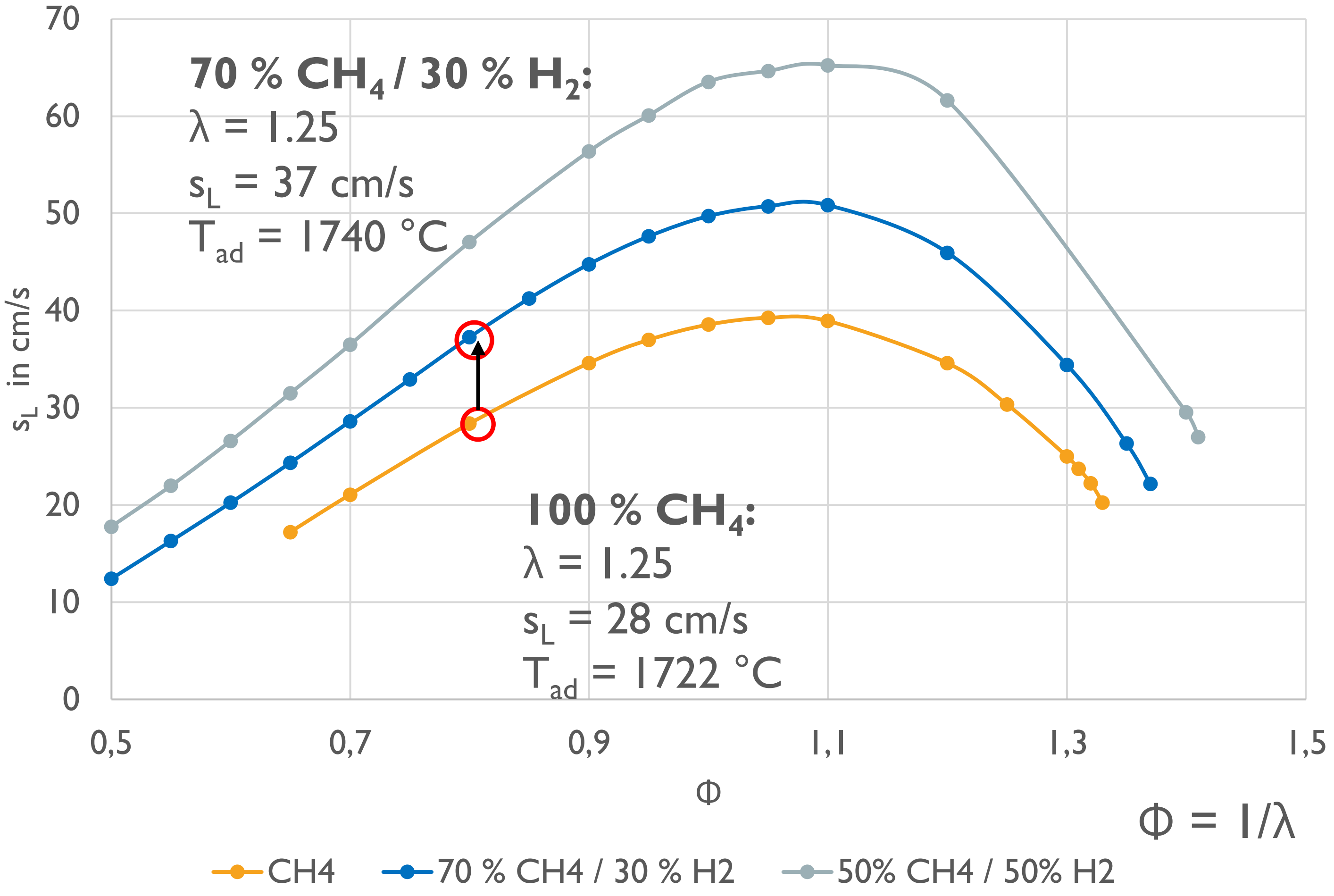
- The air excess ratio shifts towards higher values. This shift compensates some of the effects of H_2 admixture in uncontrolled premixed combustion processes, but also has consequences for adjustment.

Flame stabilization in premixed burners – no combustion control



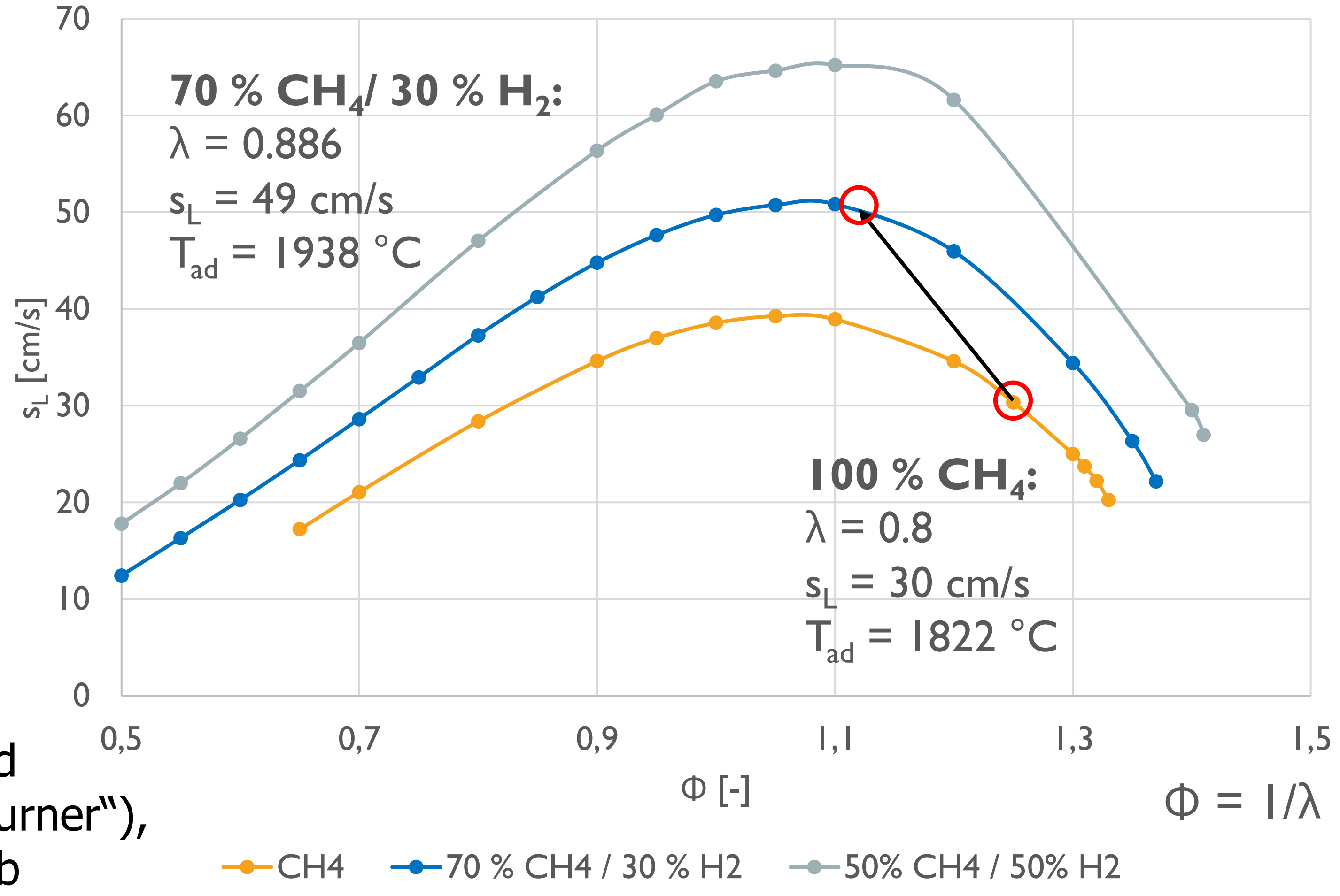
Fully premixed burner, e. g. heating appliance

Flame stabilization in premixed burners – with combustion control



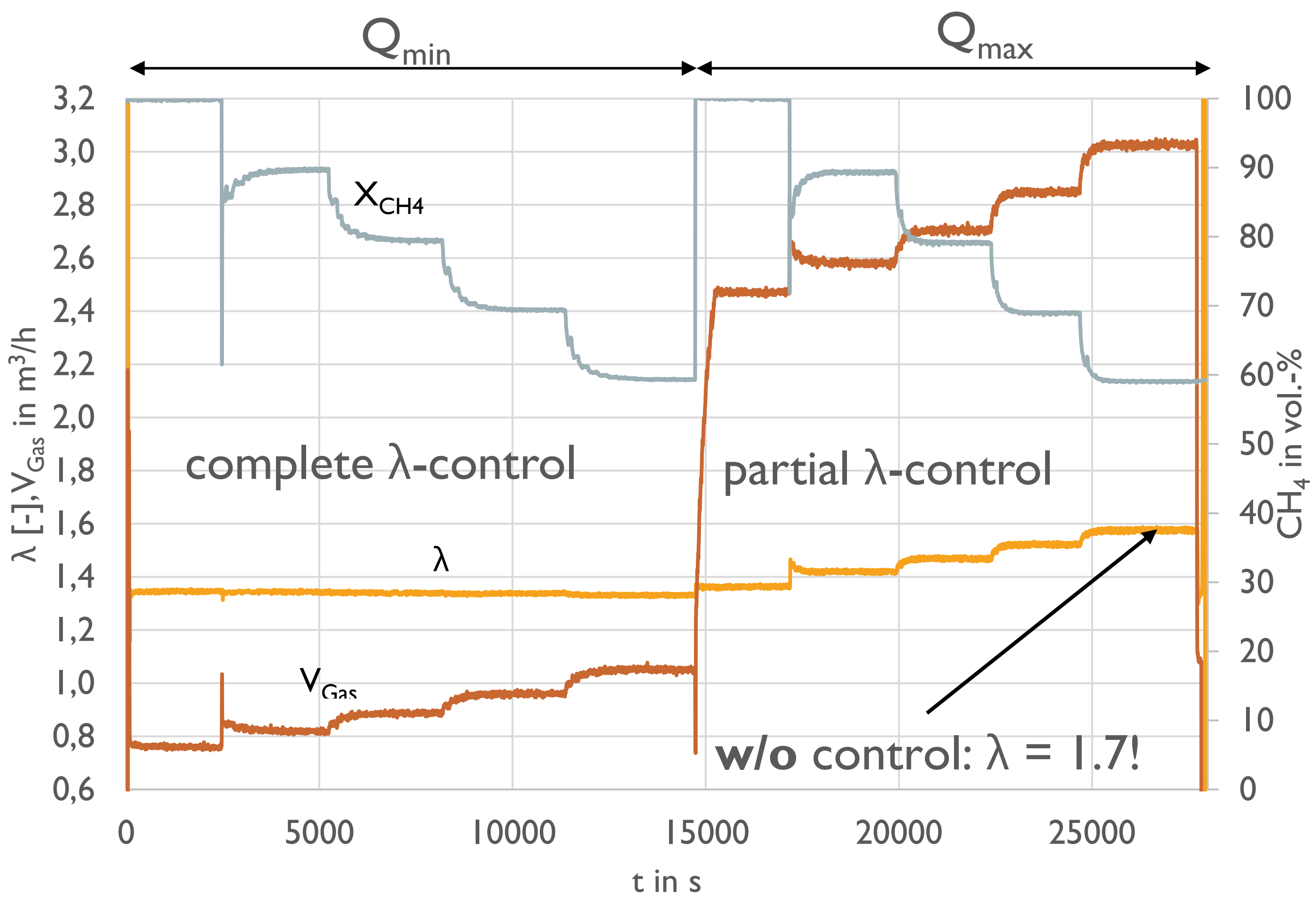
Fully premixed burner, e. g. heating appliance

Flame stabilization in partially premixed burners – no control



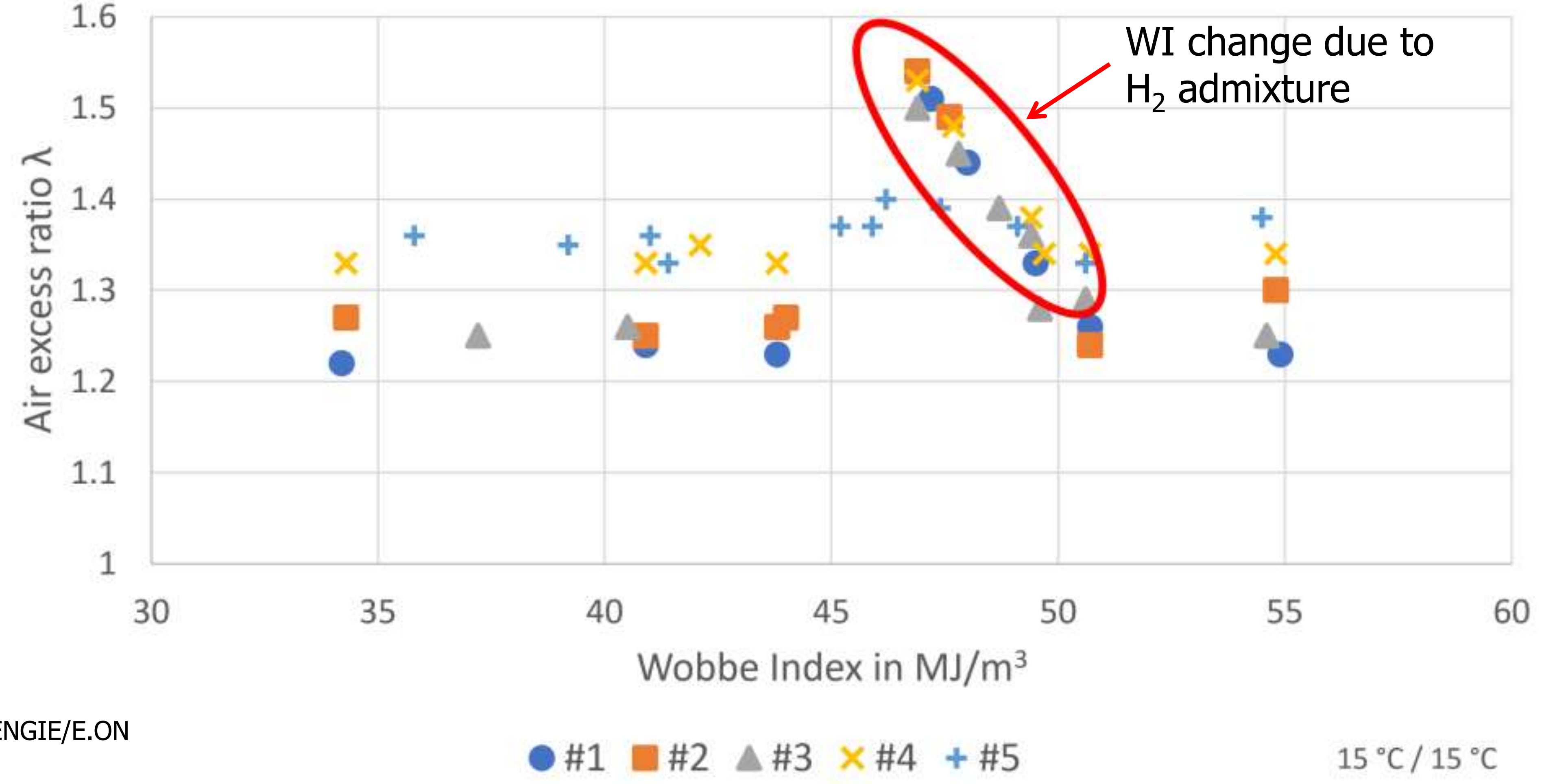
partially premixed burner („atmospheric burner"), e. g. cooking hob

Combustion control in a heating appliance



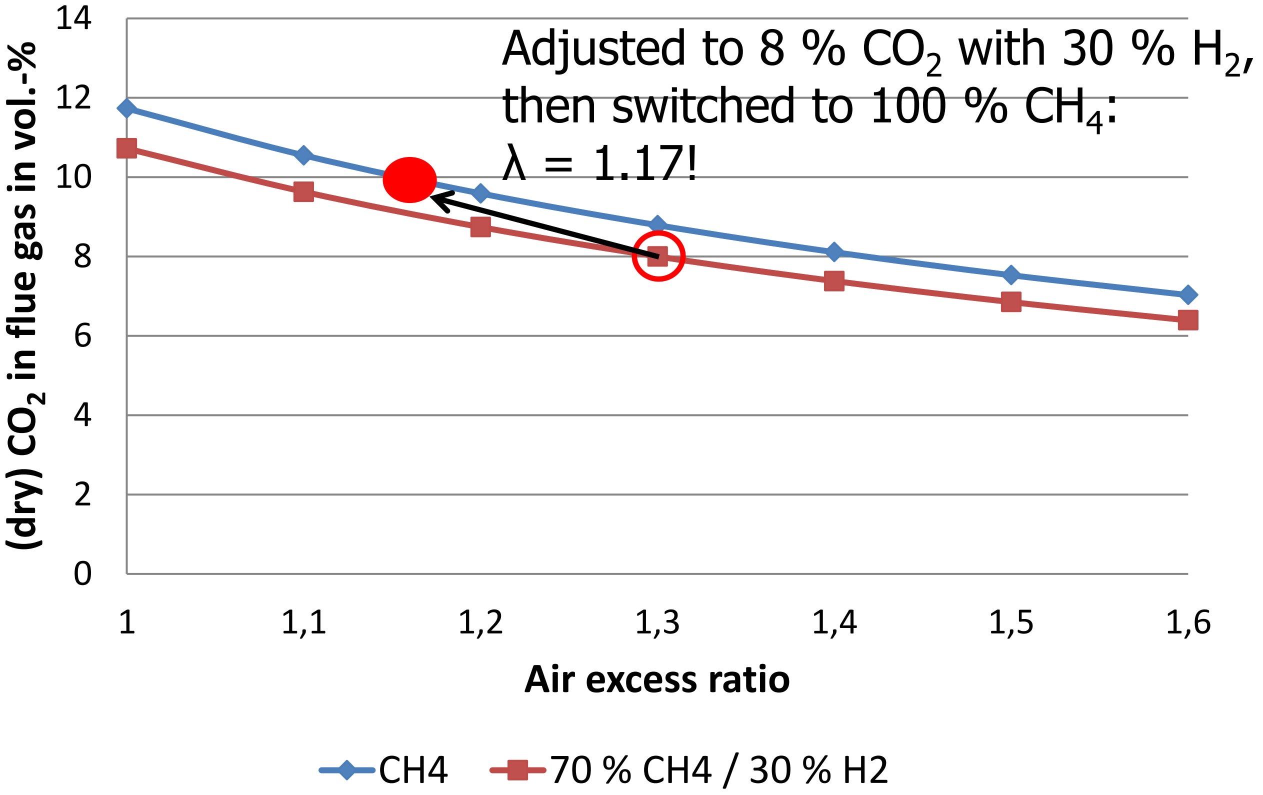
- Combustion control systems are usually designed with certain fuel types in mind.
- If the fuel **changes too drastically**, they may respond in unexpected ways.
- These measurements show results for an appliance with combustion control, based on **flame ionization measurement**.
- It can be seen that the appliance manages to maintain a constant λ with varying levels of hydrogen at minimum load (Q_{min}), but **fails to do so** at maximum load (Q_{max}).

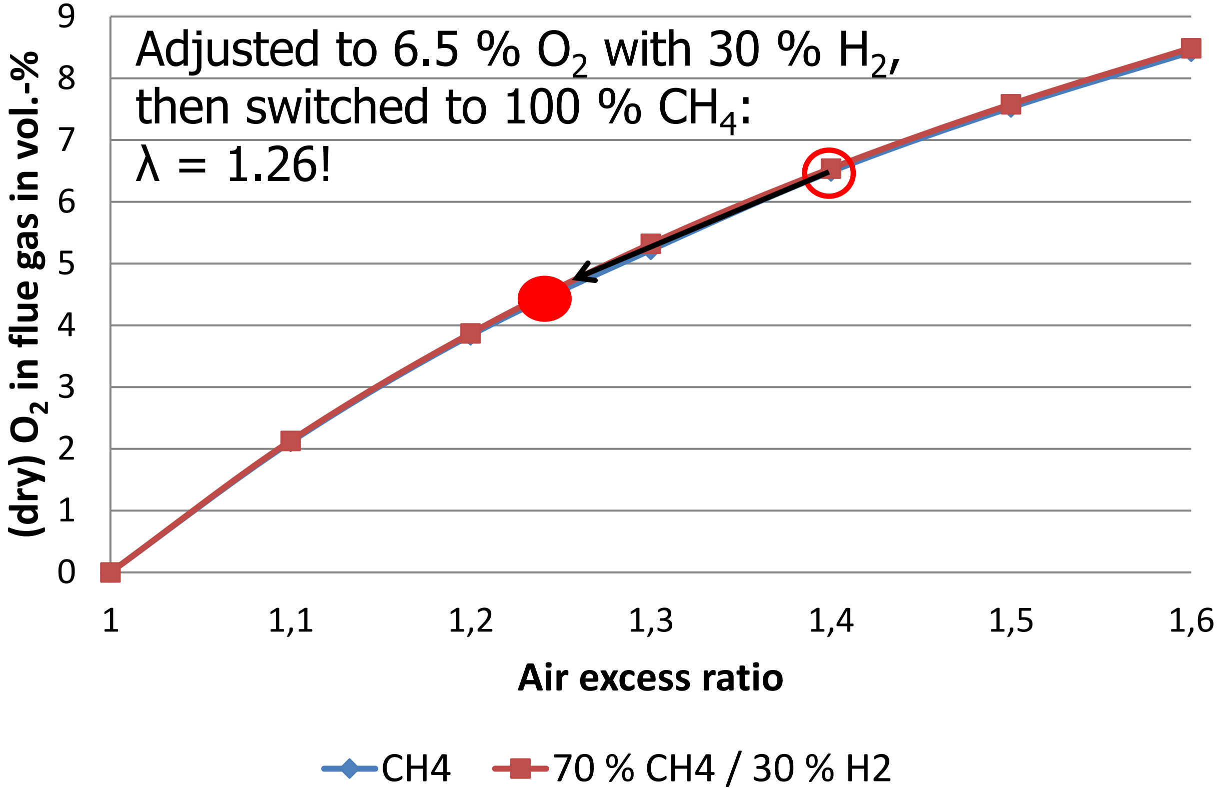
Combustion control and H_2 admixture



Source: DGC/ENGIE/E.ON

Adjustment





On-site adjustment via CO_2 causes additional uncertainty about the actual setpoint value of λ
Adjustment via excess O_2 in the flue gas is more robust => better safety margin!

Conclusions

- Hydrogen is, chemically speaking, a very different fuel from natural gas. Just looking at one gas quality criterion is not enough.

- It is important to take into account how the combustion process is implemented. Premixed combustion systems (most residential / commercial appliances) behave very differently than non-premixed combustion processes (most industrial applications).

- In uncontrolled premixed processes, many effects of H_2 admixture (T, s_L) are compensated by the shift in the air excess ratio.
  Systems with combustion control cannot exploit this effect… assuming that the control system actually works.

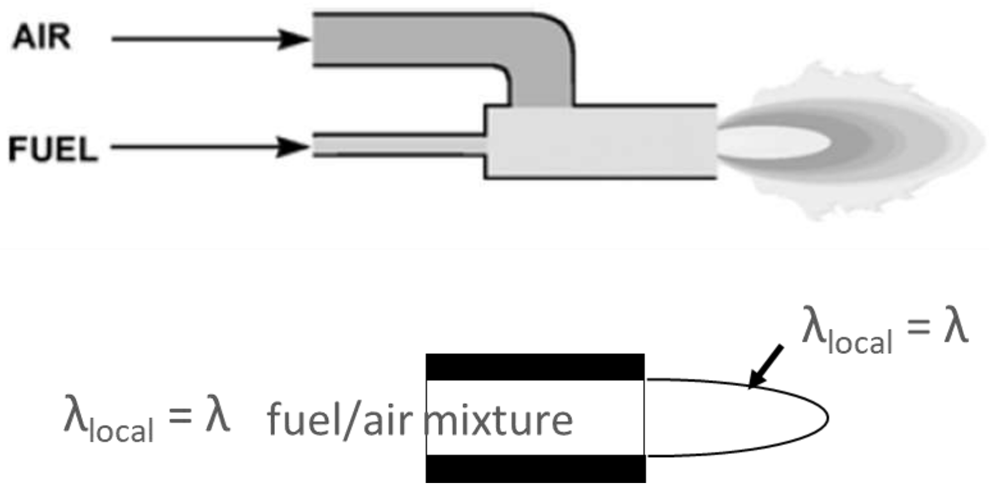
- Adjustment becomes (even more of) an issue. On-site adjustment with an unknown gas via CO_2 setpoints creates additional uncertainty.

THyGA

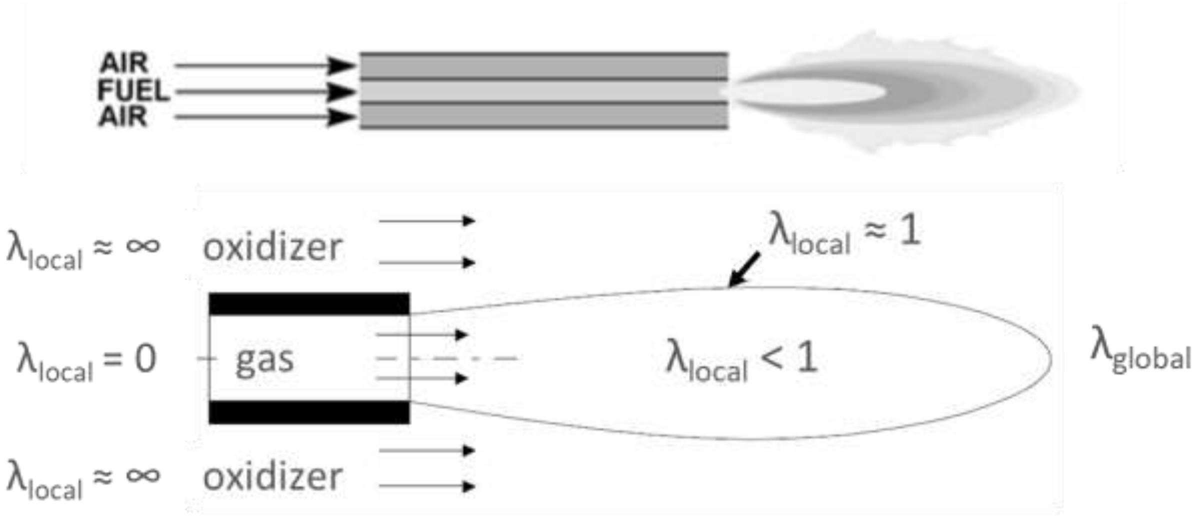
Any questions?

Premixed vs. non-premixed combustion

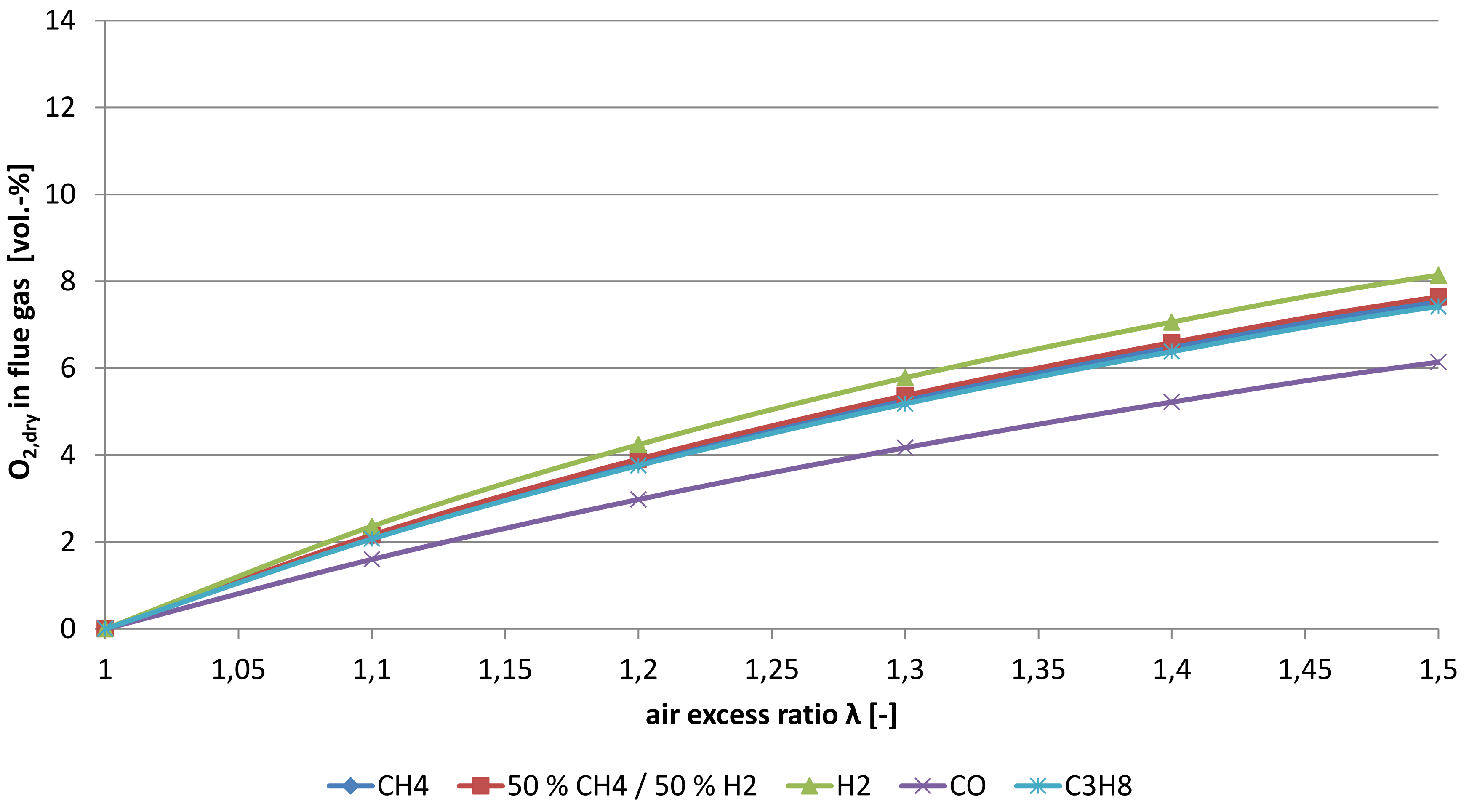
Premixed combustion



Non-premixed combustion



Adjustment



14
12
10
8
6
4
2
0
$O_{2,dry}$ in flue gas [vol.-%]
1
1,05
1,1
1,15
1,2
1,25
1,3
1,35
1,4
1,45
1,5
air excess ratio λ [-]
CH4
50 % CH4 / 50 % H2
H2
CO
C3H8

THyGA Workshop
WP3 Experimental Work
December 15th 2021

Jean Schweitzer. DGC

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No. 874983. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

WP3 - Experimental Work (combustion tests)

Agenda

1. Introduction: Scope and work organization
2. T3.1 Elaboration of the test protocols / template
3. Test results
   - 3.1 Flashback
   - 3.2 Adjustments
   - 3.3 Adjustments of appliances equipped with combustion controls
   - 3.4 Ionization current
   - 3.5 Efficiency and Emissions
   - 3.6 Heat output
   - 3.7 Other results
4. Exploitation of the first results
5. Conclusions

Please ask your questions on the chat

Some will be selected and answered after each discussion topic

All will be answered on a Q/A document available later on the THyGA website

THyGA

1- Introduction:
Scope and work organisation

Introduction: Scope and work organisation

Description

Scope of the project (reminder)

- **Domestic & commercial equipment**
  - **Not** in the scope: industrial applications, mobility, power generation
- **Hydrogen-natural gas blends (H2NG)**
  - **Not** 100% H2 (if provided appliances can cope from 0 to 100%, it can be tested)

The main goal of WP3, for the combustion tests, are

- To **define a detailed test protocol based** / define accurately the details of the testing and to guarantee the best possible reproducibility.
- To **execute short and long term testing** on as many appliance as possible in order to achieve conclusions on sensitivity to H2 by segments of technologies.

Partners in WP3.

- Labs: ENGIE, DGC, GWI, GAS.BE, DVGW-EBI
- Manufacturers: BDR THERMEA, ELECTROLUX

+ « external » Labs

Introduction: Scope and work organisation

Tasks & Timeline

January 2020	From June 2020	From August 2021		Finalised end of 2022
T3.1	**T3.2**	**T3.3**	**T3.4**	**T3.5**
Elaboration of the test protocols (from T2.5) and templates	Testing • Subtask 3.2.1: Short term combustion tests - tests for the evaluation of safety, efficiency, environmental performance (NOx, CO, UHC emissions) • SubTask 3.2.2: Long-term combustion test • SubTask 3.2.3: Leakage tests on indoor installation (long term)	Data compilation and validation • Subtask 3.3.1: Test result and analyse Short term test • SubTask 3.3.2: Test result analyse long term test	Logistic	Management and overall analysis of reporting of test results

Report D3.1, D3.2, D3.3

Report D3.4, D3.5, D3.6, D3.11

work package lead:

Introduction: Scope and work organisation

Evolution in the industry

Since the project was designed, a lot has hapened on H2 front!

CEN TCs starting to work on "H2 ready" certification

"H2 ready" concept discussed in regulation **ErP** (Ecodesign & Labelling)

Manufacturers H2 road maps publication pushed by the "**Primemovers**" initiative

DSO /TSO clearer about of possible H2% in the NG grid (up to 20 to 30%)

	A: NO H2 CERTIFICATION		B: H2 CERTIFICATION (> 2021)		
Type of appliance	A1: Existing technology < 2005	A2: Existing technology > 2005	B1: H2 ready 20%	B2: H2 ready flex (from 20% to 100%) (with a replacement kit)	B3 H2 ready 100%
Tolerance to H2 (Theoretical)	See THyGA	See THyGA	0 - 20 % (boilers) or 25% (other appliances)?	0 - 20 % and 100%	100% (not 0-100%)

RE-ADJUSTING THyGA testing Objectives to give the best value to the industry (focus on 20 to 30% H2)

Introduction: Scope and work organisation

Support of the stakeholders

The role of the Advisory Panel Group members is to advise the project to best achieve its goals of and fulfil expectations around THyGA, it implies a close follow-up of the project and its published results.

- **More than 40 members**: Association, manufacturers, research centers, DSO/TSO, utilities
- **Strong link with CEN Technical Committtees**
- **Network of "External Labs":** Through the many exchanges organized in Y1, the project saw interest of many stakeholders to participate directly by making their own tests with the THyGA protocol → these additional test results are already used in the interim results analysis

For ThyGA partners

- Help to get us as many as possible results over the « 100 appliances target »
- Help improving of the protocol by external labs
- Leads, questions and analysis that can be included in WP4 and WP5 work program

For External labs

- Practice on H2NG through a protocol already discussed with stakeholders by THyGA
- Direct support from the THyGA partners on analysis
- Best knowledge on their own appliances (manufacturers)

For All

- Community of exchanges on the topic, « we all grow together »
- Higher field of expertise available

Introduction: Scope and work organisation

Iterative process to optimize the test protocol

Evolutions in the industry

New Learnings from other projects (ex: GERG)

Analysis from WP2 (combustion theory

Test protocol a

- THyGA WP3 meetings and brainstorming

Test protocol b

- Review of the protocol shared to TCs and Industry
- **Public Workshop (6th of May 2020)**

Test protocol c

- Review in light of the first test results

…

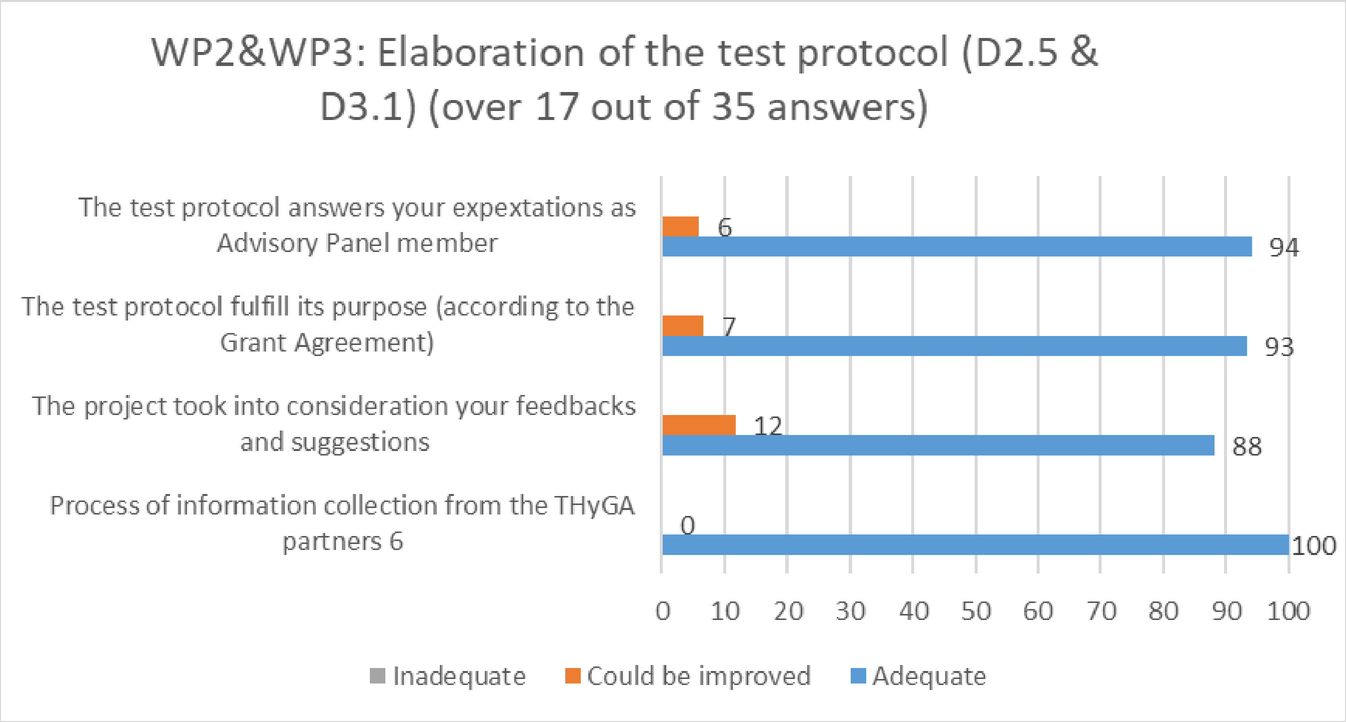
- Communication with **other labs** (not in THyGA) that will perform test
- Communication with manufacturers **before / after testing** (continuous)
- Communication with labs (internal and external) on **specific topics** (ex: unburned CH_4 and unburned H_2 measurement)
- Communication with labs on specific topics when needed (ex: Test of adjustment for boilers

Test protocol g

- Continous adaptation and improvment

Introduction: Scope and work organisation
Feedback from the advisory panel group

- Opinion of the Advisory Panel Group on the WP3 test protocol elaboration (Survey, July 2021)



Introduction: Scope and work organisation

Q/A session

Task 3.1 Elaboration of the test protocols (from T2.5) and templates

T3.1 Elaboration of the test protocols / template (from T2.5)

Objectives

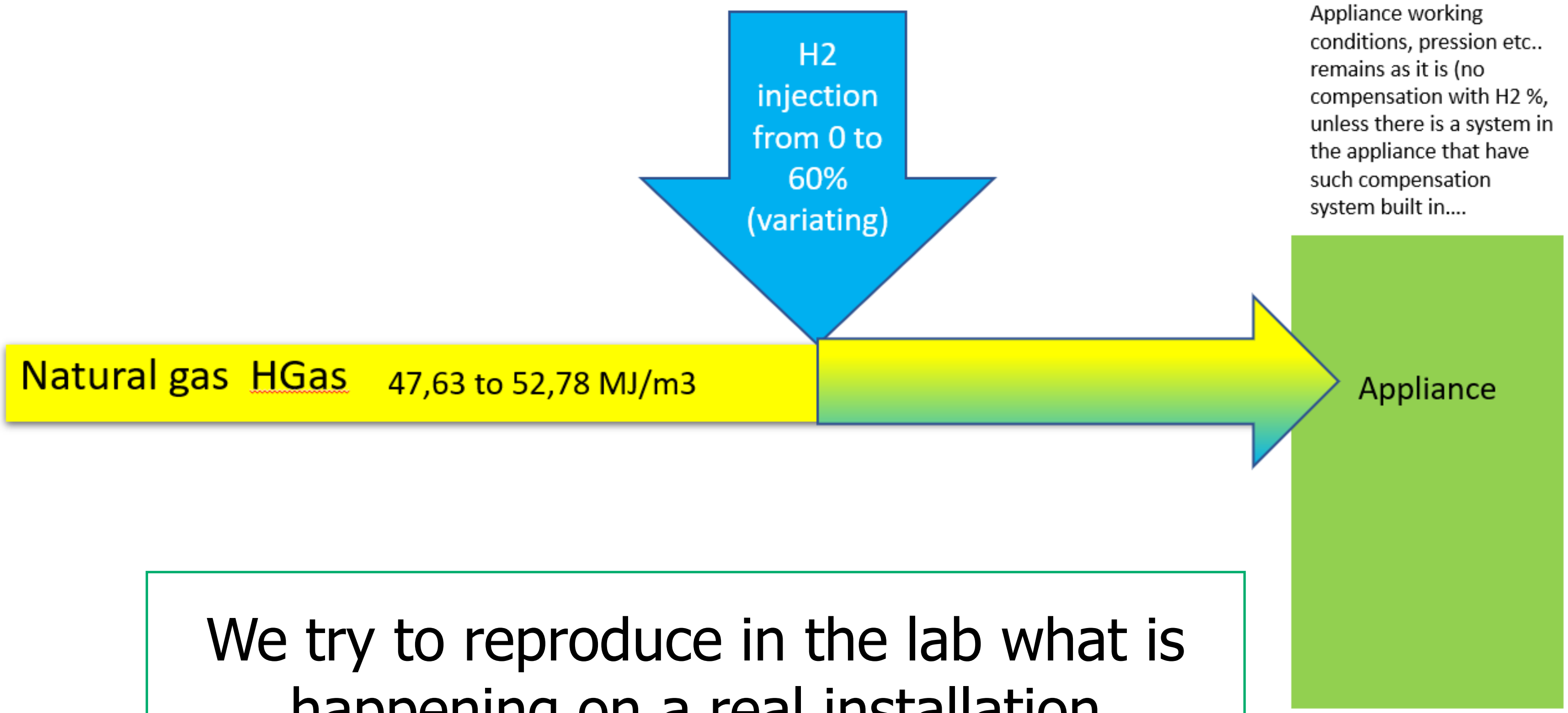
THyGA tests shall bring light on impact of NG/H2 blends on end-use including:

- SAFETY
- EFFICIENCY
- EMISSIONS
- OPERATION

T3.1 Elaboration of the test protocols / template (from T2.5)

Philosophy of the work package tests

OVERALL WORKING CONDITION USED IN THYGA

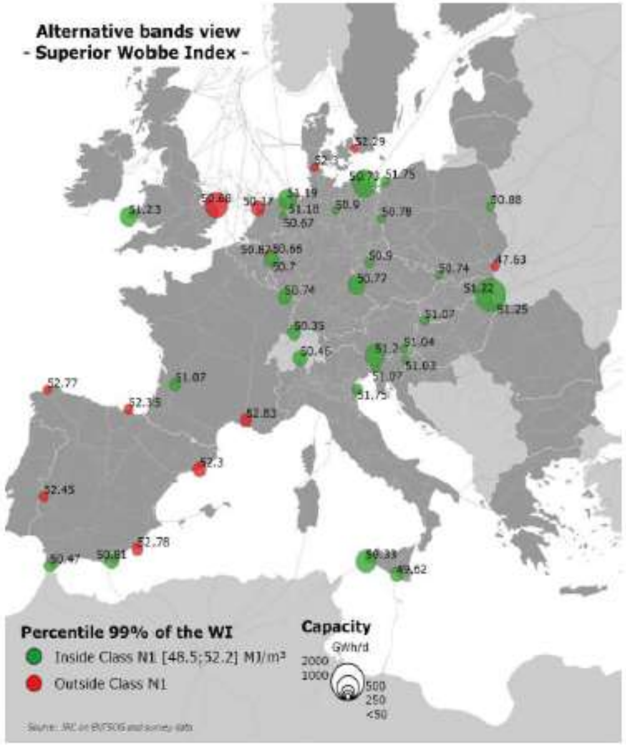


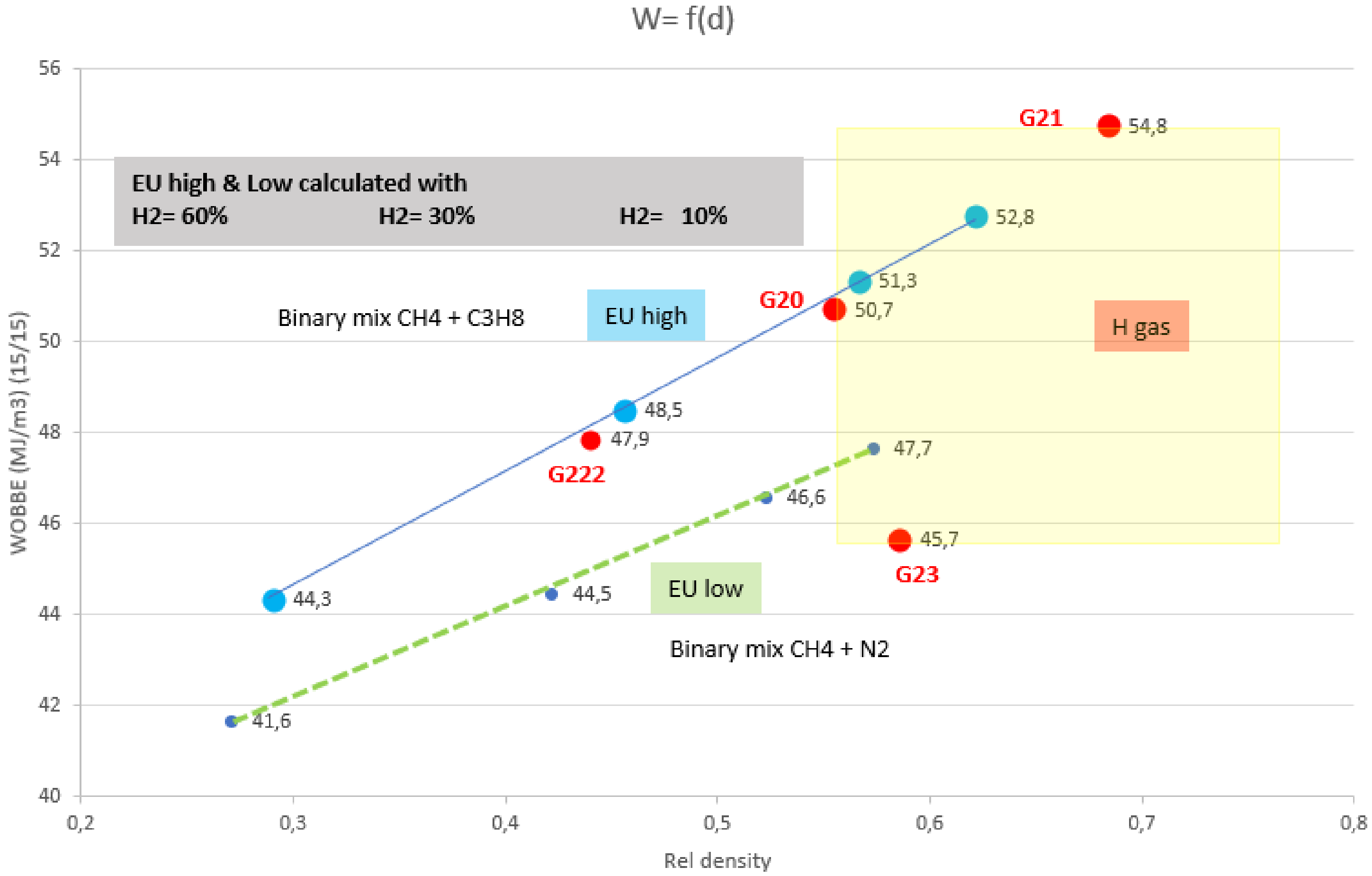
We try to reproduce in the lab what is happening on a real installation

T3.1 Elaboration of the test protocols / template (from T2.5)

Protocol and gases used for tests

100% percentile = 47,63 (EU LOW) à 52,78 (EU HIGH) MJ/m3





T3.1 Elaboration of the test protocols / template (from T2.5)

Protocol content & testing program

Combined TESTs with different H_2 (up to 60%) blends including CH_4, G222, EU-Low and EU-high:

- Safety
- Efficiency
- Emissions
- Operation

Appliances, adjustment tests

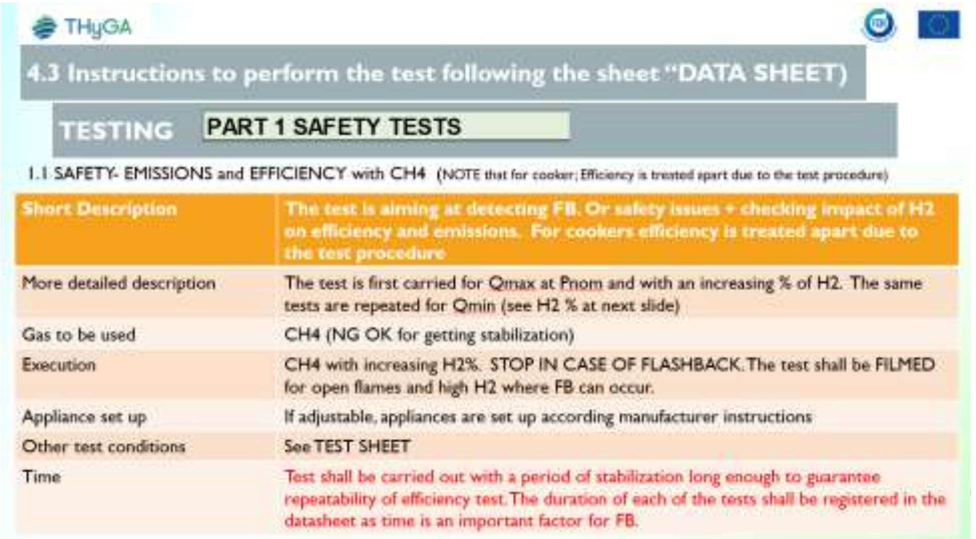
Specific safety and operation test

- Cold start.
- Hot start.
- Low air temperature (- 10 C)
- Flue gas pipe length
- ROC (PLUGG FLOW)
- Impact of H_2 on flame detection.
- Delayed ignition test.
- Soundness
- Quick variation Qmin-Qmax Shut-off
- Overheat. Meas. of temp.
- Cooker hob test with 4 burners on
- Influence of wind
- Long term (limited time)
- Fluctuation of the aux. energy
- Fluctuation of pressure

T3.1 Elaboration of the test protocols / template (from T2.5)

Protocol and testing instruction (examples)

The test protocol is gathering detailed instructions to the labs on how to perform the test in practice.



T3.1 Elaboration of the test protocols / template (from T2.5)

Reporting template's main data sheet

THyGA | Laboratory : DGC | Appliance type : EN 15502 Gas-fired heating boiler

	In discussion
20	Test conditions
	Mandatory
	or cell without lines

SETTING - TEST CONDITIONS. For all appliances unless otherwise specified test are to be peformed in test conditions according the given standards. Eg tamb = 20 +/- 5 C etc.

Dont modify those columns

TEST Nr	Q	Gas Pressure	Fires (F)	Cookers (C)	W heaters	Boilers (B) Tin/Tout	Nominal / Test Gas	H2 (% vol)	Instructions: Time for testing and stabilisation time	Date (Y-M-D)	Time (h:m)	CH4 Vol(-)	C2H6 Vol(-)	C3H8 Vol(-)	C4H10i Vol(-)	C4H10n Vol(-)	C5H12i Vol(-)	C5H12n Vol(-)	C6H14 Vol(-)	N2 Vol(-)	CO2 Vol(-)	O2 Vol(-)	H2 Vol(-)	Ws [MJ/m³]	d (-)	Hi [MJ/m³]	Hs [MJ/m³]	CO2n %	Pgas [mbar]	Tgas [°C]	Qgas gas flow rate (at [m³/h]	Qnet meas. + corr. [kW] (at 0,1013)	Tambient [°C]	Pam [mbar]	rel. Hum [%]	CO2 [%]	O2 [%]	CO [ppm]
1.1 SAFETY- EMISSIONS and EFFICIENCY with CH4 (NOTE that for cooker; Efficiency is treated apart due to the test procedure- see below)																																						
Qmax - GAS CH4 with increasing H2%. STOP IN CASE OF FLASHBACK BEFORE 60% H2										QUANTITATIVE TEST: REPORT SHALL BE BASED ON AVG (DATA FILE) AND NOT INSTANTANEOUS DATA NOTED MANUALLY														Don't change the yellow cells (calculations)														
STABILISATION with Natural gas					Adjust. with CH4 according the man. Instructions		STABILISATION with Natural gas																															
1	Q_{nom}	Pnom = 20mbar	Details in development (made by 1st lab testing)	Test to be done with cooking pan. Test En30 with bigest and smellest burner. Starting with water at 10 C ...	Details in development (made by 1st lab testing)	Tw 40/60C	CH4	0		27-07-2020	15:45	99.8	0	0	0	0	0	0	0	0.2	0	0	0	50.54	0.556	35.819	39.748	11.638	20.28	19.84	2.017	20.06	19.9	1009	10.8	9.07	4.77	64.3
2								10		28-07-2020	10:31	90.8	0	0	0	0	0	0	0	0.2	0	0	9.3	49.40	0.511	33.497	37.243	11.381	20.43	19.44	2.086	19.41	19.5	997	11.8	8.34	5.38	45.3
3								20		28-07-2020	10:41	81.1	0	0	0	0	0	0	0	0.1	0	0	19	48.23	0.465	31.133	34.693	11.075	20.42	19.33	2.182	18.87	19.5	997	12.3	7.82	5.99	38.8
4						Tr = 40C (constant water flow rate for boilers & WH)		23		27-07-2020	16:08	78.4	0	0	0	0	0	0	0	0.1	0	0	21	47.89	0.452	30.443	33.950	10.976	20.21	19.48	2.237	18.92	19.5	1006	10.7	7.75	6.18	28.4
5								30		28-07-2020	08:50	71.6	0	0	0	0	0	0	0	0.1	0	0	28	47.06	0.418	28.739	32.111	10.707	20.35	19.95	2.296	18.33	20.6	996	15.2	7.25	6.59	20
6								40		28-07-2020	10:59	61.5	0	0	0	0	0	0	0	0.1	0	0	38	45.84	0.369	26.211	29.385	10.233	20.38	19.34	2.435	17.73	19.7	997	13.4	6.66	7.26	13.6
7								50		28-07-2020	09:37	51.2	0	0	0	0	0	0	0	0.1	0	0	49	44.62	0.319	23.618	26.589	9.621	20.42	19.81	2.6	17.06	19.5	996	11.7	5.97	7.97	8.58
8								60		14-08-2020	15:21	39.7	0	0	0	0	0	0	0	0	0	0	60	43.47	0.262	20.743	23.489	8.720	20.38	19.69	2.854	16.45	19.8	1007	9.15	5.32	8.38	8.71
Additional test if flash back occurs at H2 = X FB % make a test at X FB -5% (refining the Flashback H2% point) and after increase the H2 again to check the the FB occurs again with the same H2. Check aslo the gas pressure influence																																						
Testing of the gas pressure influence									Short time test to see impact of presure variation	QUALITATIVE TEST: YOU MAY NOTING MANUALLY IN THE TABLE INSTANTANEOUS DATA: FOCUS ON POSSIBLE INCREASE OF CO, air excess change and or combu																												
9	Q_{nom}	Pnom	Test with 40% H2 at Pnom (20 mbars), Pmax (25 mbars), Pmin2 (14 mbars) if possible, Pmin1 (17 mbars) (only PB with if Pmin2) and Visual observation of the change with pressure variation			Tr = 40C	CH4	40%		14-08-2020	15:21	40	0	0	0	0	0	0	0	0	0	0	60	43.47	0.262	20.737	23.481	8.718	0	0	0	0.00	0	0	0	0	0	0
10		Pmax				Tr = 40C	CH4			14-08-2020	16:18	40	0	0	0	0	0	0	0	0	0	0	60	43.46	0.262	20.714	23.457	8.709	0	0	0	0.00	0	0	0	0	0	0
11		Pmin1				Tr = 40C	CH4			14-08-2020	16:31	40	0	0	0	0	0	0	0	0	0	0	60	43.47	0.262	20.733	23.478	8.717	0	0	0	0.00	0	0	0	0	0	0
12		Pmin2				Tr = 40C	CH4			14-08-2020	16:50	40	0	0	0	0	0	0	0	0	0	0	60	43.48	0.263	20.759	23.508	8.726	0	0	0	0.00	0	0	0	0	0	0
Qmin - GAS CH4 with increasing H2%. STOP IN CASE OF FLASHBACK BEFORE 60% H2										QUANTITATIVE TEST: REPORT SHALL BE BASED ON AVG (DATA FILE) AND NOT INSTANTANEOUS DATA NOTED MANUALLY																												
STABILISATION with Natural gas					Adjust. with CH4 according the man. Instructions																																	
13	Q_{min}	Pnom	Details in development (made by 1st lab testing)	Test to be done with cooking pan. Qmin adjusted according the standards	Details in development (made by 1st lab testing)	40/60C	CH4	0		29-07-2020	11:27	100	0	0	0	0	0	0	0	0.2	0	0	0	50.54	0.556	35.820	39.749	11.638	19.88	19.42	0.437	4.35	20.1	1004	8.86	8.11	6.42	0.53
14								10		29-07-2020	15:34	90	0	0	0	0	0	0	0	0.2	0	0	10	49.31	0.507	33.312	37.044	11.359	19.8	19.49	0.459	4.25	20.4	1005	9.5	7.8	7.05	0.53
15								20		29-07-2020	16:04	80	0	0	0	0	0	0	0	0.1	0	0	20	48.14	0.461	30.932	34.477	11.047	19.78	20.03	0.477	4.19	20.9	1005	9.82	7.07	7.67	0.13
16								23		29-07-2020	12:29	77	0	0	0	0	0	0	0	0.1	0	0	22	47.77	0.447	30.192	33.679	10.938	19.83	19.79	0.486	4.08	19.3	1004	7.67	6.91	7.86	0.78
17						Tr = 40C (constant water flow rate for boilers & WH)		30		29-07-2020	13:30	70	0	0	0	0	0	0	0	0.1	0	0	29	46.92	0.413	28.458	31.810	10.659	19.77	19.65	0.502	3.97	20.8	1004	9.34	6.54	8.29	0.44
18								40		29-07-2020	16:42	62	0	0	0	0	0	0	0	0.1	0	0	38	45.91	0.372	26.371	29.558	10.266	19.84	19.77	0.526	3.85	19.2	1005	9.58	6.08	8.79	0.2
19								50		29-07-2020	14:31	52	0	0	0	0	0	0	0	0.1	0	0	48	44.75	0.323	23.842	26.830	9.686	19.74	19.89	0.583	3.73	19.3	1004	8.83	5.46	9.38	0.1
20								60		14-08-2020	12:06	41	0	0	0	0	0	0	0	0	0	0	59	43.57	0.267	20.988	23.752	8.808	19.89	20	0.618	3.68	20	1008	6.34	4.99	9.24	0.72

More columns

More lines

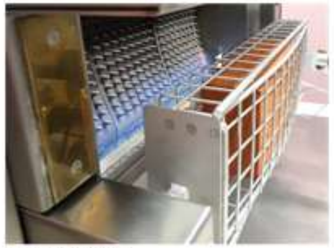
T3.1 Elaboration of the test protocols / template (from T2.5)

Appliances included in the test programme (from WP2)

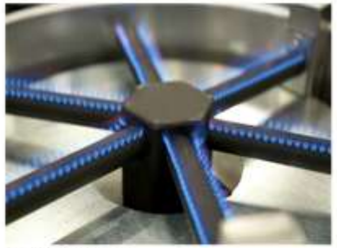
Source: GoGaS

Source: electrolux

Source: wellstraler



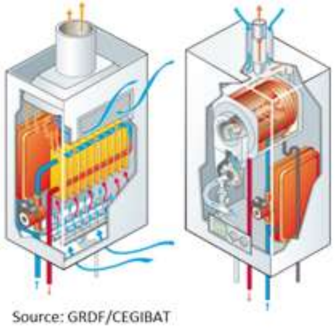
Source: SOFINOR



Source: Krampouz

Source: kalfire

Source: Brulers AEM



Source: GRDF/CEGIBAT

Table 2-2 : Market Segmentation of gas fired appliances. The overview table shows the appliance population of each market segment in EU, 2020. Unknown: no accurate data available.

BOILERS · **WATER HEATERS** · **COOKERS** · **CATERING** · **SPACE HEATERS** · **CHP** · **GHP** · **OTHER (mainly Commercial)**

THyGA Segment	Type of appliance	Category	Burner type	Standard	Estimation of Total EU Appliance Population 2020 (x 1,000)
101	BOILERS	open flued (former EN 297)	partial pre-mix/conv. (atmos. & fan-assisted)	EN 15502	13,588
102			low NO_x		2,012
103			full pre-mix		152
104		room sealed [illegible]	partial pre-mix/conv. (atmos. & fanned)		25,333
105			low NO_x		1,972
106			full pre-mix		1,781
107		condensing boiler (former EN 677)	partial pre-mix fan-assisted		2,920
108			full pre-mix (including CCB)		56,492
109		Forced draught burners / jet burners (former EN 303-3)	Forced-draught / jet		1,129
201	WATER HEATERS	instantaneous open flued	partial pre-mix/atmos.	EN 26	14,945
202		instantaneous room sealed	partial pre-mix/fanned		
203		[illegible]	[illegible]	[illegible]	3,121
204		storage, room sealed	partial pre-mix/fan-assisted		
301	COOKERS	surface burner (cooktops) with atmospheric burner or "Venturi" burner (vertical venturi burner)	single ring	EN 30-x	32,574
302			single crown		
303			multi ring (mainly double or triple ring)		
304		surface burner (cooktops) with partially pre-mix burner (long horizontal venturi)	single ring		1,352
305			single crown		
306			multi ring (mainly double or triple ring)		
307		[illegible] freestanding ranges)	atmospheric burner		3,853
308			"venturi" burner		
309			partially pre-mix		27,712
310		cavity burner "metal sheet" (ovens, freestanding ranges)	atmospheric burner		13,056
311			"venturi" burner		
312			partially pre-mix		14,658
401	CATERING	open burners and wok burners	circular burner with vertical slots	EN 203-2-1	unknown
402			circular burner with holes		
403		mixed ovens	draught burners	EN 203-2-2	unknown
404		ovens	tubular or circular burners		
405		boiling pans / pasta cookers	micro-perforated burner	EN 203-2-3 EN 203-2-11	unknown
406		[illegible]	[illegible] burner	EN 203-2-4	unknown
407		salamanders / rotisseries	[illegible] or blue flame burners	EN 203-2-7	unknown
408		brat pans	multi-ramp tubular slot burners	EN 203-2-8	unknown
409		covered burners (griddles, solid tops, pancake cookers)	tubular burner or multi-ramp tubular burner	EN 203-2-9	unknown
410		barbecues	chargrill with burner tubes w/ holes on top	EN 203-2-10	unknown
501	SPACE HEATERS	Independent gas fired convection heaters type B	heating & decoration	EN 613	4,678
502		[illegible]	[illegible]	[illegible]	[illegible]
503		Decorative [illegible] gas appliance/burner	heating & decoration	EN 13278 + EN 509	2,529
504		Independent gas fired flueless space heaters	heating & decoration	EN 14829	98
601	CHP	Stirling engines	heating & electricity production	EN 50465	14.8
602		[illegible] combustion engine			40.8
603		Micro gas turbine			0.5
604		PEM Fuel Cell			5
605		SO Fuel Cell			2.7
701	GHP	engine HP	Heating	EN 16905	60
702		[illegible]		EN 12309	
703		absorption			
801	OTHER	commercial dryers		EN 12752-1 and -2	unknown
802		infrared radiant heaters (former EN 416-1)	non-domestic, tube radiant heaters	EN 416	1,000
803		infrared radiant heaters (former EN 419-1)	non-domestic, luminous radiant heaters	EN 419	
804		[illegible]	[illegible]	EN 416	
805		air heaters (former EN 1020)	non-domestic, forced convection, [illegible] <300kW	EN 17082	1,000
806		[illegible] (former EN 525)	[illegible] forced convection, [illegible]	EN 17082	
807		air heaters <70kW (former EN778)	Ducted warm air; forced convection air heaters	EN 17082	
808		domestic washing machines		EN 1518	< 10
809		domestic dryers		EN 1518	< 10
				sum	approx. 228,000

T3.1 Elaboration of the test protocols / template (from T2.5)

Appliances included in the test programme (from WP2)

Supposed Sensitivity to H2 (1 low (premix), 2medium (partial premix); 3 high (atm. + no info on burner)	**Can be adjusted** (1) or not (0) (1 will double the sensitivity). (actual situation for GASQUAL TEST only 2 segments could be adjusted!)	**Diversity of technologies and materials**	**Existing experience** Reduction factor due to (useful) tests from previous projects	Market Orientation Factor **2030**	Estimation of Total EU Appliance Population 2020 (in .000)	PRIORITY FACTOR	%	**Number of appliances to test following market segmentation**	**rounded results**
2	0	0.5	1	0.5	13,588	6794	2%	0.84	1
2	0	0.3	1	0.3	2,012	362	0%	0.04	1
1	1	0.5	1	0.5	152	76	0%	0.01	1
2							3%	1.56	2
2							0%	0.07	1
1							1%	0.31	1
2							3%	1.44	2
1							23%	11.68	12
1							0%	0.14	1
2	0	0.5	1	0.3	43,242	12973	3%	1.6	2
2	0	0.5	1	0.6	38,796	23278	6%	2.86	3
2	0	0.5	1	0.3	5,397	1619	0%	0.2	1
2	0	0.5	1	0.6	2,292	1375	0%	0.17	1

Combining market data with other parameters to calculate the number of appliances to be tested by segments

T3.1 Elaboration of the test protocols / template (from T2.5)

Q/A session

3- Test results

3.1 Flashback
3.2 Adjustments
3.3 Adjustments of appliances equipped with combustion controls
3.4 Ionization current
3.5 Efficiency and Emissions
3.6 Heat output
3.7 Other results

Subtask 3.2.1: Short term combustion tests

Objective and content of the tests

Objective: understand how appliances react in the short term (few minutes to few hours) on different H2NG blends. The evaluation covers safety, energy efficiency, emissions, operational aspects

- Parameters to measure are:
  - ✓ **Combustion/emissions**
  - ✓ **Efficiency**
  - ✓ **Safety**
  - ✓ **Operational aspects (Normal operation of the appliances or not)**
- Parameters to vary are:
  - ✓ H2 % according the levels indicated in the call (in addition, 100% H2 will also be tested when possible, for a short time.)
  - ✓ H2 Rate of change (ROC)
  - ✓ Natural gas composition
  - ✓ Addition of H2 with constant pressure and with increased pressure (when possible) to keep the heat input constant
  - ✓ Pressure
  - ✓ Adjustment or not. (Appliances adjusted to NG in the highest range of the H gas range are expected to be more sensitive to hydrogen compared to appliances adjusted in the lowest range)

Subtask 3.2.1: Short term combustion tests

Interim test results: Analysis based on about 20 appliance tested

Report	SEGMENT Nr		Appliance category	Appliance type (2)	Burner type	For cooker hobs: burner tested?	Modulating burner (Y/N)	Pressure regulator (Y/N)	Can the appliance be adjusted (Y/N)	Combustion control (Y/N)	Max. power input (net) [kW]	Min. power input (net) [kW]
GA1_SEGM_	101		Boiler		Atmospheric		Y	Y	N	N	25.8	11.0
GW2_SEGM_	102		Boiler		Low Nox		Y	Y	Y	N	22.2	8.9
GW03_SEGM	103		Boiler		Atmospheric		N	Y	Y	N	17.0	
BA01_SEGM	107		Boiler		Low NOx		Y	Y	Y	Y	24.8	10.6
D4_SEGM_1	108		Boiler		Premix		Y	Y	Y	Y	20.0	4.8
GW1_SEGM_	108		Boiler		Premix		Y	Y	N	Y	24.0	6.9
GA5_SEGM_	201		Water heater		Atmosperhic		N	N	N	N	10.5	5.3
GA5_SEGM_	201		Water heater		Atmosperhic		N	N	N	N	10.5	5.3
D1_SEGM_3	301		Cooking Hob		Atmospheric (*)	Large	N	N	N	N	3.0	0.8
D2_SEGM_3	301		Cooking Hob		Atmospheric (*)	Small	N	N	N	N	1.0	0.5
D3_SEGM_3	301		Oven			Oven	N	N	N	N	2.5	1.0
D7_SEGM_3	301		Cooking Hob		Atmospheric	Large	N	N	N	N	2.7	0.7
D8_SEGM_3	301		Cooking Hob		Atmospheric	Small	N	N	N	N	0.9	0.3
D9_SEGM_3	311		Oven		Cavity burner	Oven	N	N	N	N	2.4	0.8
D10_SEGM_	311		Oven	Grill	Cavity burner	Oven	N	N	N	N	1.7	
GA4_SEGM_	406		Catering	Fryer	Premix		Y	Y	Y	Y	31.0	16.0
GA3_SEGM_	407		Catering (O)	Gas grill	Atmospheric		N	N	N	N	5.9	
GA2_SEGM_	503		Fire - Convection heater		Atmospheric		Y	Y	N	N	5.8	3.1

(*) Atmospheric Partially Aerated Single Ring burner" (hob)

Subtask 3.2.1: Short term combustion tests

Interim test results: Overview of the main results (for most domestic appliances)

When **replacing natural gas by H2** without changing the air quantity, **the air excess will increase** (as less air will be needed for the combustion)

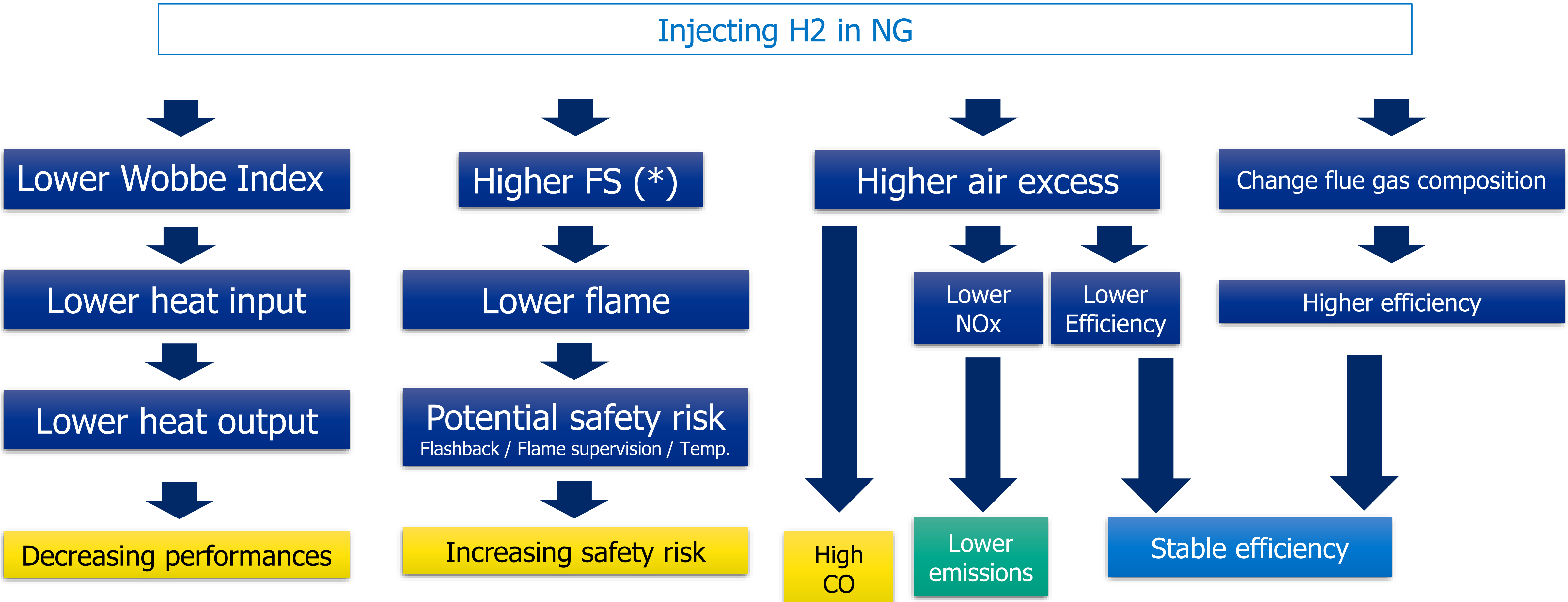
In general, the increase of air excess will:

- **Impact the flame velocity** (it will increase for atmospheric burners and be stable or slightly decreasing for premix burners)
- Impact the **flame temperature (decrease)** and then **NOx emissions (decrease)**
- **Increase the relative flue gas losses**

  For condensing boilers, the additional loss due to more flue gas loss may be compensated by larger amount of latent heat recovered (condensation).

Subtask 3.2.1: Short term combustion tests

Interim test results: Overall impact (for most domestic appliances)



(*) flame speed

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Subtask 3.2.1: Short term combustion tests

Interim test results: Overview of the main results

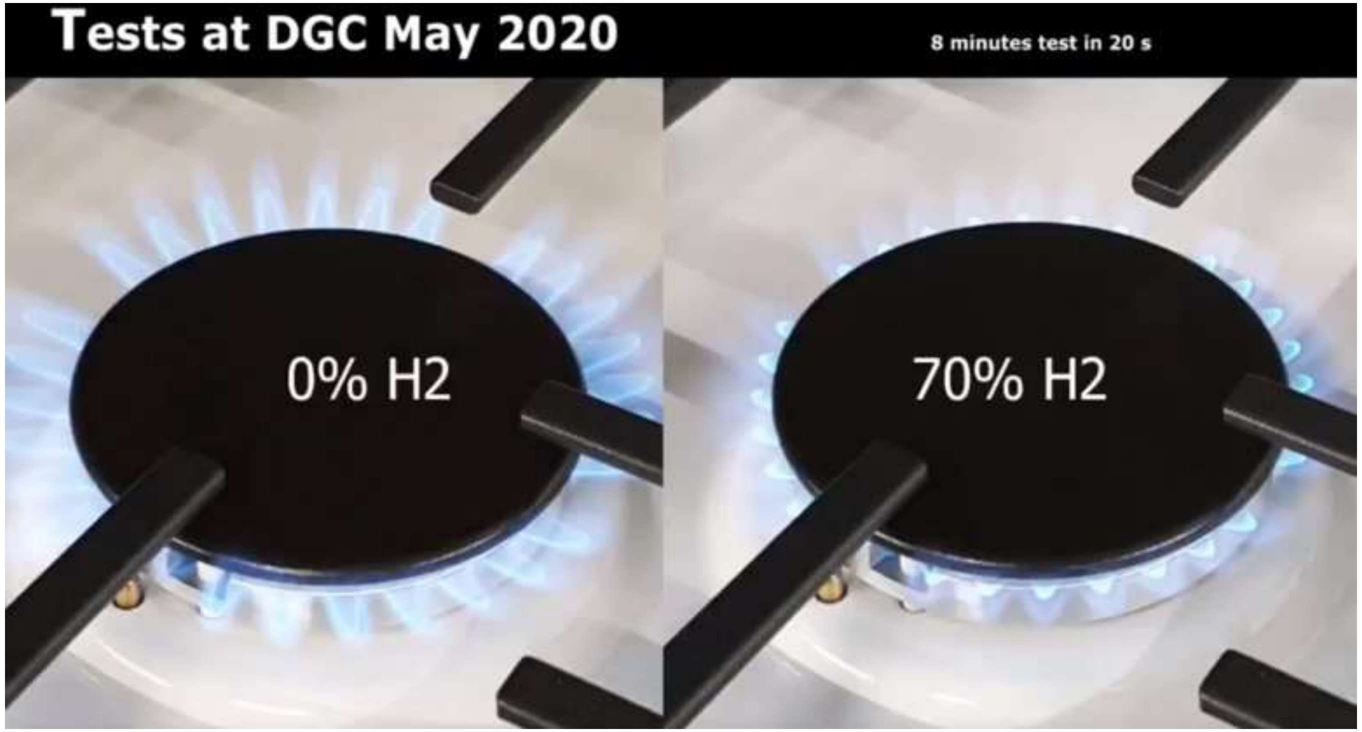
Globally

- The **atmospheric technologies tested so far have been able to cope with 30% of H2**.
- The main issues above 30% with **atmospheric burners like cooking hobs** is the **flashback** and **high temperature** due to a lower flame size. This was also expected as it is in phase with literature and theory.
- **The principal reason for issues for the premix appliances is the adjustment.** If we consider that this can be solved (eg. making adjustment by third party impossible), most appliances will have no problem anymore and can burn up gas with at least 40% H2.

APPLIANCE						H2 % Tested							
						At what level the problem may occur							
Code	Appliance	Burner	Origin	Segment	Qmax	0	10	20	23	30	40	50	60
PREMIX BURNERS													
GA04	Catering	Premix	New de	406	31								
GW02	B	Low NO	old/ use	102	22.2								
GW01	B	full prem	old use	108	24								
BA01	B	Low NO	New ap	107	24.8							X	X
D4	B	Premix	Sent by	108	20							x	X
D5	Boiler	Premix	Sent by	108	20.8							X	X
ATM BURNERS													
D3	EN30 free	atmosp	Bought	301	2.5	X				X	X		X
D2c	EN30 free	atmosp	Bought	301	1	X							X
D1	EN30 free	atmosp	Bought	301	3	X						X	
D7	CH	Surf. at	sent by	301	2.703	X	x		x		x		
D8	CH	Surf. at	sent by	301	0.901	X			x		x		
D9	C Oven	Cavity	sent by	311	2.432	X			x		x		
D10	C Oven	Cavity	sent by	311	1.712	X					x		
GA03	Catering (	Atmos	New ap	407	5.9	X					X		
GA05	WH	Atmos	Already	201	10.5	X			X		X		
GA02	EN613 Co	Atmos	Already	503	5.8	X			X		X	X	X
GA01	B	Atmos	Already	101	25.8	X			X		X	X	
GW03	B	atmosp	old/use	103	17	X	X	X	X	X	X	X	X

Subtask 3.2.1: Short term combustion tests

Interim test results: Overview of the main results



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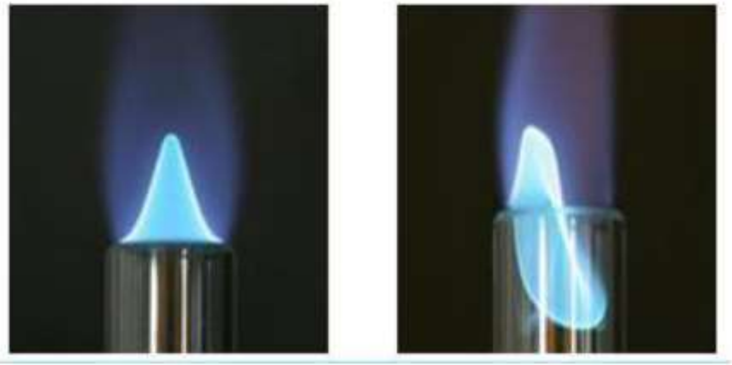
Subtask 3.2.1: Short term combustion tests

Interim test results: no Q/A session

Deep dive in the results in the next slides !

3.1 Flashback



Picture THyGA application 2019

WP3 - Experimental Work

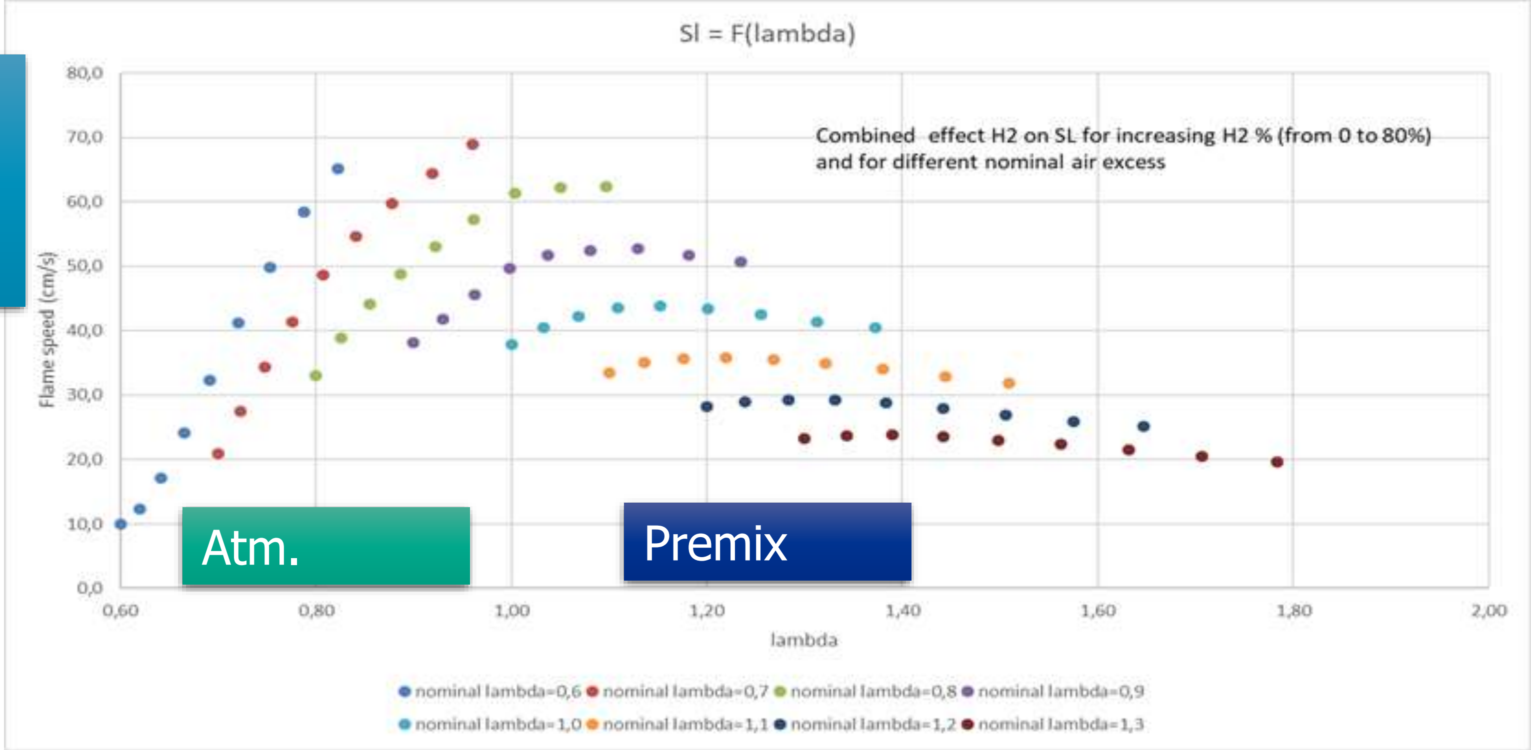
Progresses, status and achievements: *Task 3.3 Data compilation and validation*

Subtask 3.3.1: Test result and analyse Short term test   Intermediate results

Air excess is increasing with the addition of H2 for most of appliances

But flame speed will only increase with H2 when initial lambda < 1.2 (= mostly atm. burners)

Flash back is therefore more expected for atm. appliances

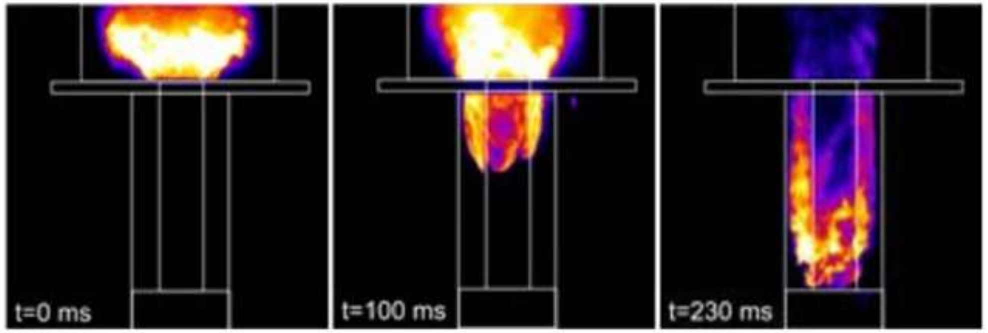


Subtask 3.2.1: Short term combustion tests

Flashback: Results

Flashback or partial flashback was observed on 5 appliances, 4 of them being atmospheric appliances.

- Partial flashback for a full premix boiler (BA01) was observed at 60% H2 (but not at 50%).
- For the atmospheric appliances, signs of partial flashback (e.g., increasing of combustion noise) was observed from 40%H2. Flashback was generally observed above 40%H2 (40, 50, 60% tests).



Source : University of Michigan at the 2014 University Turbine Systems Research Workshop

The flashback occurrence may sometimes be difficult to identify for appliances where the burner is not visible (typically for premix appliances).

Consequently, there may have been some partial flashback in some case, that we are not aware of.

Subtask 3.2.1: Short term combustion tests

Flashback: impact of time

FB may appear after long operation time!

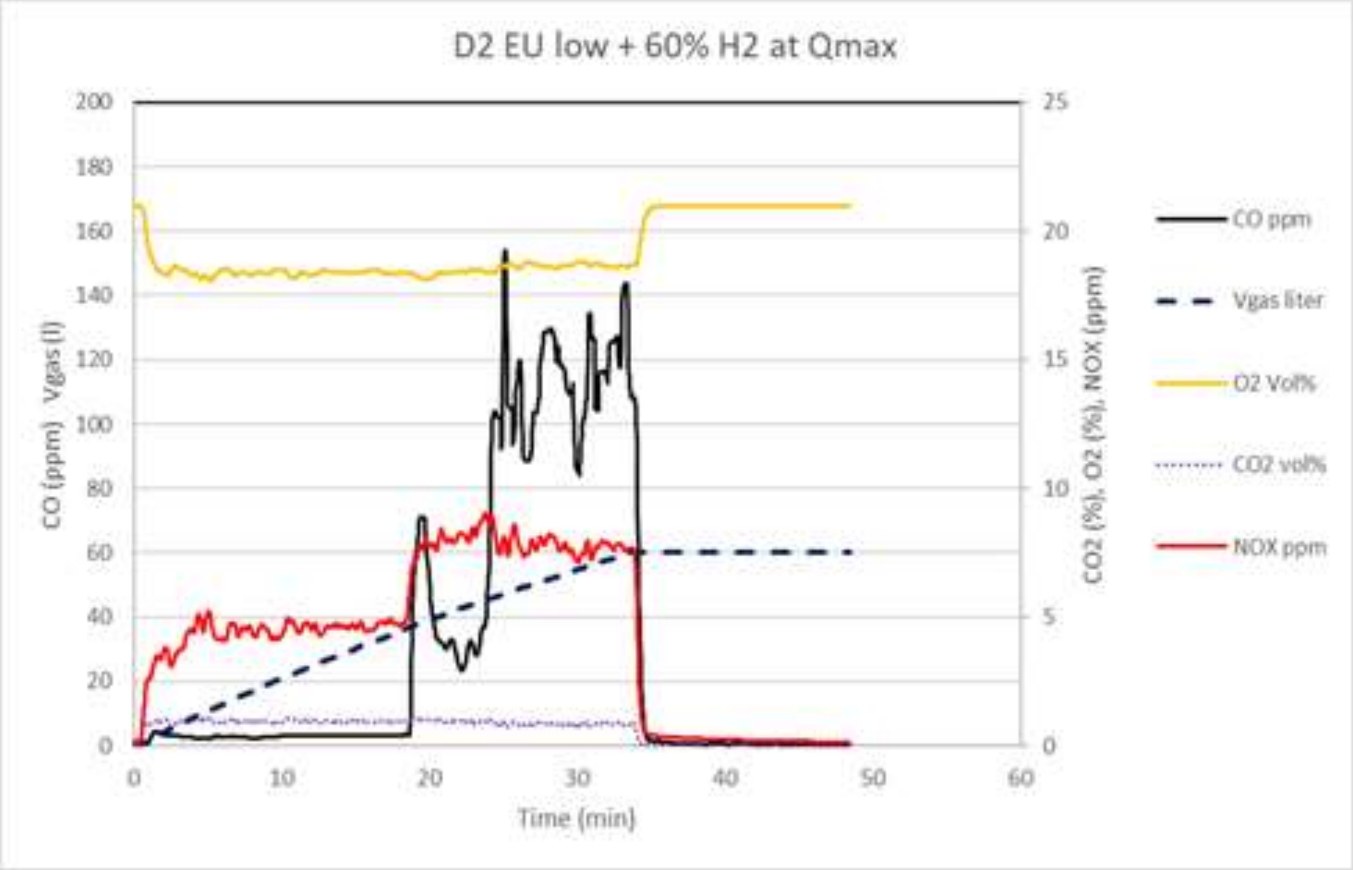
Test showing FB under following test conditions, Qmax, Pnom, CH4 = 40% H2 = 60%

Picture burner after Flash back. The small burner (tested here) is comapred to a large one (not tested). Change in color is noticable, but there is also a deformation of the burner

Present procedure from standards for flash back is not adapted to H2.
→ THyGA has updated own procedure
→ THyGA results are already shared with CEN

Subtask 3.2.1: Short term combustion tests

Flashback: can be accompanied by an **increase in CO**



Subtask 3.2.1: Short term combustion tests

Flashback: Q/A session

3.2 Adjustments

Adjustment of air excess during maintenance or commissioning.

Done on Premix burners appliances = Condensing boilers + some catering equipment + other

Subtask 3.2.1: Short term combustion tests

Adjustments: Example of manufacturer instruction

Adjustment on CO2

TABELLE 1: Ventilator-Drehzahlparameter und CO_2-Werte (%)

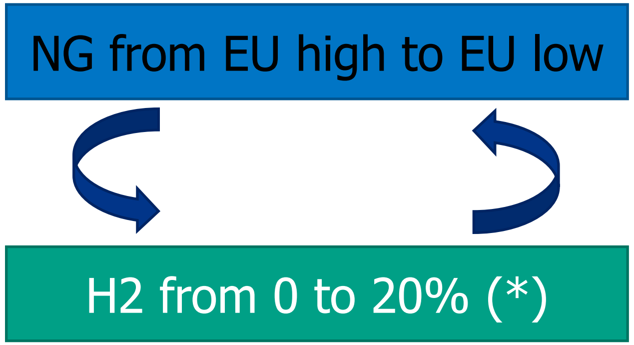
	PARAMETER - Drehzahl [U/min]							Vorderer Gehäusedeckel geschlossen		
	Prime 1.24	Prime 1.24	Prime 26	Prime 30	Prime 26	Prime 30	P min	CO2% Nenn und Toleranzen		CO max
	DP003*	GP007*	DP003*	DP003*	GP007*	GP007*	GP008*			
	28kW	*24kW*	*26kW*	*30kW*	*20kW*	*24kW*	*4,8kW*	*Pn Max*	*P min*	*ppm*
G20	8300	7300	7800	9150	6200	7300	2200	9,0% (8,8÷9,4)	8,5% (8,1÷8,6)	<250
G30	7700	6800	7500	8700	5800	6800	2200	10,4% (10,2÷10,8)	9,8% (9,2÷9,8)	<250
G31	7700	6800	7500	8700	5800	6800	2200	10,3% (10,2÷10,8)	9,7% (9,2÷9,8)	<250

* Parameter für Drehzahländerung

Boiler D4 instruction manual

Subtask 3.2.1: Short term combustion tests

Adjustments: THyGA scenarios



(*) During adjustment and 0 to 20% or more after

For test **A**:

- appliances are adjusted with **EU high**
- and tested with **EU low, and EU low + H2** (10%, 30%, 60%)

For test **B**:

- appliances are adjusted with **EU low**
- and tested with **EU high, and EU high+ H2** (10%, 30%, 60%)

CASE	EU low + 0 to 60% H2	EU low	CH4	EU high + 0 to 60% H2	EU high
A	Used				Adjusted
B		Adjusted		Used	

For test **G**:

- appliances are adjusted with **EU low + 20%H2**
- and tested with **EU high, and EU high + H2** (10%, 30%, 60%)

For test **H**:

- appliances are adjusted with **EU high + 20% H2**
- and tested with **EU low, and EU low + H2** (10%, 30%, 60%)

CASE	EU low + 20% H2	EU low +0 to 60% H2	CH4	EU high + 20% H2	EU high + 0 to 60% H2
G	Adjusted				Used
H		Used		Adjusted	

Subtask 3.2.1: Short term combustion tests

Adjustments: Illustration with the test of D4 Boiler (1/3)

INITIAL VALUES ADJUSTED ACCORDING THE MANUAL

3.1 ADJUSTMENT A (mostly to see FB & CO).

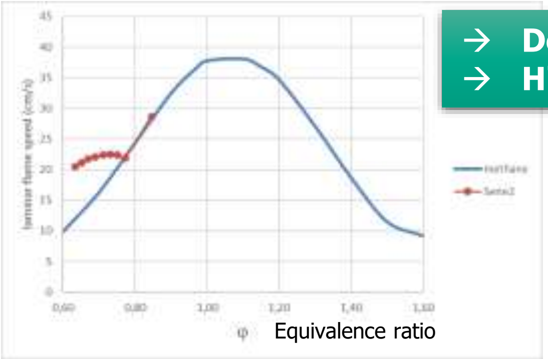
Qmax - GAS set to EU high and used with EU low with increasing H2%.								LY IN THE TABLE INSTANTANEOUS DATA: FOCUS ON POSSIBLE: high CO, abnormal operation, etc... NOTING OBSERVATIONS AR													
STABILISATION AFTER ADJUSTMENT CH4 (at Qmax and Q min)								nances is required													
84	Qmax		NR	NR	NR	EU high	0	52.52	0.620	39.437	43.623	11.941	0.00	20.6	1016.7	20.6	9.0	5.2	56.6	17.9	7.9
85			NR	NR	NR	EU low	0	48.66	0.577	35.143	38.981	11.679	0.00	20.7	1016.7	20.7	7.8	6.8	19.3	6.8	4.6
86			NR	NR	NR	EU low	10	46.58	0.526	32.050	35.639	11.363	0.00	20.4	1016.6	20.4	7.3	7.4	14.2	5.2	3.9
87			NR	NR	NR	EU low	30	44.48	0.428	27.447	30.684	10.635	0.00	20.2	1016.6	20.2	6.4	8.4	7.4	3.3	3.0
88			NR	NR	NR	EU low	60	41.57	0.271	20.131	22.808	8.631	0.00	20.1	1016.5	20.1	4.5	10.1	3.7	1.9	1.8
Additional test if flash back occurs at H2 = X FB % make a test between the two last points																					
89	Q_{max}	Pnom	NR	NR	NR	EU low	X1	#######	0.000	0.000	0.000	#####	##########								
90			NR	NR	NR	EU low	X2	#######	0.000	0.000	0.000	#####	##########								
Qmin - GAS set to EU high and used with EU low with increasing H2%.																					
STABILISATION AFTER ADJUSTMENT CH4 (at Qmax and Q min)								nances is required													
91	Qmin		NR	NR	NR	EU high	0	52.76	0.621	39.667	43.873	11.950	0.00	21.1	1017.0	21.1	8.4	6.1	1.7	8.5	3.4
92			NR	NR	NR	EU low	0	47.88	0.574	34.485	38.264	11.646	0.00	20.3	1017.0	20.3	7.4	7.5	1.6	4.5	2.3
93			NR	NR	NR	EU low	10	46.57	0.525	32.028	35.616	11.360	0.00	19.9	1017.0	19.9	7.0	8.1	1.4	3.2	1.7
94			NR	NR	NR	EU low	30	44.46	0.427	27.416	30.650	10.630	0.00	19.7	1016.9	19.7	6.0	9.2	1.1	2.0	1.2
95			NR	NR	NR	EU low	60	41.55	0.270	20.087	22.761	8.613	0.00	19.8	1016.9	19.8	4.4	10.6	0.8	1.2	0.9
Additional test if flash back occurs at H2 = X FB % make a test between the two last points																					
96	Q_{min}	Pnom	NR	NR	NR	EU low	X1	#VÆRDI!	#####	#####	#####	#####	#VÆRDI!								
97			NR	NR	NR	EU low	X2	#VÆRDI!	#####	#####	#####	#####	#VÆRDI!								

Subtask 3.2.1: Short term combustion tests

Adjustments: Illustration with the test of D4 Boiler (2/3)

For test **A**:

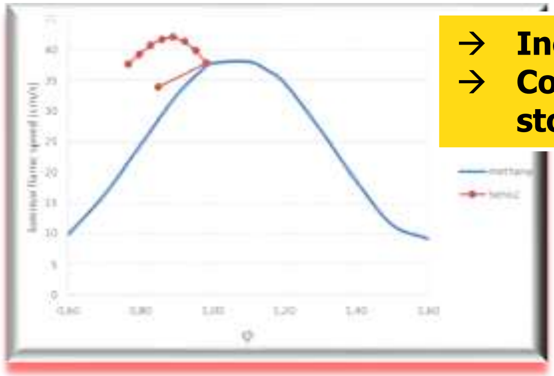
- appliances are adjusted with **EU high**
- and tested with **EU low + H2**



→ **Decrease of SL**
→ **Higher air excess**

For test **G**:

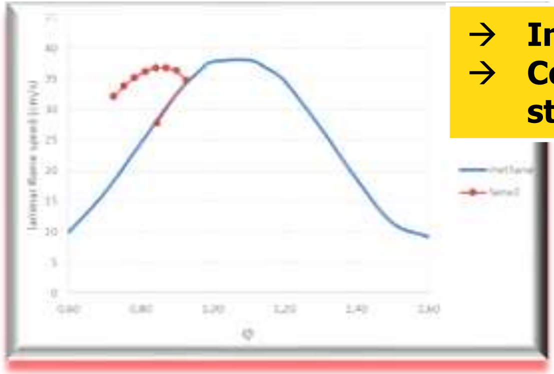
- appliances are adjusted with **EU low + 20%H2**
- and tested with **EU high + H2**



→ **Increase of SL**
→ **Combustion closer to stoichiometry**

For test **B**:

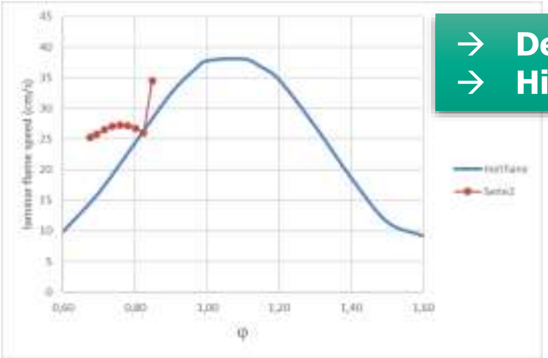
- appliances are adjusted with **EU low**
- and tested with **EU high+ H2**



→ **Increase of SL**
→ **Combustion closer to stoichiometry**

For test **H**:

- appliances are adjusted with **EU high + 20% H2**
- and tested with **EU low + H2**



→ **Decrease of SL**
→ **Higher air excess**

Subtask 3.2.1: Short term combustion tests

Adjustments: Illustration with the test of D4 Boiler (3/3)

What we see from the first tests

- Adjustment G is the most problematic: high CO
- A,B,H are showing only positive H_2 impact

New options for testing:

- 10% and 30% H_2 instead of 20%
- Adjustment with O_2 instead of CO_2

Subtask 3.2.1: Short term combustion tests

Adjustments: Conclusions so far (1/2)

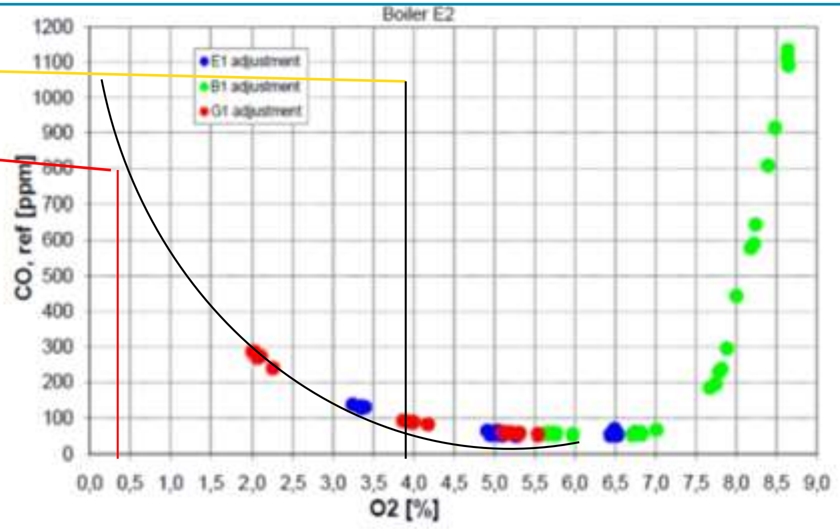
Most critical situation = Appliance set with gas with low Wobbe including H2 and used suddenly with high Wobbe gas (bringing combustion close to stoichiometry)

Appliance adjusted for CO_2 = 9%

	Tair	Patm	Tamb	CO2	O2	CO	NOx	NO2
Low Wobbe + H2	20.5	1017.5	20.5	9.0	3.8	111.3	40.8	14.2
High Wobbe	20.5	1017.4	20.5	11.6	0.4	1024.9	135.2	22.6

Very high CO

Typical CO evolution with air excess (GASQUAL)



Potential consequence on the market:

- Installers need to be able to assess the % of H2 in the grid during installation and maintenance.
- Or adjustment shall be banned

Subtask 3.2.1: Short term combustion tests

Adjustments: Conclusions so far (2/2)

Worst case scenario: gas quality may change suddenly after the adjustment

Biomethane

Or a NG in the lowest range of Wobbe

↓

Injection 20% H2

↓

Adjustment CH4 – G20

↓

Nord see gas or heavy LNG

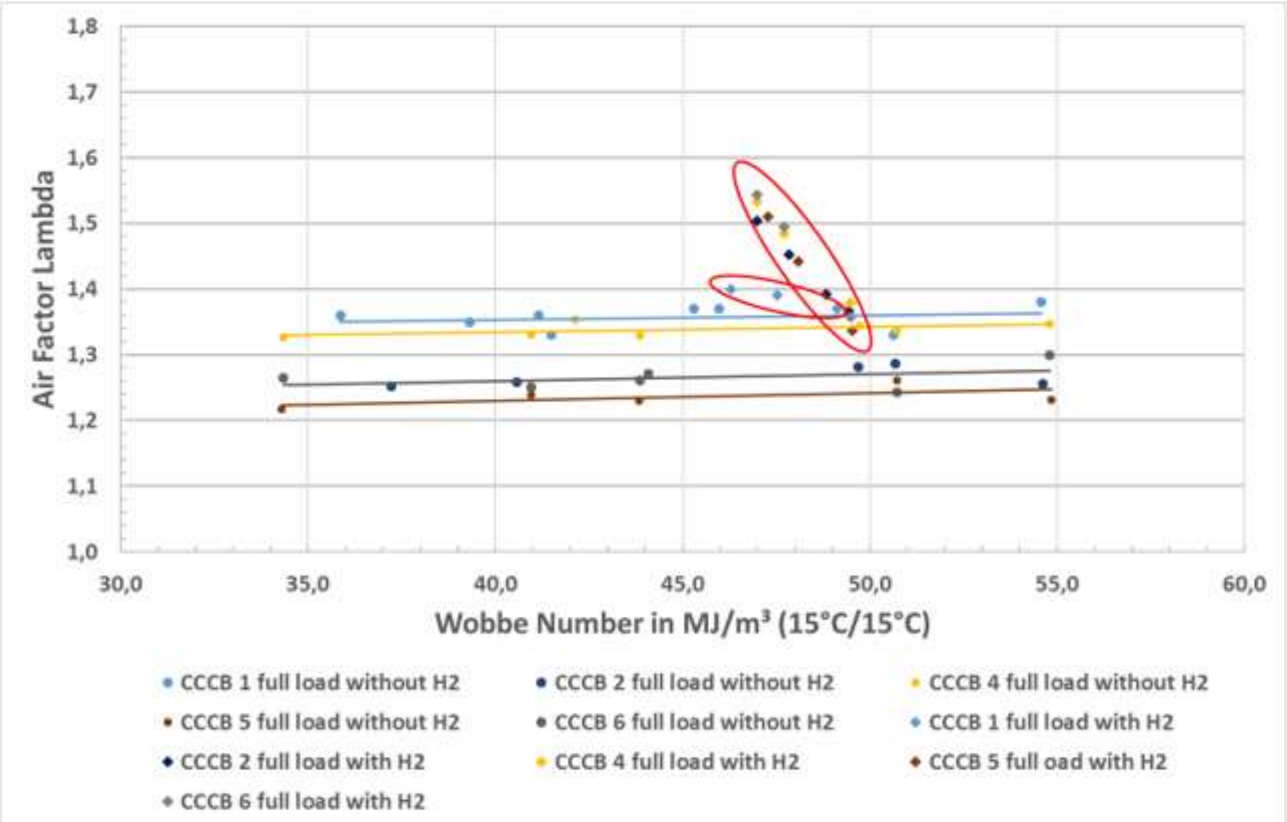
Subtask 3.2.1: Short term combustion tests

Adjustments: Q/A session

3.3 Adjustments of appliances equipped with combustion control (CC)

Subtask 3.2.1: Short term combustion tests

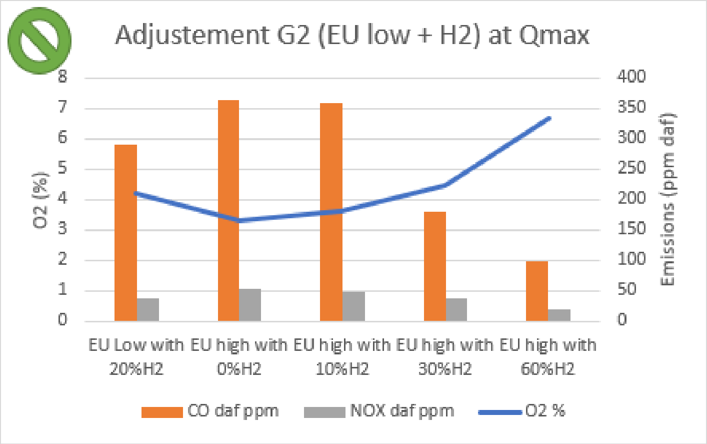
Adjustments of appliance with CC: impact of H2

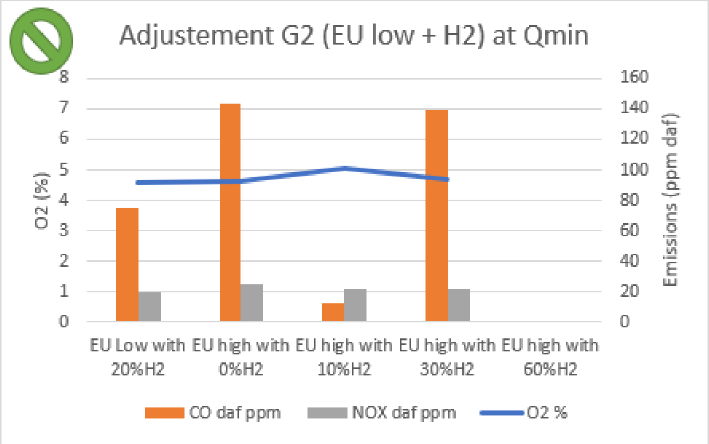


Subtask 3.2.1: Short term combustion tests

Adjustments of appliance with CC: Illustration with boiler D5 (1/2)

Combustion control somehow works at Qmin (O2 more or less constant)





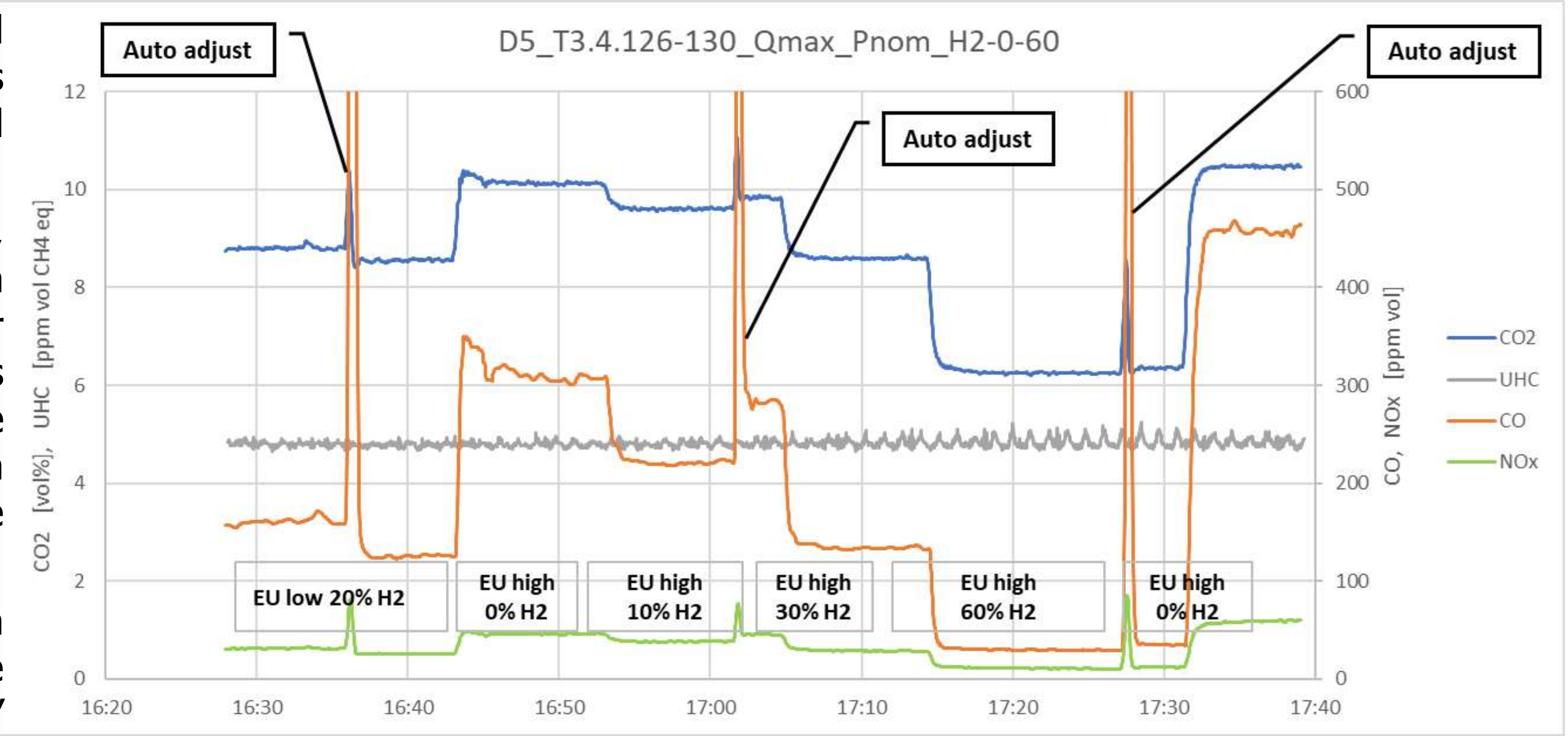
Boiler D5 equipped with Combustion Control

- For the test 3.3c (Adjustment G2), the appliance is adjusted with [EU low + 20% H2] to obtain a CO2 value of 9,2 % (nominal load) given by the manufacturer in the boiler manual.
- The set value for O2 that correspond to 9,2 % CO2 and with G20 (pure methane as this is the reference condition for the adjustment) is calculated to 4,44 % O2.
- The increase of CO from [EU low + 20% H2] to [EU high] is not critical

Subtask 3.2.1: Short term combustion tests

Adjustments of appliance with CC: Illustration with boiler D5 (2/2)

- Case of a boiler with a CC (D5) where the boiler may be adjusted with CO2 as reference, (but this is not part of the standard commissioning procedure).
- According to the manual, adjustment is only required when converting to another fuel gas or when extraordinary maintenance is performed? involving the replacement of a component, such as the P.C.B. or components in the air, gas and flame control circuits.
- When performing this test with 20% H2 in EUlow, we could observe some instability in the “auto adjust” function of the boiler, with frequent auto adjust attempts accompanied of CO peaks.



Subtask 3.2.1: Short term combustion tests

Adjustments of appliance with CC: Q/A session

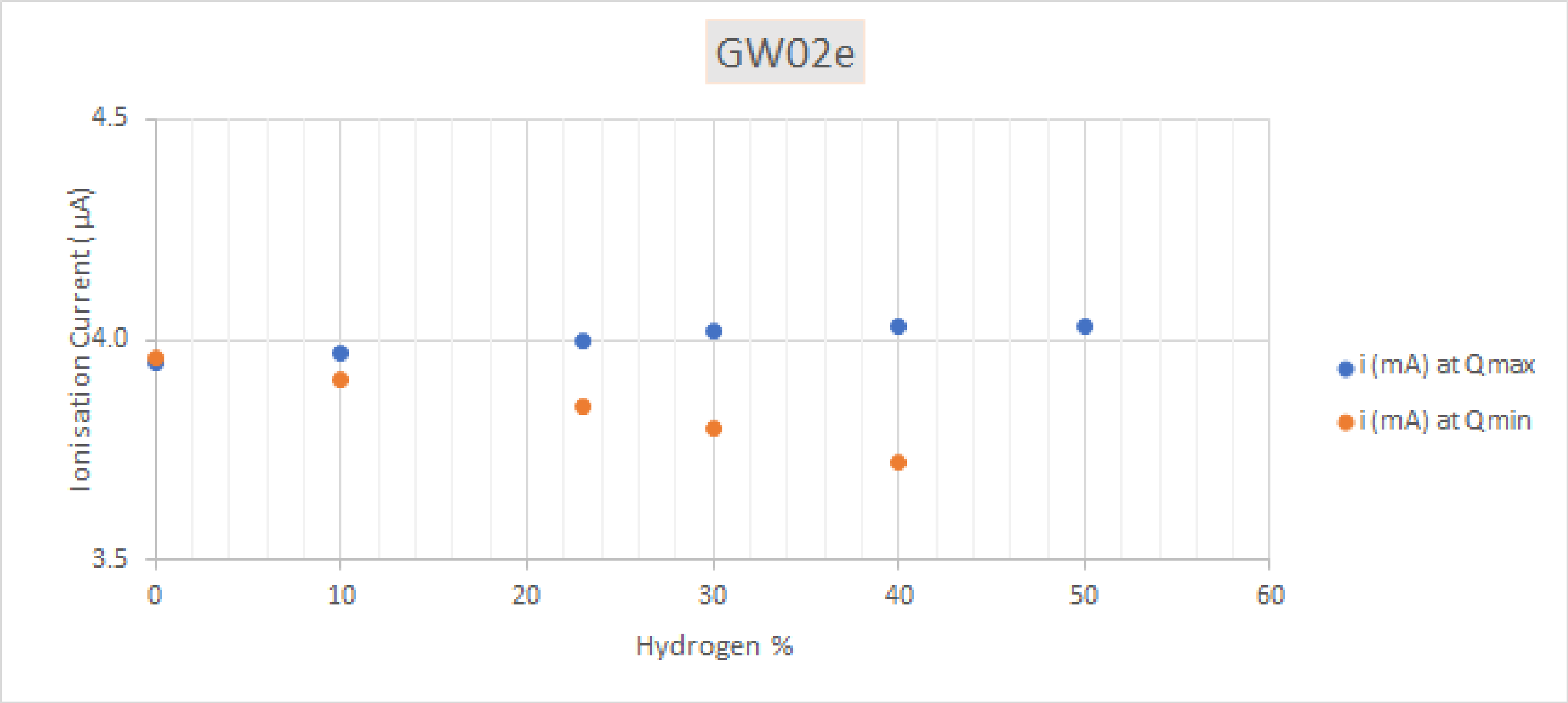
Patrick I suggest to have QA for the rest of the presentation at the end

3.4 Ionisation current

Subtask 3.2.1: Short term combustion tests

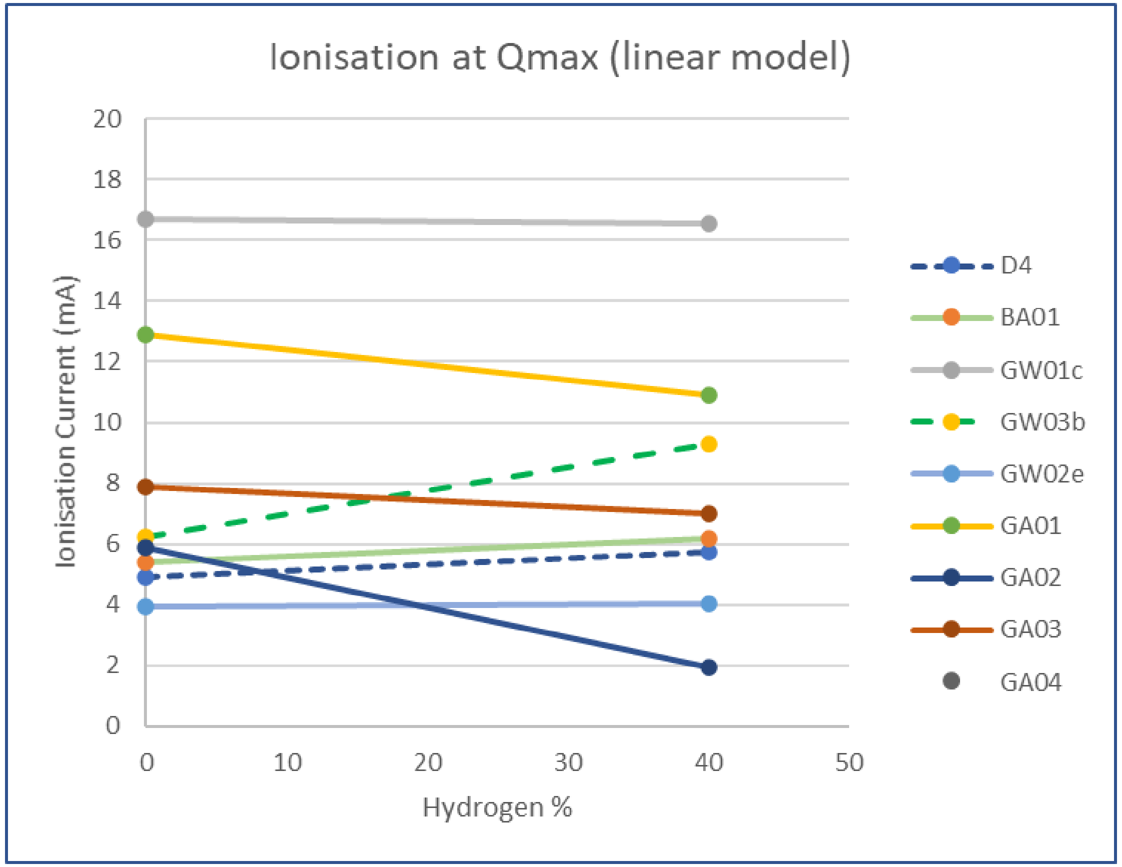
Ionisation current: first results (1/2)

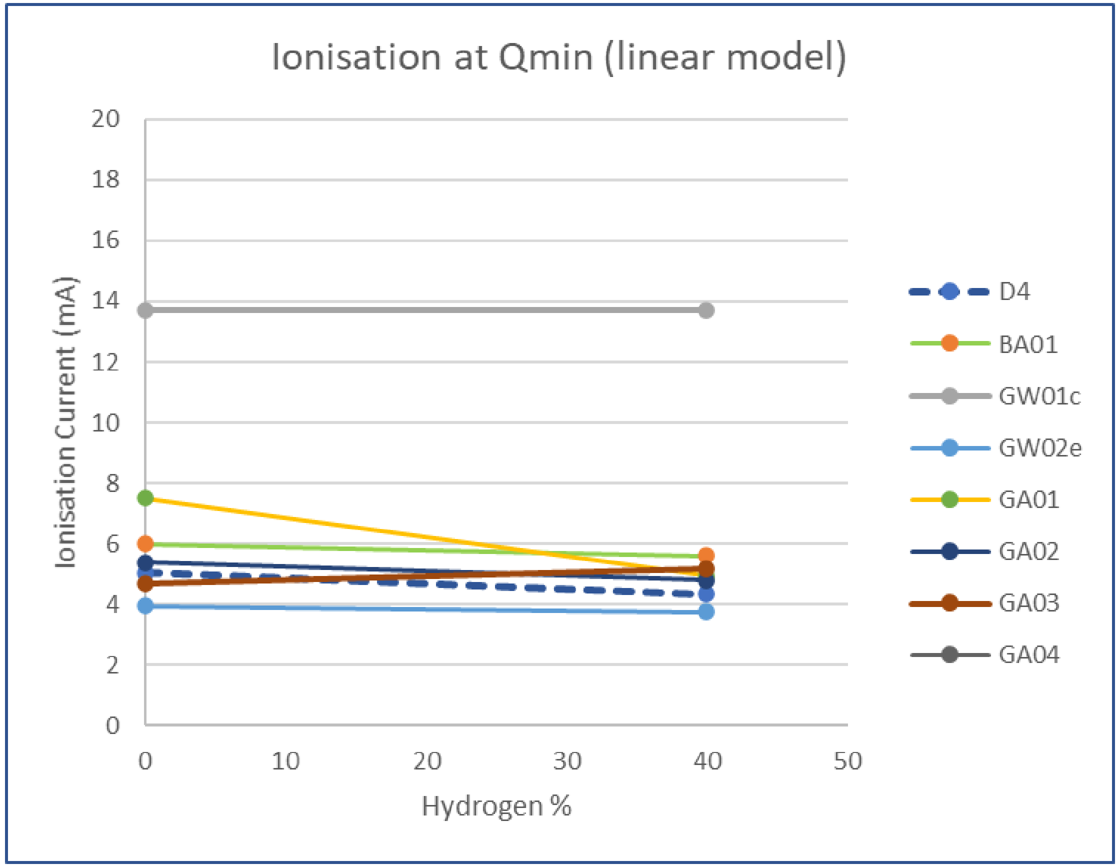
Impact on ionisation current → relative stability of the values → Ionisation technology still work for flame supervision



Subtask 3.2.1: Short term combustion tests

Ionisation current: first results (2/2)





Subtask 3.2.1: Short term combustion tests

Ionisation current: Q/A session

3.5 Efficiency and Emissions

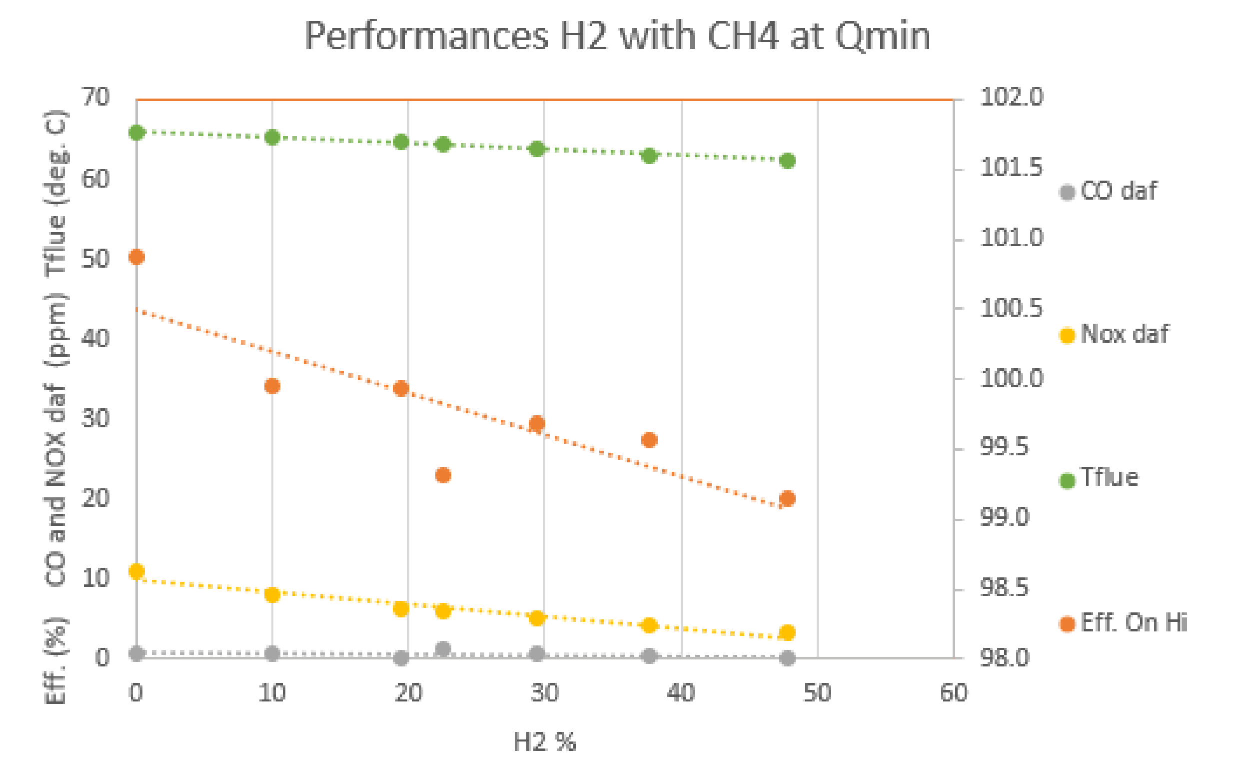
Subtask 3.2.1: Short term combustion tests

Efficiency and Emissions: first results

Impact of some indicators, mainly because of the change of air excess

FOR BOILERS when H2 % is increasing:

- **Efficiency not very much impacted**, but the result will be depending on the water temperature. *(Especially close to dew point it can make a difference in latent heat recuperation for condensing boilers).*
- **NOx** will be decreasing
- **CO** can or not be impacted
- **CH4** emission decreasing with H2

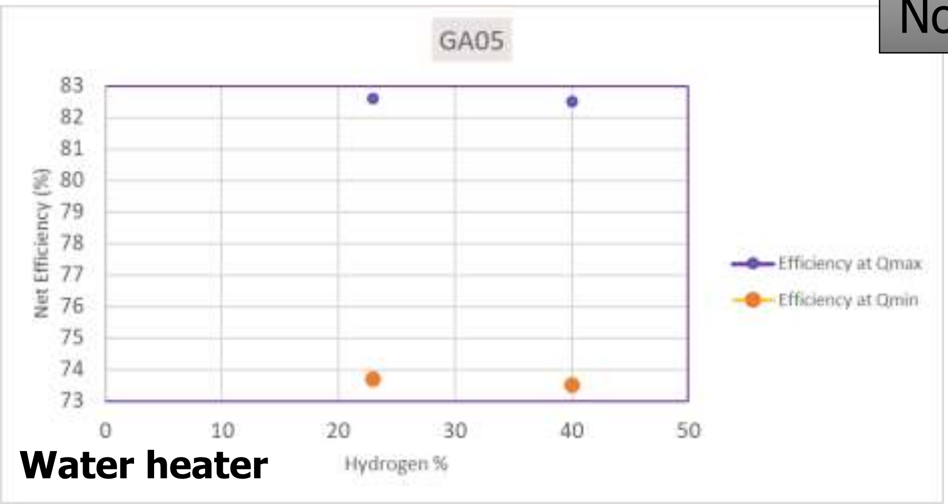


Result on a premix cond. boiler

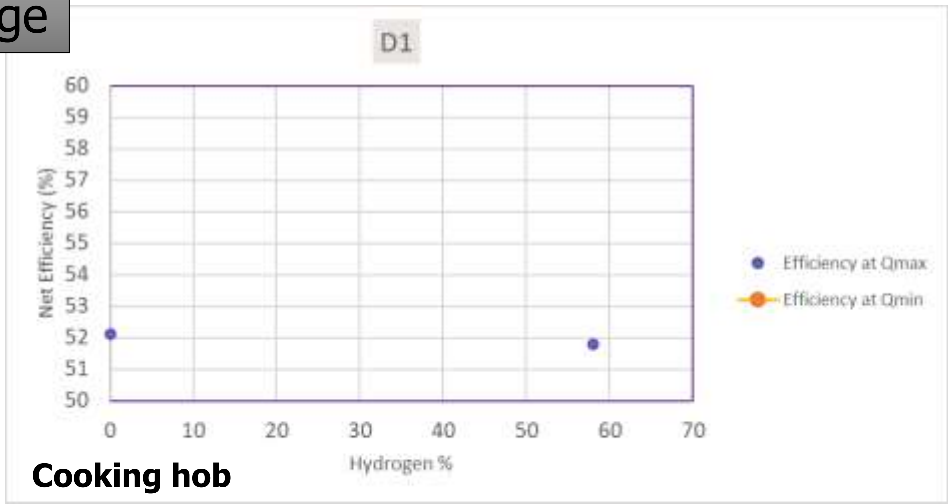
Subtask 3.2.1: Short term combustion tests

Efficiency

No change

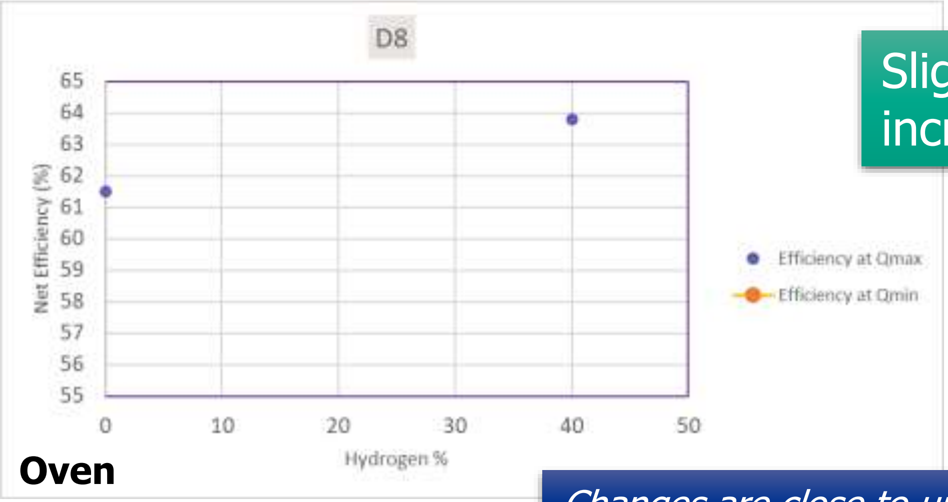


Water heater

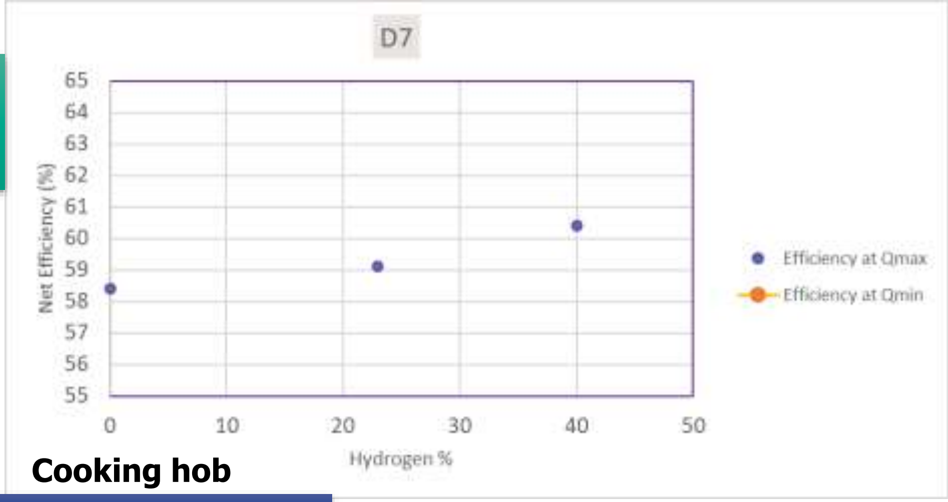


Cooking hob

Slight increase



Oven

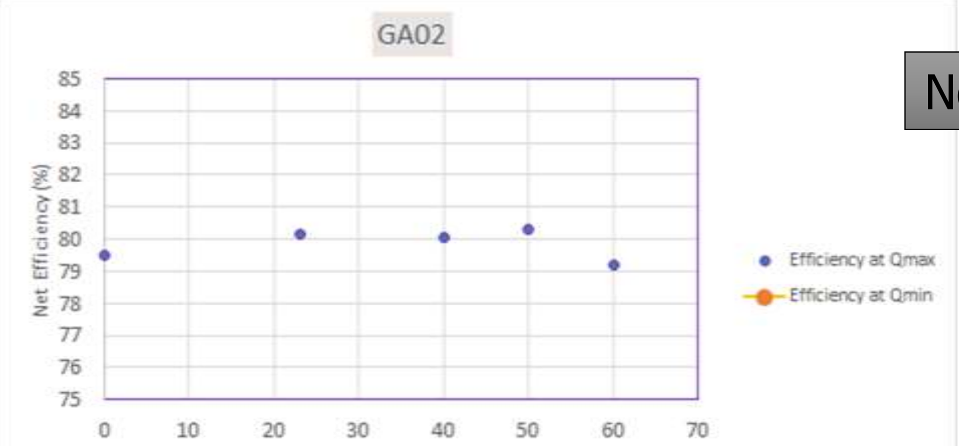


Cooking hob

Changes are close to uncertainty of measurement

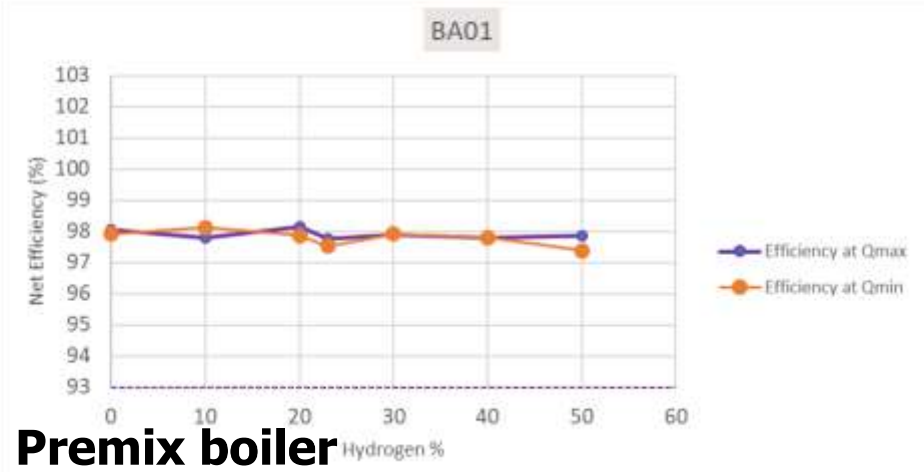
Subtask 3.2.1: Short term combustion tests

Efficiency

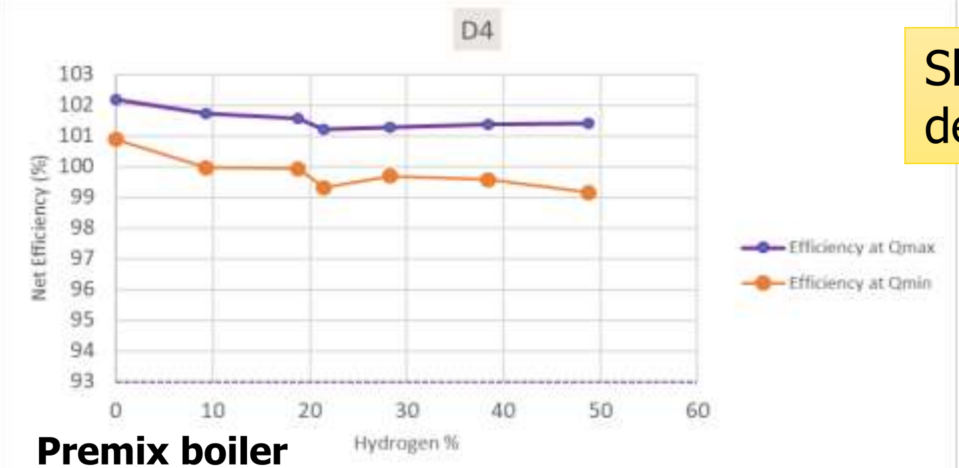


Decorative fire

No change



Premix boiler



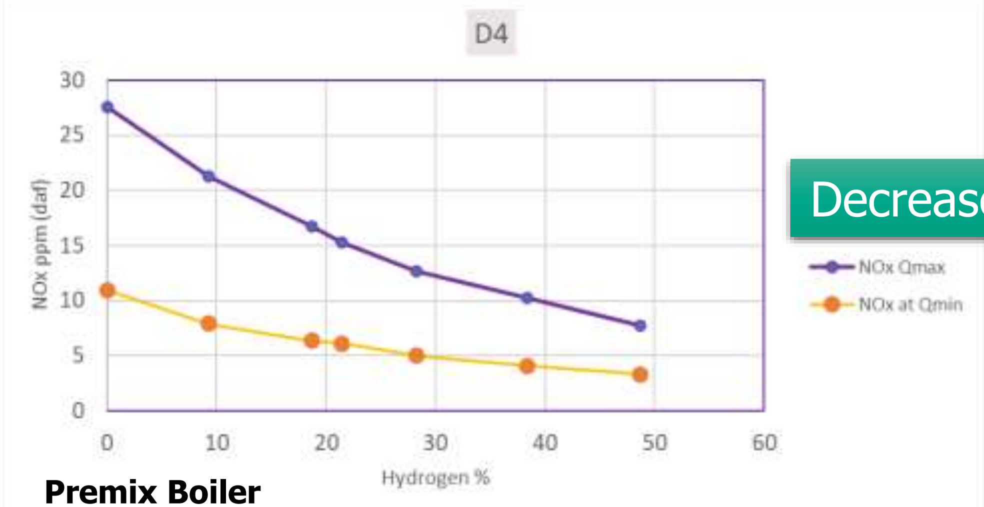
Premix boiler

Slight decrease

Changes are close to uncertainty of measurement

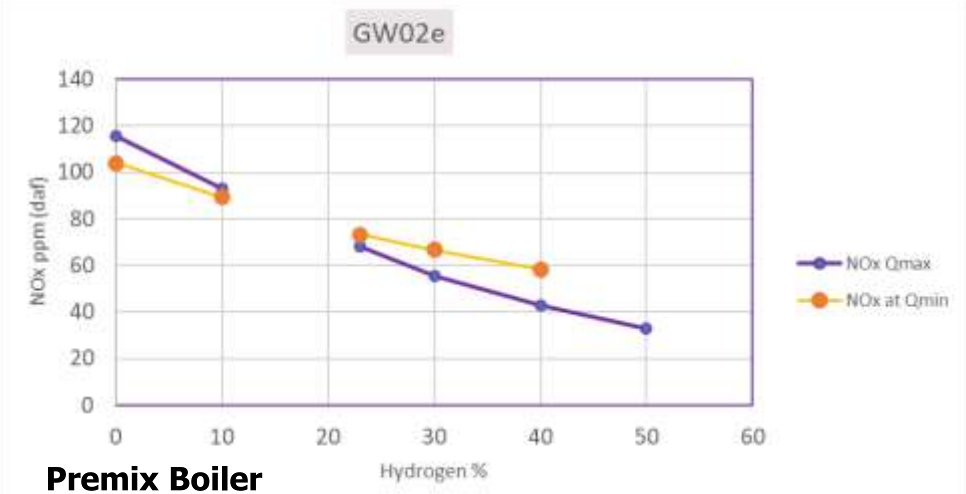
Subtask 3.2.1: Short term combustion tests

NOx Emissions

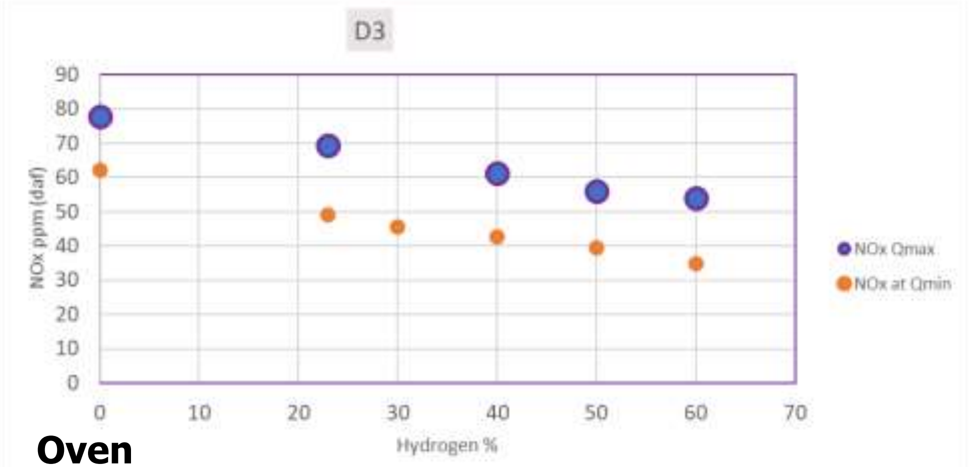


Premix Boiler

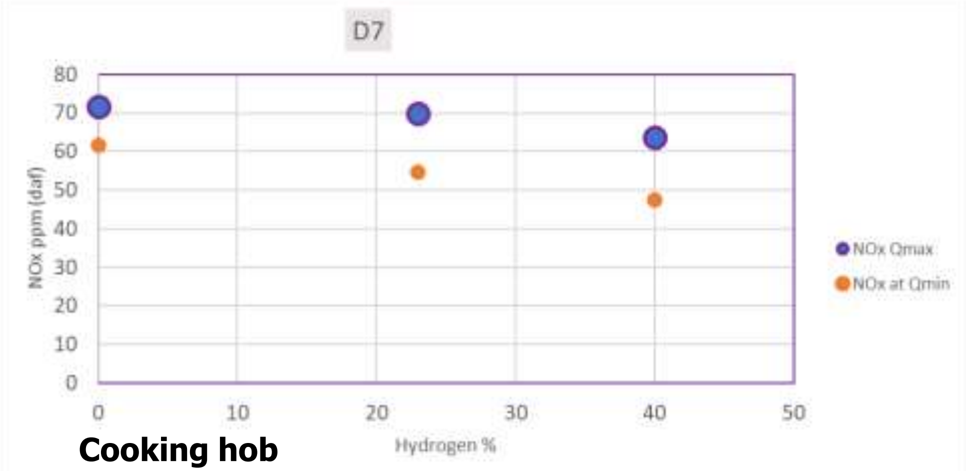
Decrease



Premix Boiler



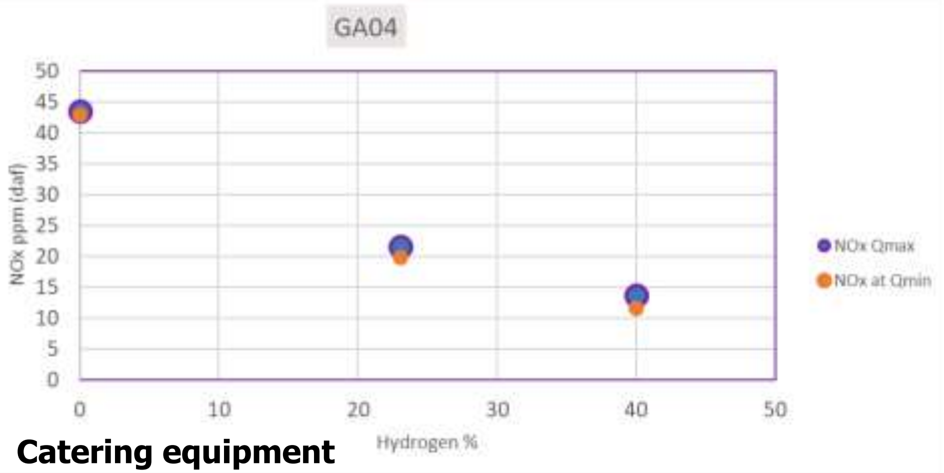
Oven



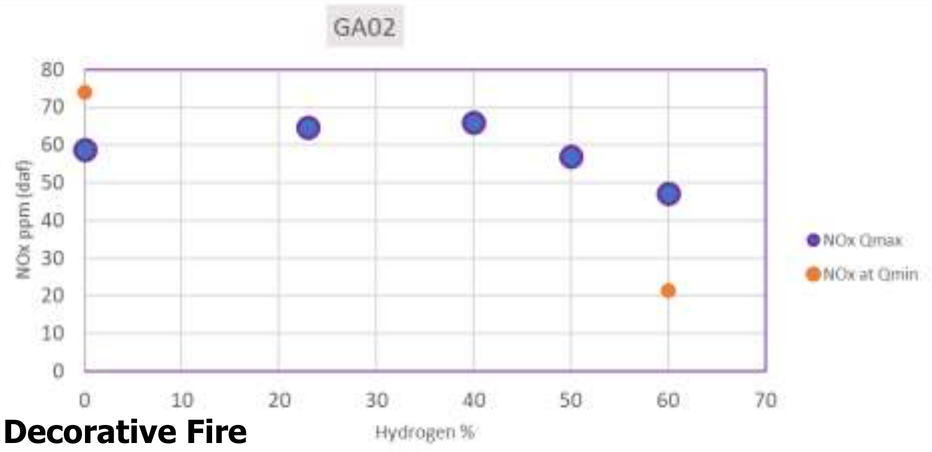
Cooking hob

Subtask 3.2.1: Short term combustion tests

NOx Emissions



Catering equipment



Decorative Fire

Decrease

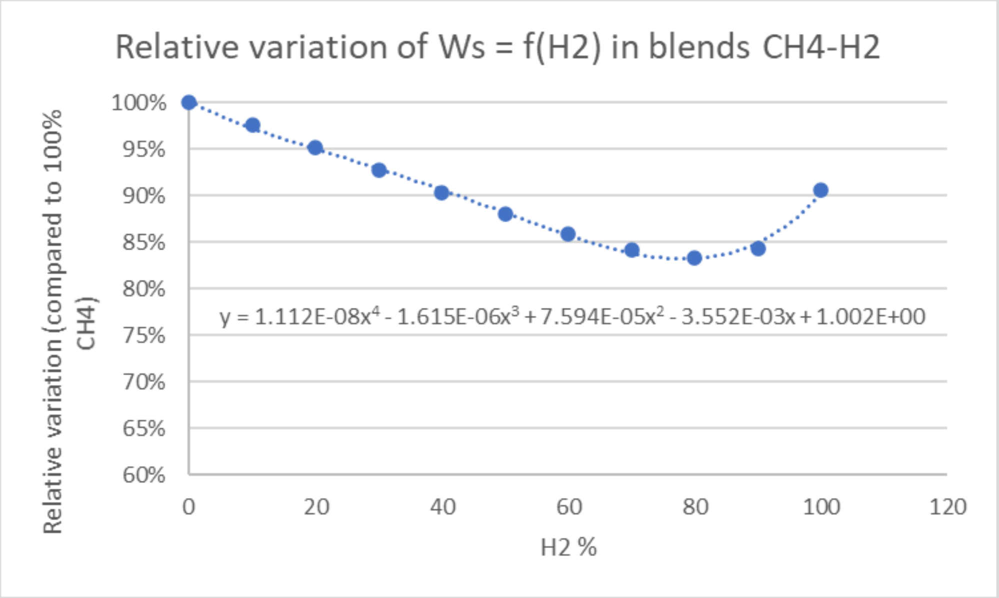
Subtask 3.2.1: Short term combustion tests

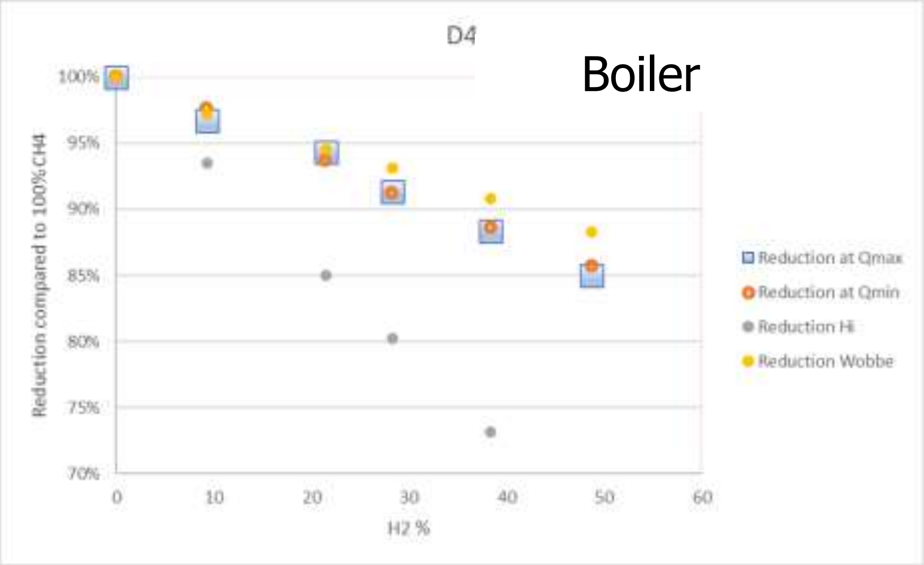
Efficiency and Emissions: Q/A session

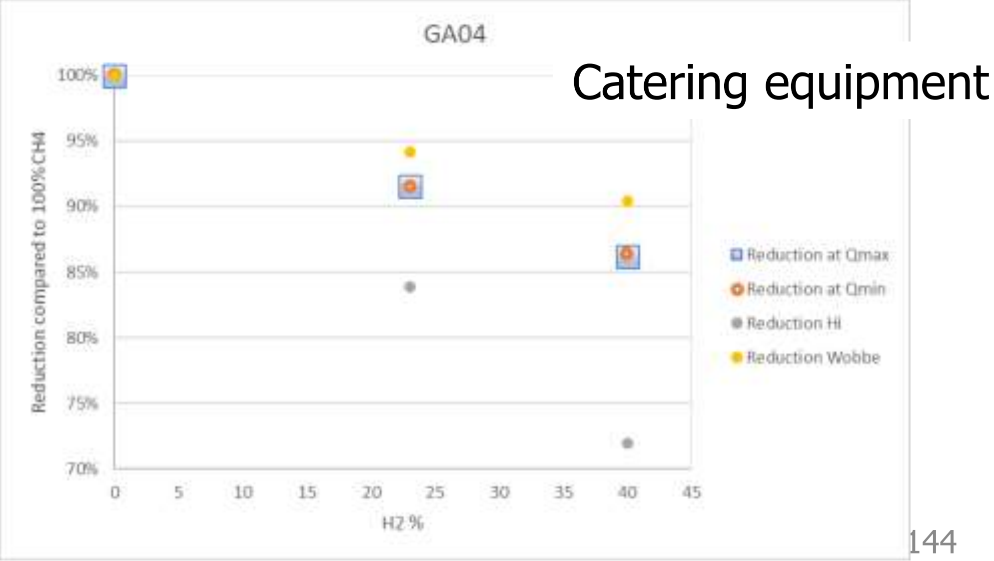
3.6 Heat output

Subtask 3.2.1: Short term combustion tests

Heat output: first results







3.7 Other results

Subtask 3.2.1: Short term combustion tests

Other results: Safety aspects that are not an issue (so far)

- Both impacts of "**low air temperature (- 10 °C)**" and "**Flue gas pipe length**" have been tested on 1 and 2 appliances (boilers) respectively, and the results from the test done show no impact of hydrogen.
- **ROC (PLUG FLOW)** was executed on 13 appliances without showing any issue (generally variation from 0 to 40% H2 and the other way round).
- The **delayed ignition** test was made on **1 appliance only** with 30% H2. There was no safety issue, but we need to have a few more of those tests.
- The **soundness** was newly tested on 1 appliance and there was no issue observed. There is no specific test protocol for hydrogen natural gas blends.
- **Fluctuation of the auxiliary energy** was tested on 1 appliance, without impact on safety.
- For **overheating due to hydrogen**, the temperature was measured on a gas cooker hob.
- The **influence of wind** on exhaust ducts was tested on 2 appliances (no impact).
- **Long-term** (limited time) consisted in testing appliances for few hours when possible. Some tests were done and have not shown issues so far.

Subtask 3.2.1: Short term combustion tests

Heat output: Q/A session

Subtask 3.2.2: Long term combustion tests

Objectives

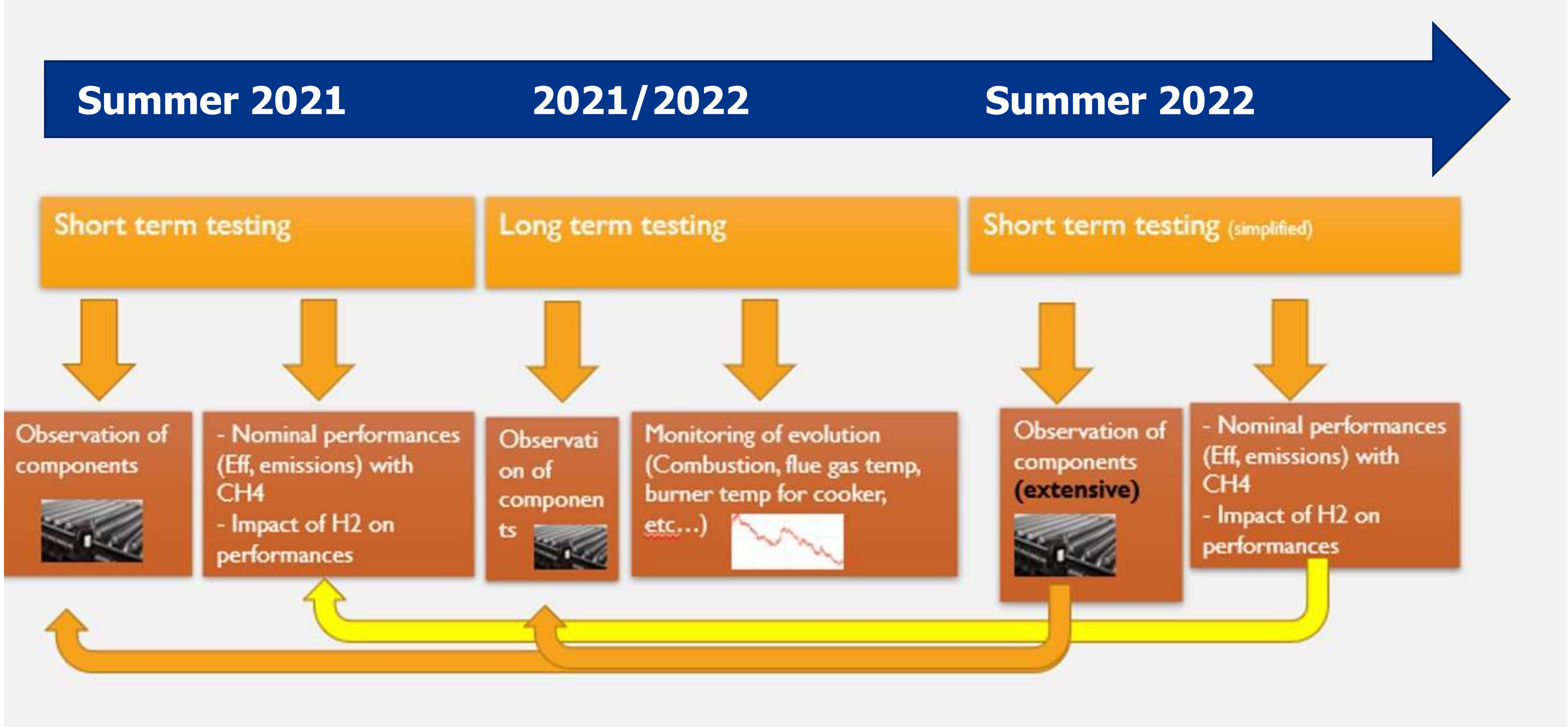
Objective: to observe possible appliances alterations (performances or physical alteration) in the long term (few month) with given H2/NG mix.

- Possible alterations are monitored by measurements in the combustion gas (flue gas).
- The appliances tested will be dismantled at the beginning and end of the tests (visual observations).
- The idea of the long term testing is to simulate a real testing in accelerating time by severe tests constrains (cycling of the burner, high temperature, possibly overload, etc.)

DGC's long term test rig is especially designed to monitor gas appliances performances over testing periods of several weeks or months.

Subtask 3.2.2: Long term combustion tests

Methodology and planning



Other results

Q/A session

4 Exploitation of the first results

Exploitation of the first results

Dialog with CEN TCs

- Workshops and exchanges on the THyGA program and protocol

MAY 6, 2020

1st Workshop of the THyGA project

This first public event gathered around 100 stakeholders. The workshop was aimed at presenting first research results, methodology and discuss the specific consequences of hydrogen blending for the gas appliances sector, with the participation of researchers, manufacturers and associations.

Read more

OCTOBER 30, 2020

WEBINAR "IMPACT OF HYDROGEN ADMIXTURE ON RESIDENTIAL AND COMMERCIAL COMBUSTION PROCESSES INSIGHTS FROM COMBUSTION SCIENCE"

Another sucessful event with > 360 registrations! Available for download And don't forget, you can also DOWNLOAD THE REPORT And the replay of the webinar for those that couldn't join:

Read more

MARCH 21, 2021

WP4 – Technical workshop "H2NG supply to residential and commercial appliances – standardization and certification".

A key issue in a transition to common use of relevant shares of hydrogen in natural gas supply is safe operation and reliable functioning of end-use appliances. The lifetime of these end-use appliances is considerable and so new gas appliances put on the market should ideally be compatible with these admixtures as soon as possible. ...

Read more

- Participation of THyGA partners to the TCs, dissemination of the results and advancement of the project

Exploitation of the first results

Synergy with other projects – GERG PNR: Objectives

Priority 8

End use equipment

Consequences for End use equipment with H2 in NG

Partners

DGC (lead), DNVGL, DBI, Engie, KIWA

GERG THE EUROPEAN GAS RESEARCH GROUP

OBJECTIVES

- To develop a **status review on the use of H2 and H2NG blends for End Use equipment** above 20% H2
- To clarify the need for amendments and the **need for new standardization. (PNR)**

ISSUES TO BE ADDRESSED

- **Safe operation**
- **Environmental** impact
- **Energy efficiency**
- **Overall performance**s of the end use equipment for the service it is designed for

SCOPE

- **Domestic and commercial**
- **Mobility**

Exploitation of the first results

Synergy with other projects – GERG PNR: What is pre-normative research?

PNR = Research undertaken prior to standardization

1. **Understanding the impact of H2 on appliances** in order to allow the development of test methods & standards
2. **Investigating appliances or aspects that are not yet covered** in the literature
3. **Developing methods to test appliances** to assess the safety, emission, efficiency, fitness for purpose, taking into account the specific requirements of H2.

GOAL OF THE GERG PROJECT = ESTABLISH THE STATE OF THE ART (about sensitivity to H2) AND IDENTIFY PNR NEEDS

Exploitation of the first results

Synergy with other projects – GERG PNR: **Example of identified PNR topics**

H2NG / H2 / both	Topic	Gap in knowledge to fill or challenge to tackle	Proposed solution(s)
Both	Test procedure for Explosion risk in appliances / Delayed ignition	The test of **DELAYED IGNITION** with H2NG may need to be adapted to the % of H2 in the gas • Gas leakage inside the appliance • Unburned gas accumulation inside the appliance / resistance to delayed ignition.	Investigate the relevant properties of H2NG and risks associated
H2NG	Testing FB & flame stability	The present test **procedures for FB are not sufficiently detailed** for H2NG. Harmonised criteria to declare flashback or partial flashback would be useful.	Analyse in detail test results and experiences with FB / to adapt existing procedures.
H2NG	Adjustment of premix appliances	The **adjustment of appliances** when hydrogen is blended into natural gas brings a major risk for safety (CO)	R&D that would all help in proposing technical solutions (adapted adjustement. H2 sensors, etc.)

Exploitation of the first results

Synergy with other projects – GERG PNR: Main results

In red = point on-going investigation in THyGA

A. A lot of experimental work is still on going within THyGA. There is still some flexibility to adapt the actions

B. Some TCs are very active to introduce ”H2-ready” or ”X%H2-ready” testing/certification.

1. Wait before starting new action: Try to incorporate some of athe action in THyGA
2. Coordinate as much as possible the priorities with the TC's

SEGMENT (Added col	TYPE of PNR (added colum	Priority (high /med iu	Work Package	Chrono No.	H2NG/ H2/both	Topic	Gap in knowledge to fill or challenge to tackle	Research project (PNR)
Domestic & Com	Missing Knowledge [illegible] H2	1-High	WP8	17	Both	Domestic & commercial	**Safety devices and controls** •Proper functioning of safety devices (e.g. flame supervision by electrode or by UV cell, safety times of burner controls, TTB,...) •Leak-tightness, test results for controls	Waiting for more THyGA results
Domestic & Com	Missing Knowledge on Horizontal aspects	1-High (but wait for THyGA)	WP8	24	Both	Domestic & commercial	Very little is known on **long-term impact of H2** and H2 combustion on appliances. Long-term field tests (Ameland, etc.) have not shown specific issues, but the levels of H2 used so far were modest (in general 10% or less). THyGA will bring more info (long-term test) on possible impact on materials and potential consequences on safety and performance. Atmospheric	Waiting for more THyGA results
Domestic & Com	Installation, maintenance,	1-High / to be discussed by safety authorities	WP8	16	H2NG	Domestic & commercial	**For existing installed appliances that are not designed or certified for H2NG**, exposing them to H2NG brings up the question of product liability and responsibility for those installed appliances. Solution shall be found so to guarantee the safety of the user.	At the moment, it is not possible to define a PNR action, but depending on the solutions envisaged, there could very well be a need to develop, test and validate assessment methods for the "onsite" verification that applinaces can cope with H2NG.
Domestic & Com	Certification Test specific. Horizontal	1-High check if treated elsewhere	WP8	29	Both	Domestic & commercial	**The test of DELATED IGNITION with H2NG may need to be adapted to the % of H2 in the gas** •Gas leakage inside the appliance •Unburned gas accumulation inside the appliance / resistance to delayed ignition. Shall the	Theoretical investigations on how to relate the blends characteristics related to Lower Explosion Limits (LEL) and Upper Explosion Limits (UEL), Limiting Oxygen Concentrations (LOC), etc. to safety aspects of gas appliances (delayed ignition test etc.)
Domestic & Com	Missing Knowledge [illegible] H2	1-High Check if in WP7	WP8	18	Both	Indoor installation: Missing	Tightness (indoor gas line), most recent results show contraditory results on **tightness of existing sealings on indoor piping** of gas installations.	Investigation of natural pipe used sealings
Domestic & Com	Missing Knowledge on Horizontal aspects	2-Medium	WP8	22	Both	Domestic & commercial	The % of water in the flue will increase with injection of H2. The effect of this is not very well documented in the literature, but the following may occur: Increased risk of corrosion, impact on sensors, design of condensate evacuation, quality of cooking with ovens, condensate with cooking hobs, etc.).	The phase 1 of such a project would be a theoretical approach, the phase 2 could be part of long-term or combined with long-term testing **(see pt Nr 24)**
Domestic & Com	Missing Knowledge [illegible] H2	2-Medium	WP8	23	H2NG	Domestic & commercial	**Catering equipment**. Very few investigations although there are some similarities with domestic appliances. Large range of products (Open burners and wok burners, Mixed ovens, Ovens, Boiling pans / pasta cookers, Fryers, Salamanders / Rotisseries, Brat pans, Covered burners (griddles, solid tops, pancake cookers, Barbecues) and burners (Atmospheric Burner	Extend THyGA test program when relevant (wait for THyGA conclusion)
Domestic & Com	Missing Knowledge [illegible] H2	2-Medium	WP8	27	H2NG	Domestic & commercial	**Fuel cells (only newest technologies are covered by THyGA)** **GHP** **Infrared radiant heaters** **Air heaters**	Extend THyGA test program when relevant (wait for THyGA conclusion)
Domestic & Com	Missing Knowledge [illegible] H2	2-Medium	WP8	28	H2NG	Domestic & commercial	**Cookers are the** second most investigated segment. Here again the multiplicity of the products and components (Hobs and ovens), (burner typology) etc. results in not all configurations being treated.	Extend THyGA test program when relevant (wait for THyGA conclusion)
Domestic & Com	Installation, maintenance,	2-Medium [illegible]	WP8	15	Both	Domestic & commercial	**Commissioning & maintenance** Procedures for installation & replacement and maintenance of installations/appliances/components using NG/H2 blends or 100% H2. H2-ready appliances may need to be subjet to specific requirements for their commissioning	<--------
Domestic & Com	Missing Knowledge on Horizontal aspects	3-Low	WP8	19	Both	Domestic & commercial	Heat transfer conductive/radiative is impacted by the presence of hydrogen. This can be a problem for technologies based on radiation of the flame.	Waiting for more THyGA results
Domestic & Com	Missing Knowledge [illegible] H2	3-Low	WP8	25	Both	Domestic & commercial	Some data for some appliances. Increase of noise that may not be an issue, but close to thresholds as for example ErP	Testing appliances for noise at different % of H2
Domestic & Com	Missing Knowledge on Horizontal aspects	3-Low (for 20%)	WP8	26	Both	Domestic & commercial	**Aspect of the flame.** Not well documented in literature. Especially important is the impact on the flame for appliances with a decorative function. See THyGA. How to evaluate by testing if the flame aspect is acceptable?	Waiting for more THyGA results
Domestic & Com	Certification Test specific. Horizontal	3-Low or medium (20%)	WP8	21	Both	Domestic & commercial	**OVERALL reasonably documented, but still not 100% clarity**. Ignitions (cold and hot)	Waiting for more THyGA results

5 Conclusions

Conclusions, so far (interim results)

Existing installed appliances

From a technical perspective, a **future injection of 20% of H2 in existing natural gas grids seems today to be a reasonable hypothesis** for the domestic and commercial appliances treated in the study.

- A main technical challenge is the **adjustment of appliances with gas containing hydrogen**. Technical solutions are probably possible, but need to be developed maybe in relation with the new gas quality class system? (see harmonisation of gas quality)
- **Sudden variations of H2 % seems not to be an issue**, but this conclusion is only valid for boilers & cookers etc. and not for engine-based technologies or FC.

Still some technical "grey " areas, from the actual knowledge there is still a lot of uncertainties (part of them would be clarified in THyGA) such as:

- **New technologies:** especially those with other burner technologies or features not present in the tests until now.
- **Long-term effects** of hydrogen addition to natural gas.
- Aspects not yet treated in literature and THyGA (delayed ignition etc.)
- There are still uncertainties but maybe the main issue today is **liability and responsibility when exposing appliances to gases they are not certified for** (not in the scope of THYGA ☺)

Conclusions, so far (interim results)

New appliances

New appliances ("H2 ready") will be covered by a **new certification** that should guarantee the safety.

The certification of H2 ready appliances needs **development of appropriate test methods**. Some are presently under development in TCs (see also WP4 of THyGA)

Possible technical developments for combustion controls of H2NG blends will need a **re-assessing of the safety of fully premix burners when air gas ratio is becoming constant**.

https://www.dbi-gruppe.de/h2ready.html

Worcester Bosch and BDR Thermea are developing hydrogen ready boilers

https://www.h2bulletin.com/the-hydrogen-ready-boiler-market/

Any question?

HyDelta

Julio Garcia-Navarro

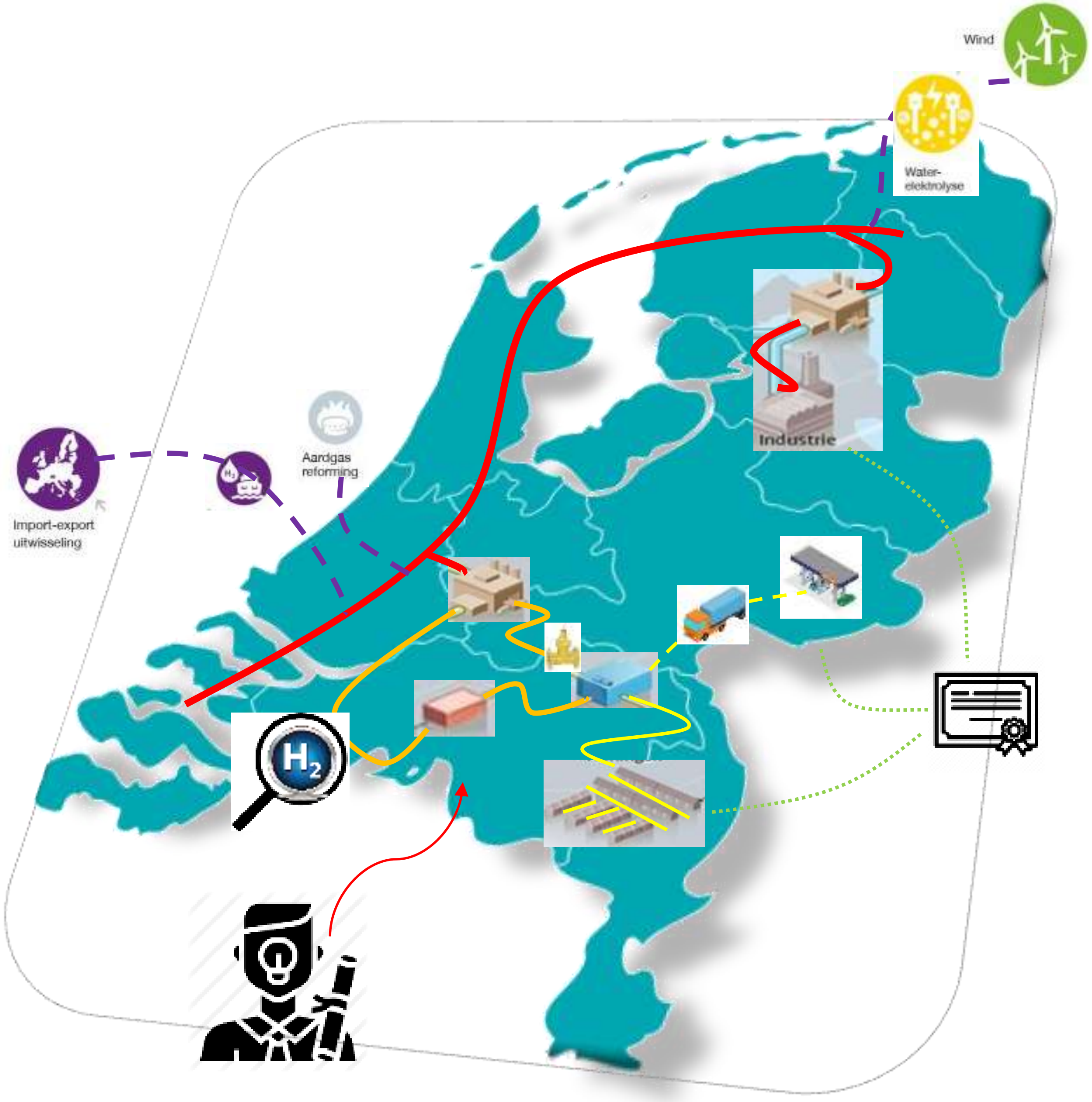
HyDelta

HyDelta highlights

THyGA workshop

Julio Garcia-Navarro

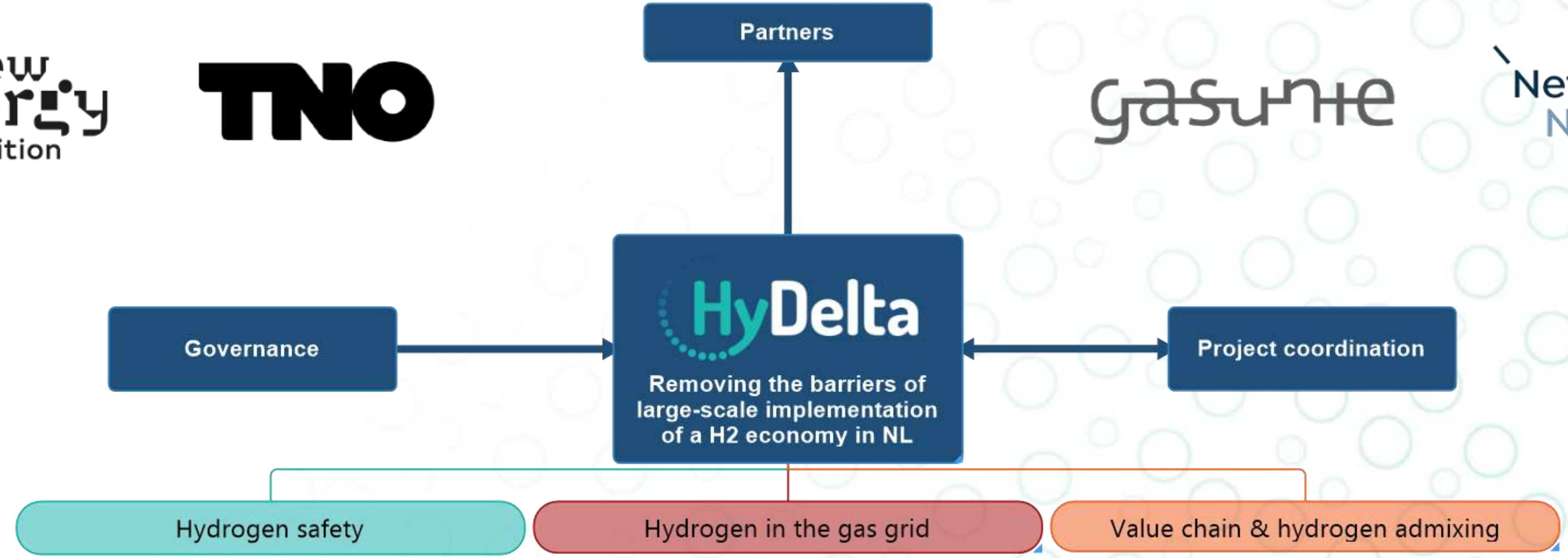
15-Dec-2021



Project consortium

What is HyDelta (1.0)?

HyDelta 1.0 is a **consortium** project **aimed** at conducting **research** on the area of **transport** of **hydrogen** in the existing **NG network** in **NL**



Start of project: Q4 2020. **End of project**: Q2 2022. **Total budget**: ~2.4M

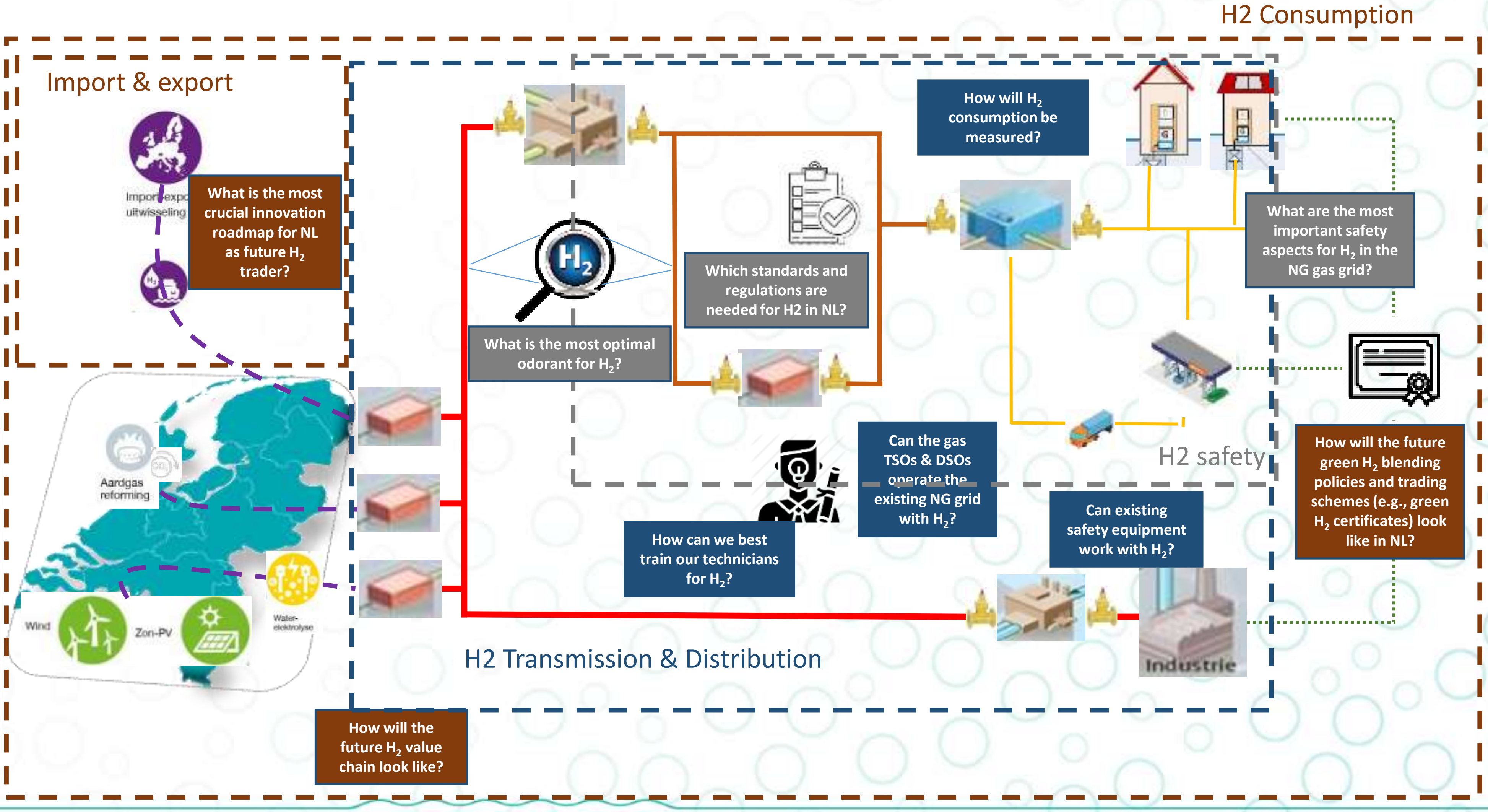
Beyond HyDelta – recent milestones about H2 in NL

Hydrogen in NL

1. Hyway27 was approved
    1. On **21 September** it was **announced** that there will be **€750M reserved** for the **construction** of the **national** hydrogen **infrastructure**
    2. **15 GW** of transport capacity will be made available before 2030
2. National government released the multi-annual programs of:
    1. National Hydrogen Program (**NWP**) (**07-Jul**)
    2. Infrastructure for Energy & Climate (**MIEK**) (**26-Nov**)
        - Both show the **trajectories** to be taken by the government to **support** the **development** of **Dutch hydrogen economy** (between **2022** and **2025**).
3. National project overview: 130+ hydrogen projects (status May 2021), including:
    1. Salt **cavern storage** (Zuidwending)
    2. H2 **mobility** – HRS, buses, trucks, cars
    3. Hydrogen in **homes**
    4. **Offshore hydrogen** production

HyDelta project overview – research questions

Overview of the research questions in HyDelta 1.0



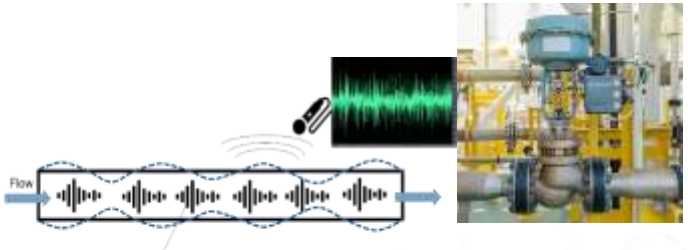
Legend

- Hydrogen safety
- Hydrogen in the gas grid
- Value chain & hydrogen admixing

Some results and milestones achieved (1/3)

Some results from the project

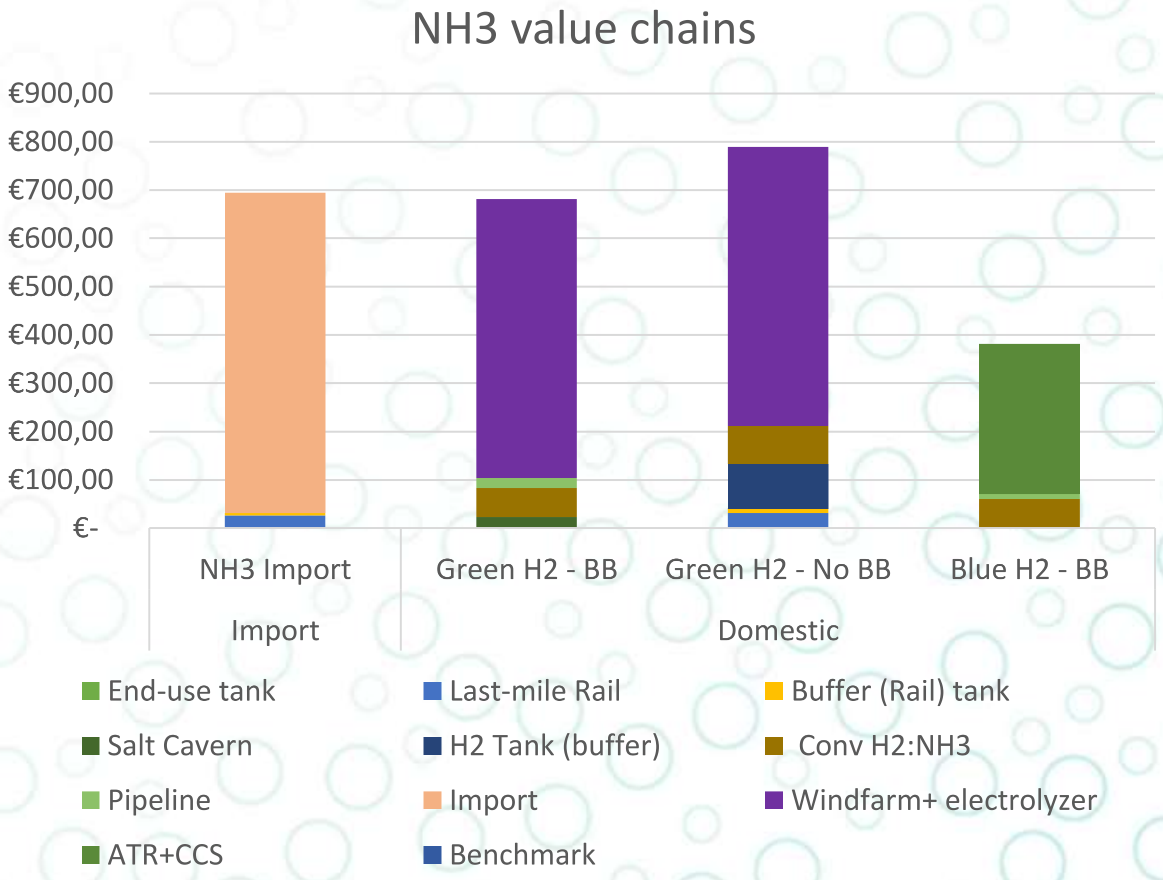
Looking at **simulations** to understand the **effect** of **H2** on equipment – **erosion rate** of metallic pipes, **noise** levels, etc.



Quantifying the **safety** of hydrogen **installations** in homes – comparing with **existing NG risk** & checking the **response** of **pressure reducers** for hydrogen

Maximum leak rate at test pressure equal to maximum operating pressure		
Type of pipeline	Natural gas Max. leakage (dm³/h)	Hydrogen Max. leakage (dm³/h)
Main pipelines	5,0	5,0
Connection pipe - new	0,2	0,2
Connection pipe - existing	1,0	0,7
Meter-connections	0,1	0,1

Analyzing **value chains** to identify **hurdles** and **windfalls** of **green** H_2 – focus on **carriers** (e.g, NH3) from various **pathways**



Some results and milestones achieved (2/3)

Some results from the project

Testing of **shut-off valves** – several valves from the **existing NG transmission** network are being **tested** for safe **operation** with **H2** at **67 bar**

Looking at the **current demand** for **personnel** towards 2050 and beyond to **work** on the **conversion** of the **NG network to H2**.

- *2030-2040*

  Gasunie: 573 fte's per year for construction of hydrogen backbone.

- *2040-2050*

  Regional network operators: 0-161 fte's per year for modification of gas distribution network.

- *>2050*

  Regional network operators: 0-161 fte's per year for modification of gas distribution network.

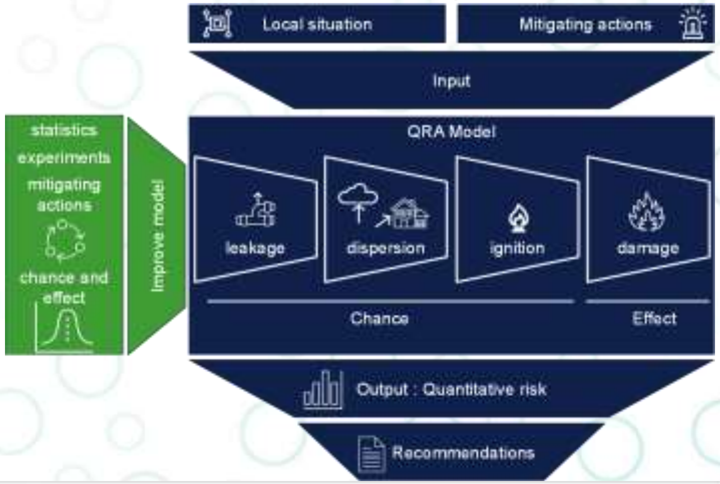
Some results and milestones achieved (3/3)

Some results from the project

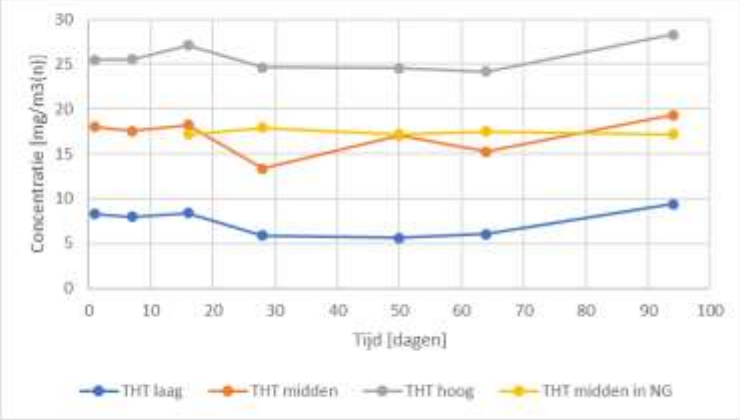
Proposing **rollout** of potential **mandatory blending** quota **schemes** for H2 in different scenarios and various actors

Proposal:	1: Industrial	2: Gases	3: Fuels
Market sectors	(Specific) industrial applications (e.g. ammonia, methanol, refineries)	Gas suppliers	Fuel suppliers for transport applications
Obligated Target parties	End-user: Industries consuming hydrogen	Suppliers: Gas suppliers	Suppliers: Fuel suppliers that deliver more than 500.000 litres, kg or Nm^3 of fuel annually
Base of quota	% of total H_2 used in processes	% of total gas delivered	% of their total taxed fuels (GJ) supplied
Accepted quota energy carriers	• Renewable H_2 • (Low-carbon H_2)	• Renewable H_2 • (Biomethane) • (Synthetic methane)	• Current accepted renewable fuels • Renewable H_2

Continuing the **risk assessment** for hydrogen in the **distribution grid** towards transport of **100% hydrogen**



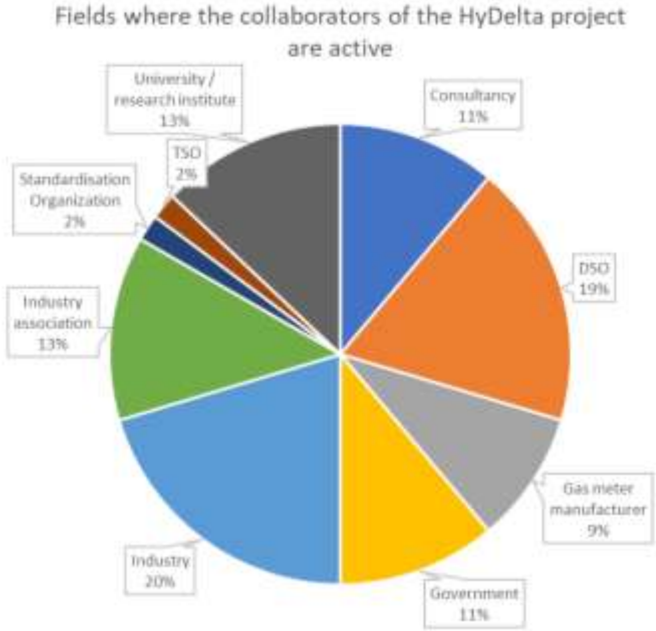
Assessing **hydrogen odorants** – looking at the **long-term stability** for safety operations in the **odorized** (i.e., low pressure) **network**



Active (inter)national collaborations

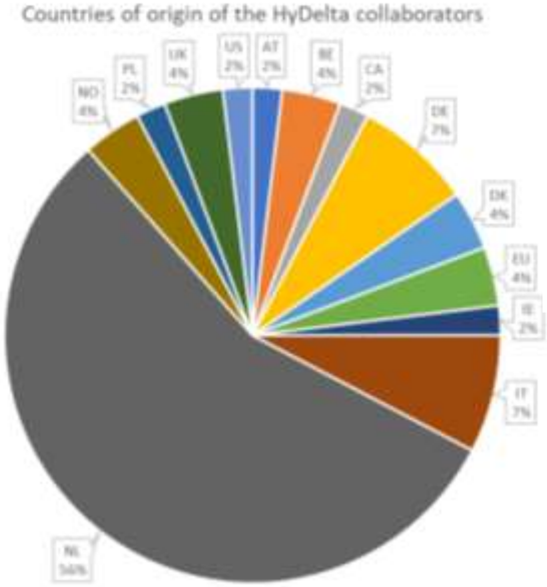
Internal HyDelta survey on active (inter)national collaborations

The **HyDelta consortium** has established **collaboration** with **52** institutions from **different countries** and **sectors**



Per **sector**

Per **country**



Some of the **partners** are also **active** in the following **TCs**:

- **CEN TCs 234 :** gas infrastructure & **237:** gas meters
- **ISO TCs 193**: Natural gas, **158**: Gas analysis
- Liaison with **CEN TC 238**: Appliances for gas compositions

How are we **collaborating** with external **partners**?

Thank you for your attention!

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THyGA Workshop

Next steps

December 15th 2021

Testing **Hy**drogen admixture for **G**as **A**pplications

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No. 874983. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

THyGA project: next steps

Communication and disseminations activities so far

- Public deliverables & events
  - ✓ **D2.1**: Market segmentation of domestic and commercial natural gas appliances
  - ✓ **D2.2**: Impact of hydrogen admixture on combustion processes – Part 1: Theory + Workshop
  - ✓ **D2.3**: Impact of hydrogen admixture on combustion processes – Part 2: Practice
  - ✓ **D2.4**: Non-combustion related impact of hydrogen admixture - material compatibility + Workshop
  - ✓ **D2.5**: Testing programme for hydrogen tolerance tests of domestic and commercial natural gas appliances

  - ✓ **D3.5**: Intermediate segment of technologies by segment report on the impact of the different H2 concentrations on safety, efficiency, emissions and correct operation January 2022 + Workshop
  - ✓ **D3.6**: Intermediate long-term effect of H2 on appliances tested January 2022

  - ✓ **D4.1** Certification & standardization framework
  - ✓ **D4.2** Overview of relevant existing certification experience and on-going standardization activities NEW + Workshop
- THyGA Newsletter: distribution through GERG Mailing, Social media, THyGA and GERG websites; included in the FCHJU newsletter
- Publications, ex: 'THyGA Burning Bright', Global Voice of Gas by the International Gas Union,
- Participation in conferences: IGRC, Wind Meet Gas, FCH JU review days, GERG's 60 years…

THyGA project: next steps

What is expected in the newt months

- WP3: A lot of tests !! The road is still long until the end of the test plan but the results will be analyzed and sent regularly to the Industry (advisory panel group, Technical Committees)
  - Disclosure of the results on « non combustion » test (leakage tests)
  - A public workshop will be held in T4 2022

- WP4: many discussions about the best way to provide effective support for standardization and certification.
  - A public workshop will be held in T3 2022

- WP5: a new and interesting topic for the THyGA partners and the industry
  - You can also expect a public Workshop in T4 2022

- WP6: a relentless activity !
  - Participation to conference, scientific publication, animation of the communication about the partner’s progresses
  - To finalize the project → Public final workshop in December 2022

THyGA project: next steps
Interim results

- The presentation and replay of the workshop will be available on the THyGA project website soon
- We will add a Q/A document for the questions we couldn't answer in direct

- A big **THANK YOU**
  - to the FCH JU's and European Commission for supporting THyGA ans its activities
  - But also today's presenters, and especially the colleagues from GRHYD, HIGGS, HyDelta and HyDeploy
    - Isabelle ALLIAT (isabelle.alliat@engie.com)
    - Julio GARCIA-NAVARRO (j.garcia@newenergycoalition.org)
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    - Adam MADGETT (amadgett@northerngas.co.uk)
    - Javier SANCHEZ LAINEZ (jsanchez@hidrogenoaragon.org)
    - Jean SCHWEITZER (jsc@dgc.dk)

  - And of course, to all stakeholders (advisory panel group, CEN TCS, labs) helping the project since the beginning

Find Us Online

VISIT THE THyGA WEBSITE

All public presentations and deliverables of the project will be available on the project website

thyga-project.eu

GERG LINKEDIN & WEBSITE

For regular updates, you can also follow the GERG LinkedIn page and website

CONTACT EMAIL

Do not hesitate to contact us by email at contact_thyga@engie.com

THyGA

Thank you very much for joining! See you soon for another THyGA event!