THyGA

TEST PROTOCOL
for testing in laboratories
WP3

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.

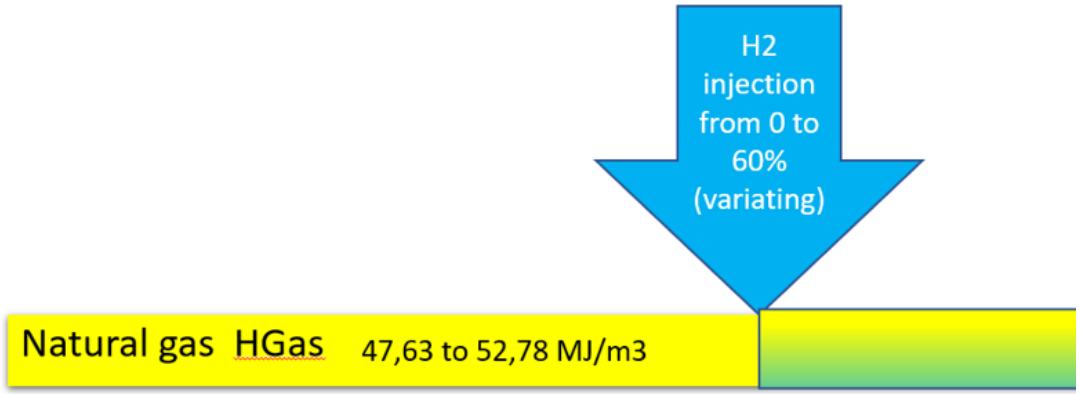
TESTS IN WP3

1. Combustion tests “short term” = Influence of H2 mix in NG on safety, performances and operation of the stock of existing appliances.
2. Combustion tests “long term” = Possible degradation of appliances due to long term exposure to NG/H2 Mix
3. Leakage test = Ability of existing indoor gas line and gas components to cope with H2/NG mix.

The project aim at test as realistic as possible.

The idea is to evaluate the impact of X% of H2 blended in natural gas, **without any action on the grid (eg. Pressure change) or the appliance**.

Maintenance operations that also includes the **adjustments of appliances** will also be investigated.



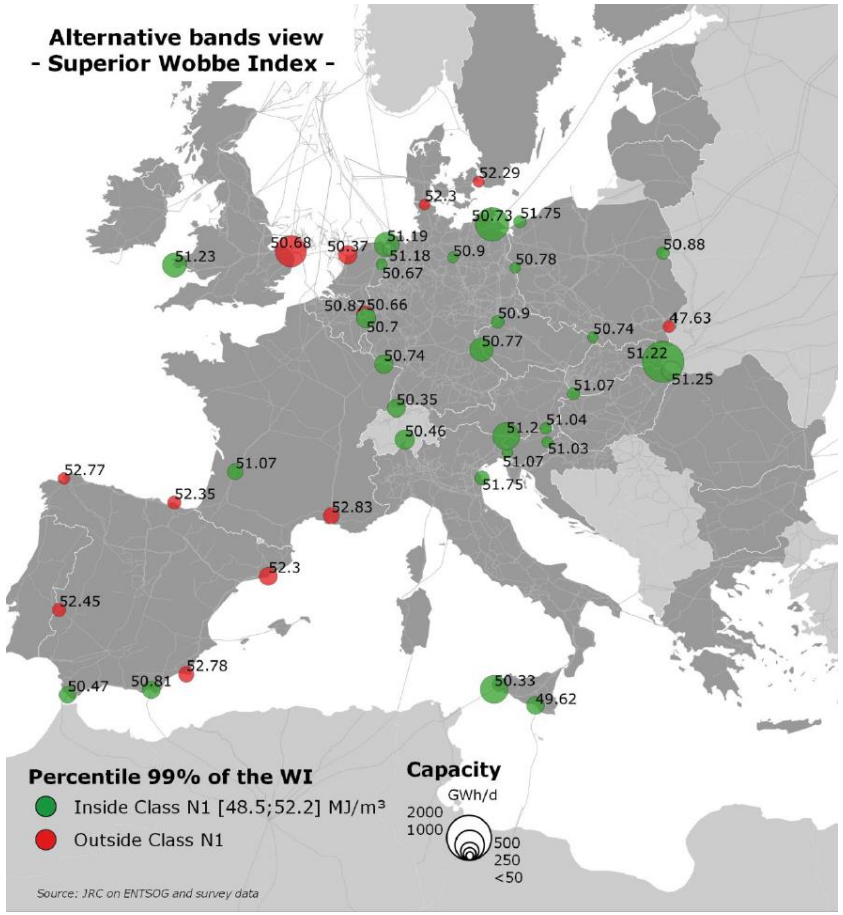
TEST GASES FOR THyGA

Wobbe range: Considering EU distributed H gas. Based on JRC/ENTSOG 2019

Real gas spec. Ws distributed in the EU:

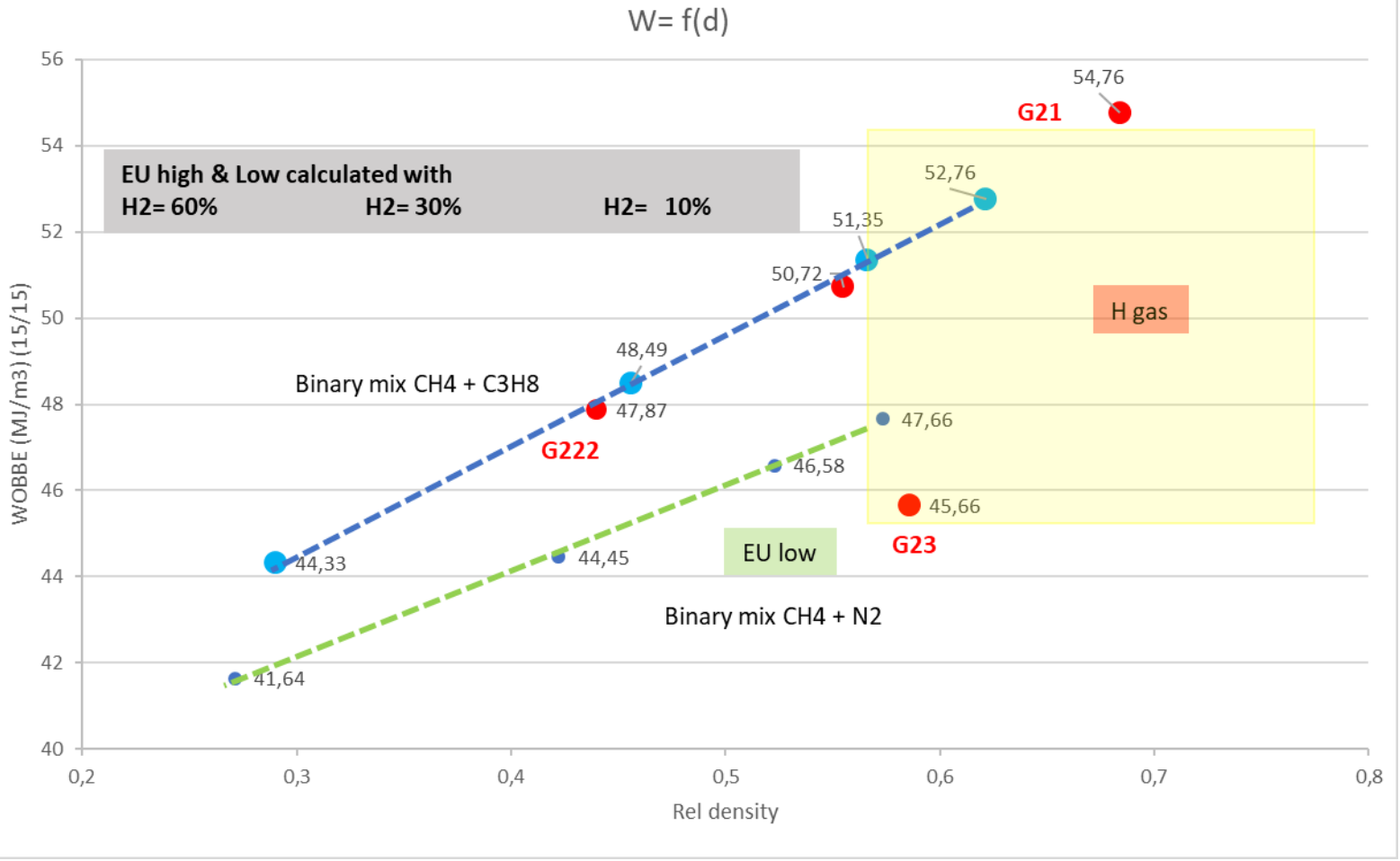
100% percentile = **47,63 (EU LOW) to 52,78 (EU HIGH) MJ/m3**
(15/15) **dWobbe= 5,15 MJ (*)**

(*) *99% percentile* = 48,5 to 52,2 MJ/m3 (15/15) / **dWobbe = 3,7 MJ**



DISCLAIMER. JRC/ENTSOG 2019
The data source for the sensitivity analysis is public, gas quality data for 2015 and 2016 were provided by ENTSOG for the SFGas study on natural gas quality. These data sets correspond to a limited subset of all points.
The numbers on the graph are the measured 99th percentile Superior Wobbe Index (15C/15C) of each individual data set.
The 1-99th percentile of data was analyzed, as decided upon by SFGas TF1 of the study on gas quality. The gas quality ranges assessed for this sensitivity analysis are of a purely exemplary nature.
The distributed gas quality conformed to national specifications. The size of the markers corresponds to capacity, not actual flow rates.

TEST GASES FOR THyGA: Short term tests



Nominal gases chosen for the tests are *CH4, EU low, EU high* combined with H2.

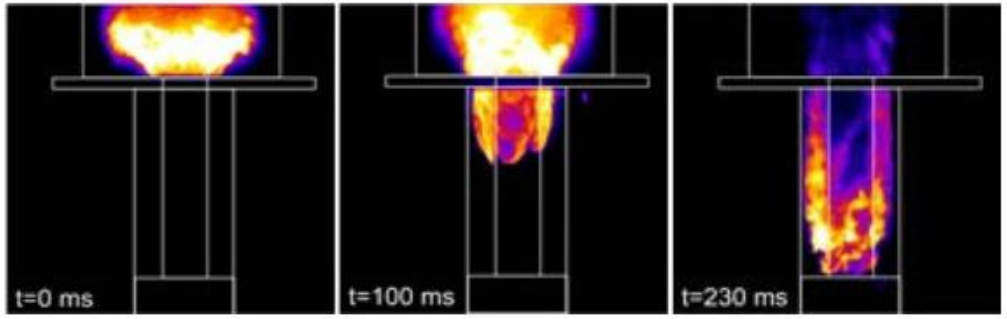
Tests comprise various scenarions of adjustement with thoses gases (with/without H2)

For each test gases choices is based on the analysis of data calculated including Flame speed, Wobbe and Density

TEST PROGRAMME

X	M	1.1 SAFETY- EMISSIONS and EFFICIENCY with CH4 (NOTE that for cooker; Efficiency is treated apart due to the test procedure- see below)
X	A	1.2 SAFETY- EMISSIONS and EFFICIENCY with EULOW (NOTE that for cooker; Efficiency is treated apart due to the test procedure- see below)
		1.3 Deleted
X	A	1.4 Extreme conditions. Cold start.
X	A	1.5 Hot start. (possibly connected to a previous test)
	A	1.6 Extreme conditions. Low air temperature (- 10 C) (only GWI)
NR	A	1.7 Extreme conditions. Flue gas pipe length
X	A	1.8 ROC (PLUGG FLOW)
X	A	1.9 Impact of H2 on flame detection. (TO BE DONE WITH 1.1) Measurement of the Ionisation signal
X	A	1.10 Flash back analyse. In case there has been flash back, this part is dedicated to make the analyse.
	M	*2.1 PERFORMANCES (EFFICIENCY) with CH4 FOR COOKERS ONLY*
	A	*2.2 PERFORMANCES with CH4 (extented range for H2) MERGED WITH1.1* **Cookers only**
	A	*2.3 PERFORMANCES (EFFICIENCY) with EU low. FOR COOKERS ONLY*
X	A	2.4 UHC and H2 emission at start stop
X	M	3.1 ADJUSTMENT A (mostly to see FB & CO). ONLY FOR APPLIANCES THAT CAN BE ADJUSTED
X	M	3.2 ADJUSTMENT B (mostly to see FB & CO)
X	M	3.4 ADJUSTMENT H (mostly to see FB & CO)
X	M	3.3c ADJUSTMENT G2 (mostly to see FB & CO)
	A	4.1 Delayed ignition test.
	A	4.2 Soundness
X	A	4.3 Quick variation Qmin-Qmax Shut-off condition (cookers and fires only). Qualitative test (observation)
	A	4.4 Overheat. Measurement of the temperature
	A	4.5 Other t Coooker hob test with 4 burners on
	A	4.6 Influence of wind
	A	4.7 Long tem (limited time) Appliances shall run from 1 hour to few hours (at the end of the testing)
	A	4.8 Fluctuation of the auxiliary energy
	A	4.x Other test to check more parameters.

Flashback



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

FIGURE HIPS GERG PROJECT DGC

Flashback is one of the main parameters: we need to be certain to reproduce the testing.

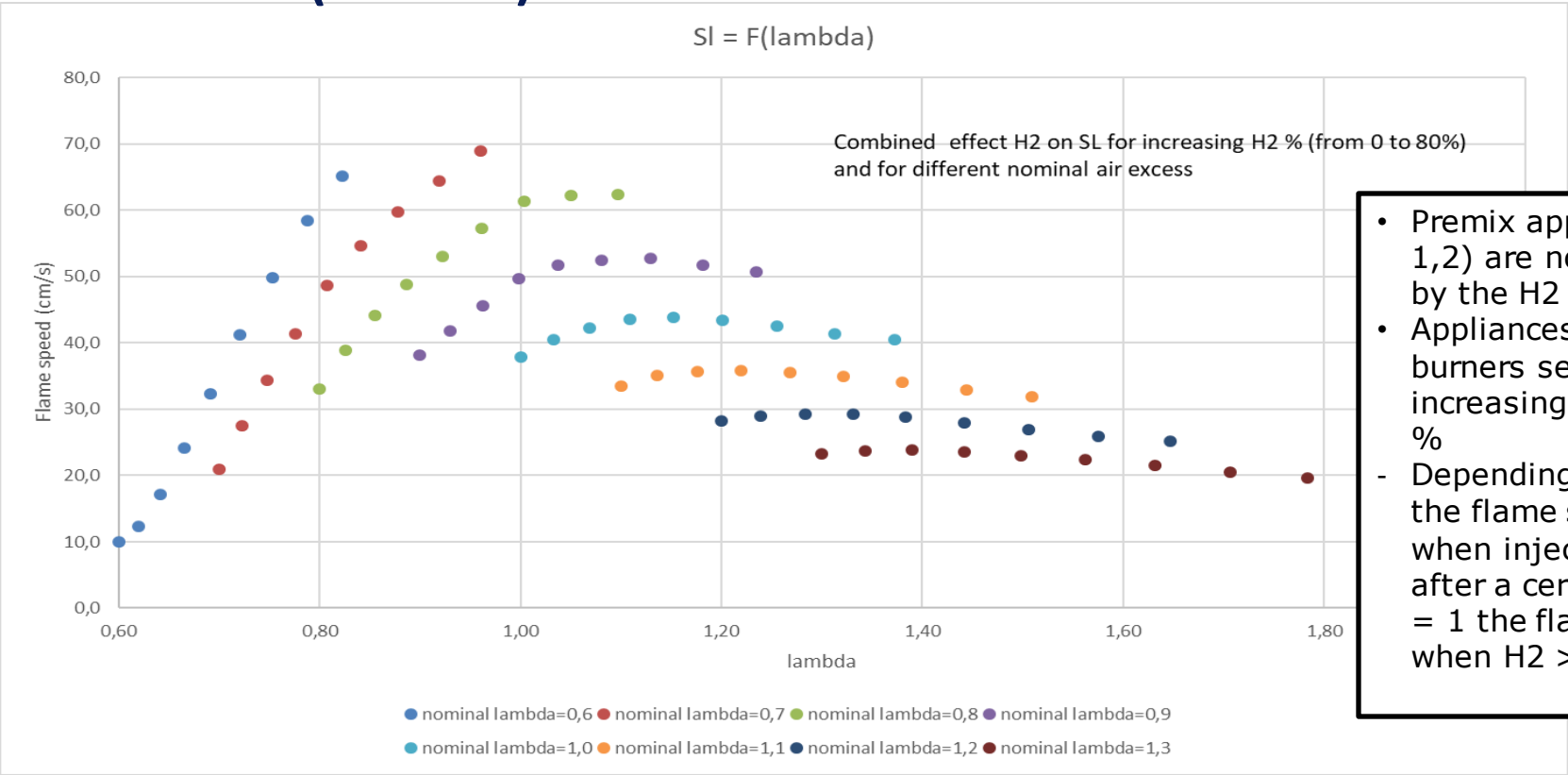
FB is more likely to happened with atm. appliances (detection with Temperature proble at top & below burner when possible).

Labs will are as far as possible film open flames and observe possible noise increase.

Justification of the testing proposal

FLAME SPEED

Observations : The flame speed is very much depending on the initial air excess (lambda) in the front flame



- Premix appliances (eg. Lambda = 1,2) are not very much impacted by the H2
- Appliances with atmospheric burners see the flame speed increasing very fast with the H2 %
- Depending on the burner type the flame speed may increase when injecting H2 AND decrease after a certain % (eg for lambda = 1 the flame speed is reducing when H2 > 40%)

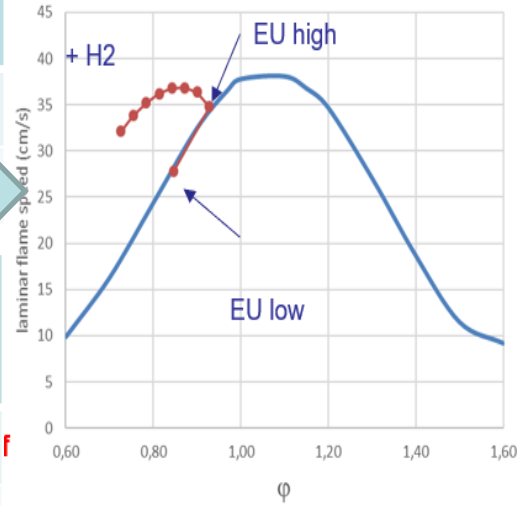
Testing part 3

Test of the impact of adjustment (premix appliances)

Wobbe

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

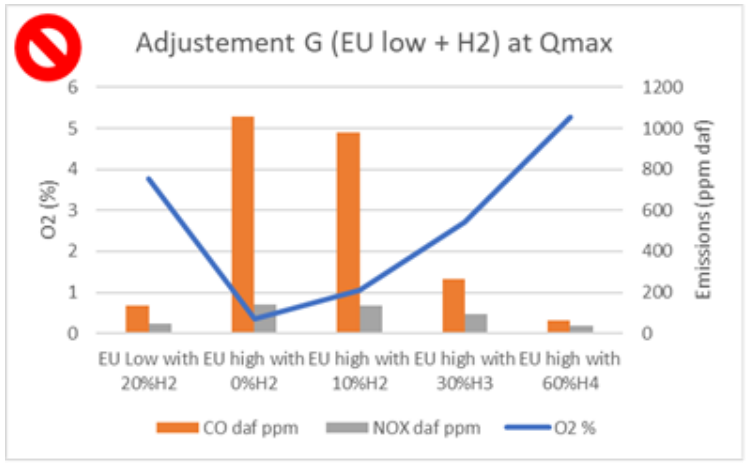
CASE	EU low + 20% H2	EU low +0 to 60% H2	CH4	EU high + 20% H2	EU high + 0 to 60% H2
G	Adjusted	→	→	→	Used
H		Used	←	Adjusted	

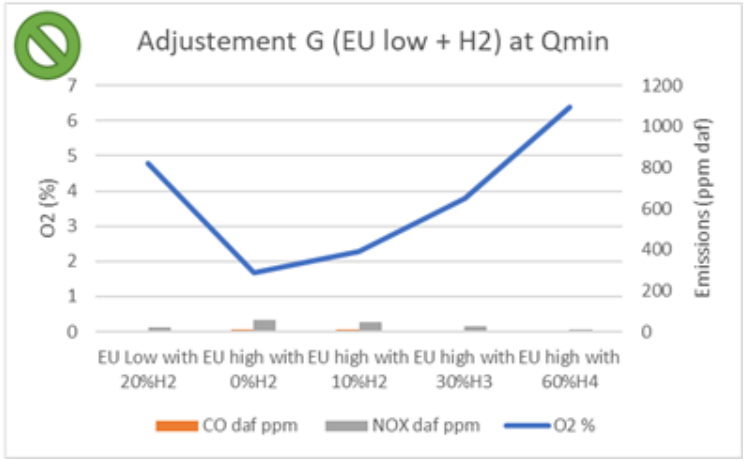


equivalence ratio φ

$$\varphi = \frac{V_{air,,min}}{\dot{V}_{air,actual}} = \frac{1}{\lambda}.$$

Some results





Condensing boiler with premix burner

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

Some picked up results

1) Adjustment G is so far the most extreme situation seen **for premix condensing boiler**.
2) Flashback may occur after long operation time (**Cooker hob**) and may not always be easy to see (partial flashback)

Additional slides

Test protocol elements (mainly from the GRANT AGREEMENT)

SCOPE
(appliances to test)

DOMESTIC & COMMERCIAL APPLIANCES:
- *Boiler*
- *Water heaters*
- *Cookers*
- *Fires & Heaters*
- *Catering*

& NEW TECHNOLOGIES:
- *GHP*
- *mCHP*
- *FC*

FOCUS
(what to measure)

SAFETY
- *CO*
- *Flashback*
- *Overheating*

EMISSION
- *NOx*
- *CO*
- *CxHy*

EFFICIENCY
- *Flue gas Eff*
- *El. Cons.*

OPERATION

RELEVANT (influence) PARAMETERS

GAS
- Initial Natural gase composition
- % of H2 (up to 60%)
  - Low = <10% Vol.
  - Medium = 10-30% Vol.
  - High = 30-60% Vol.
- Rate of change of H2 (ROC)

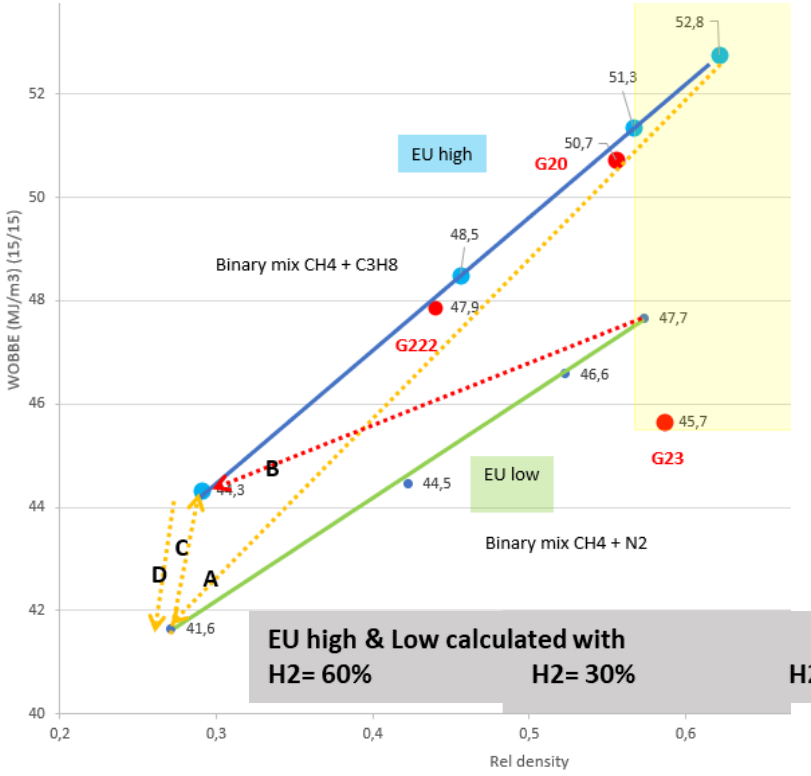
APPLIANCE
- Appliance adjustment (for a given gas)
- Qmin/Qmax
- Used /unused appliances?

TEST CONDITIONS
- Extreme conditions (Air temperature, gas overpressure, cold start)
- Long term impact of H2
- Other

Testing part 3

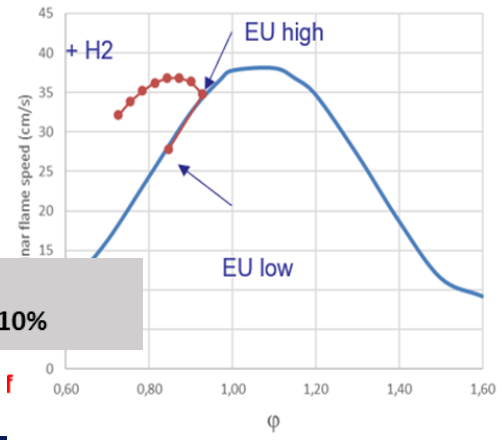
CASE	EU low + H2	EU low	CH4	EU high + H2	EU high
A	Used	←	←	←	Adjusted
B		Adjusted	→	Used	
C	Adjusted	→	→	Used	
D	Used	←	←	Adjusted	

Investigation of Flame speed impact and or CO

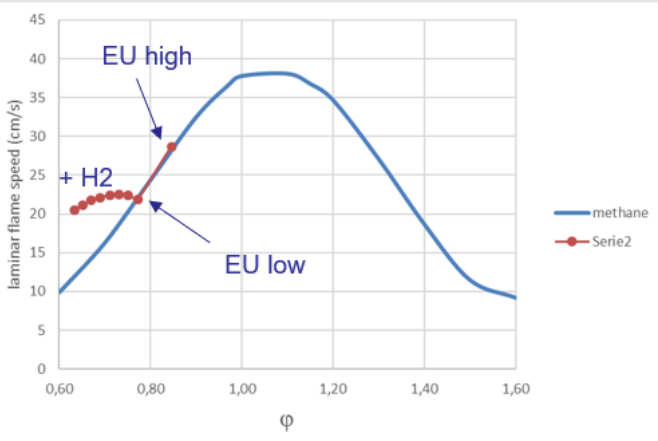


EU high & Low calculated with
H2= 60% H2= 30% H2= 10%

B



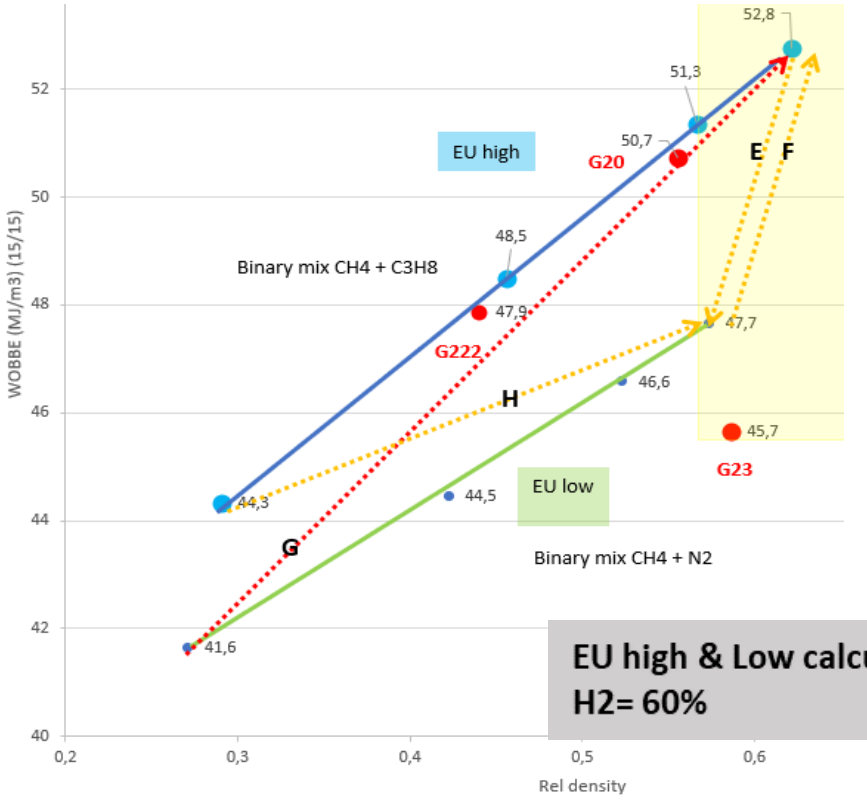
A



Testing part 3

CASE	EU low + H2	EU low	CH4	EU high + H2	EU high
E	NOT SPECIFIC THyGA (was tested in GASQUAL)	Used	←		Adjusted
F		Adjusted	→		Used
G	Adjusted	→			Used
H		Used	←	Adjusted	

Other adjustments tests with focus on CO



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