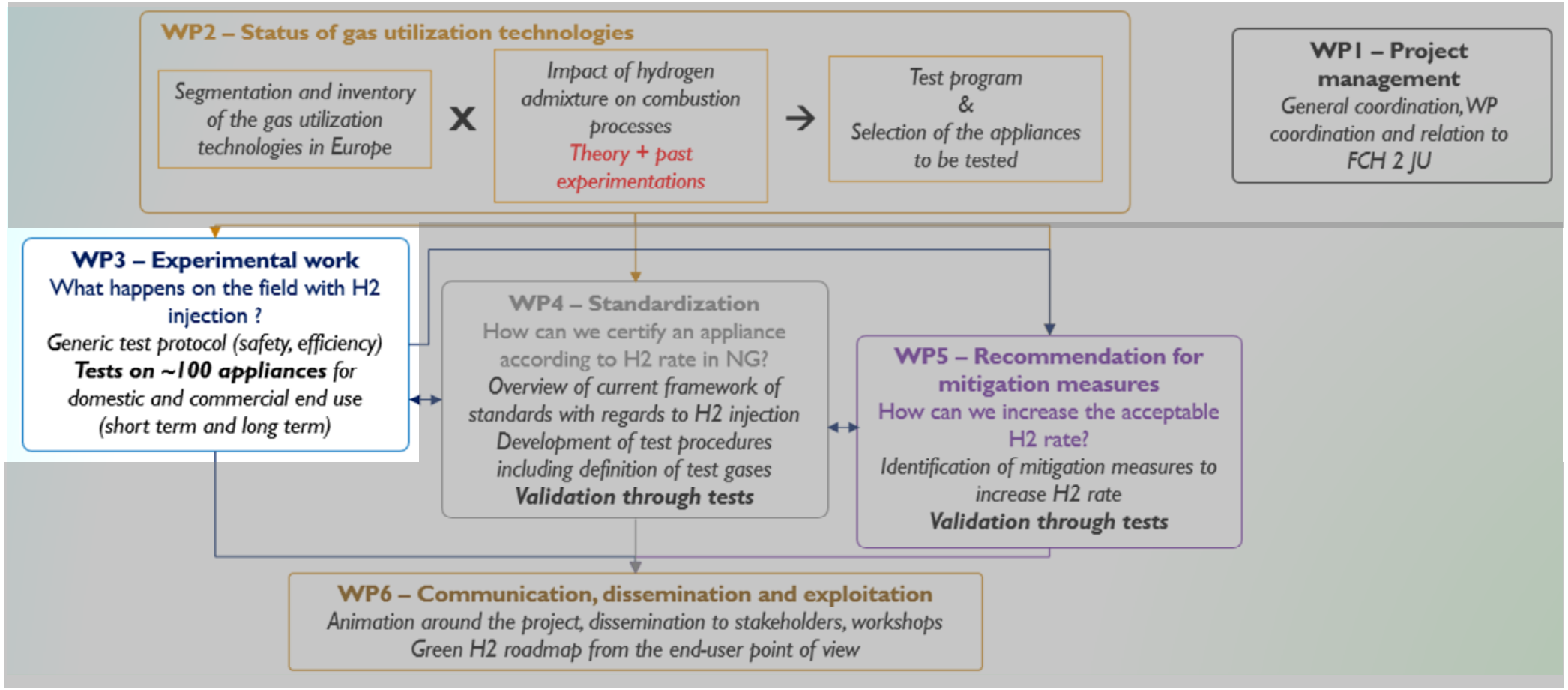
Testing Hydrogen admixture for Gas Applications

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.

THyGA WP organisation



Important: the protocol discussed in this document relates to WP3 only (so it does'nt cover the testing for WP4 & WP5)

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.

Protocol history

The protocol proposed in this document is resulting from **the analysis of previous testing done** in the frame of projects like NATURALHY and **analysis of results from combustion science** especially on the impact of H2 on flame speed

The protocol has been discussed and re-designed at the **Kick off meeting of THyGA** and later at several dedicated meetings with the project partners.

The present version is reflecting the work done, the discussions and decisions taken so far during the project.

The project is open to suggestions for improvements when relevant and when possible (if additional costs that may occurs are not prohibitive). Further changes and fine-tuning are planned in the course of the project in light of the results.

Timeline to build the test protocol

THyGA

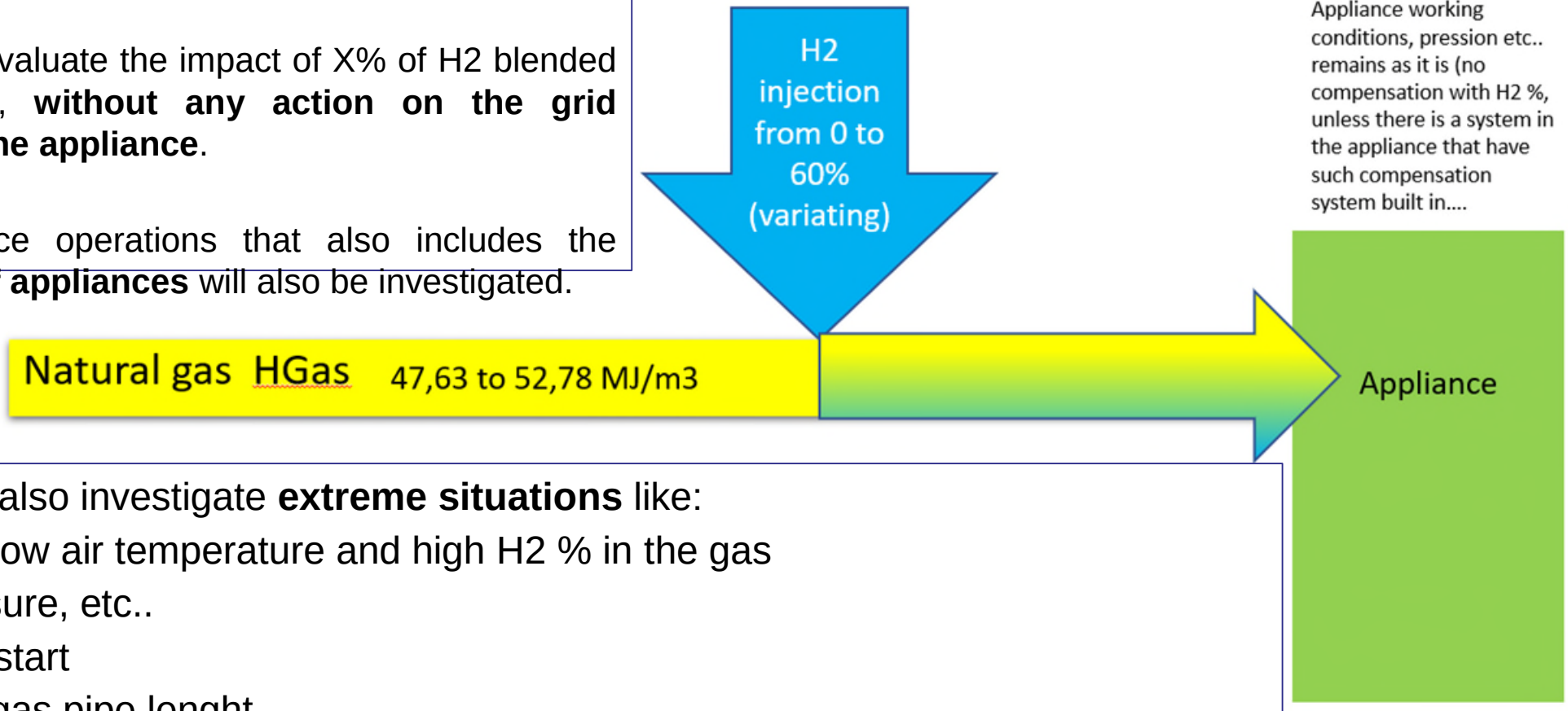
1. First discussion with all partners (end of January 2020) at Kick off meeting -> **experimental test protocol V01**
2. Calculation work for W,d,SL & other WP2 activities related to the test protocol. (eg. Using Combustion science in support of the work)
3. Testing Protocol based on combustion science & previous test results (this document). First input from TCs **experimental test protocol V02**
4. Real testing/validation of the protocol (appliance tested by one or two labs) Spring 2020
5. Discussion of the results. Simplification in view of optimizing the value of testing (workshops in May) -> **test protocol V03**
6. Tuning in view of results from all labs (September or so) **test protocol V04** (after that fine tunings may still be done in light of new results)

Overall philosophy of THyGA TESTING in WP3

The project aim at tests 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 (pressure) or the appliance**.

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



We will also investigate **extreme situations** like:

- Very low air temperature and high H2 % in the gas
- Pressure, etc..
- Cold start
- Flue gas pipe lenght

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

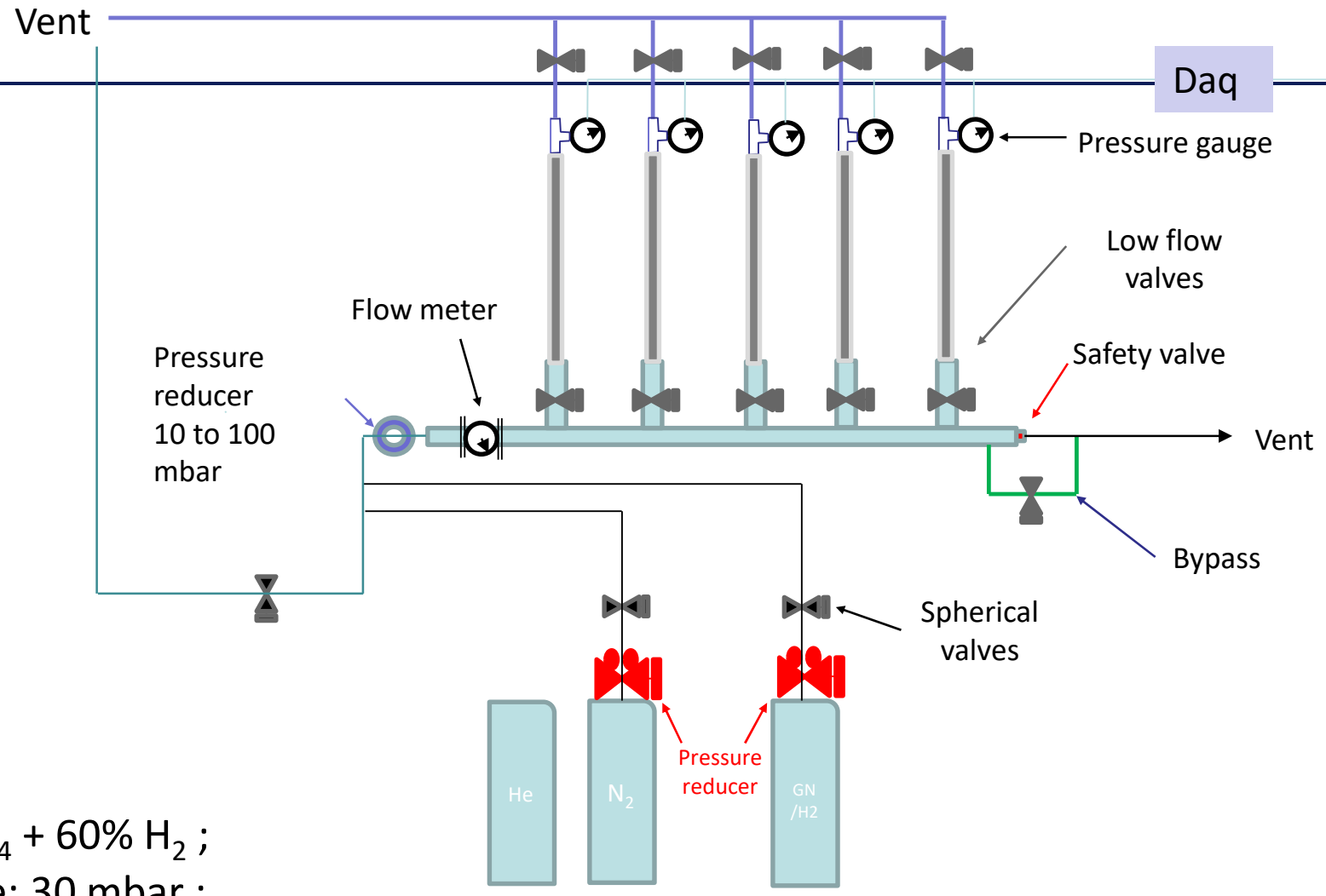
- Appliance adjustment (for a given gas)
- Qmin/Qmax
- Used /unused appliances?

TEST CONDITIONS

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

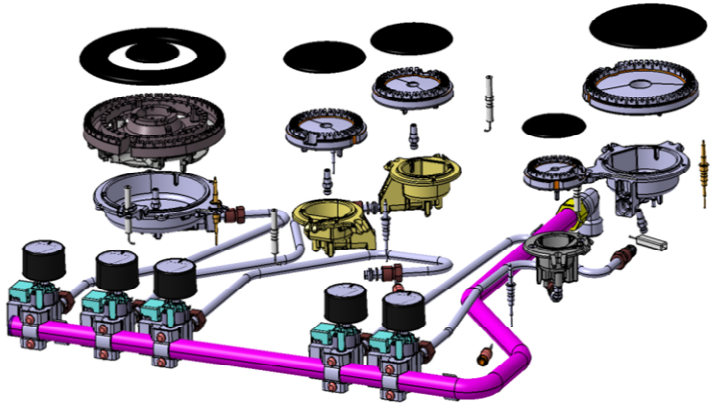
Leakage tests

Set up



- Gas: CH_4 + 60% H_2 ;
- Pressure: 30 mbar ;
- Monitoring of the pressure in the lines ;
- Measuring the flow of each line alternatively

Old and new components (from gas existing lines and appliances)



Combustion tests

“Standard tests” and “Additional tests”

We have to optimize the work so to get the best out of the time and budget allocated. For that reason we need to make sure that all the measurements and testing done have an added value to the project.

We have organised the work as following

1) **Standard test** that apply to all appliances and covers the majority of cases (systematical testing)

2) **Addtitional testing**, on some parameters or some aspects and for some segments when this is relevant). Those should bring information on aspects that are not treated in 1) and that cannot be treated extensively or systematically for cost reasons

TEST GASES FOR THyGA WP3

TEST GASES FOR THyGA

Considering EU distributed H gas

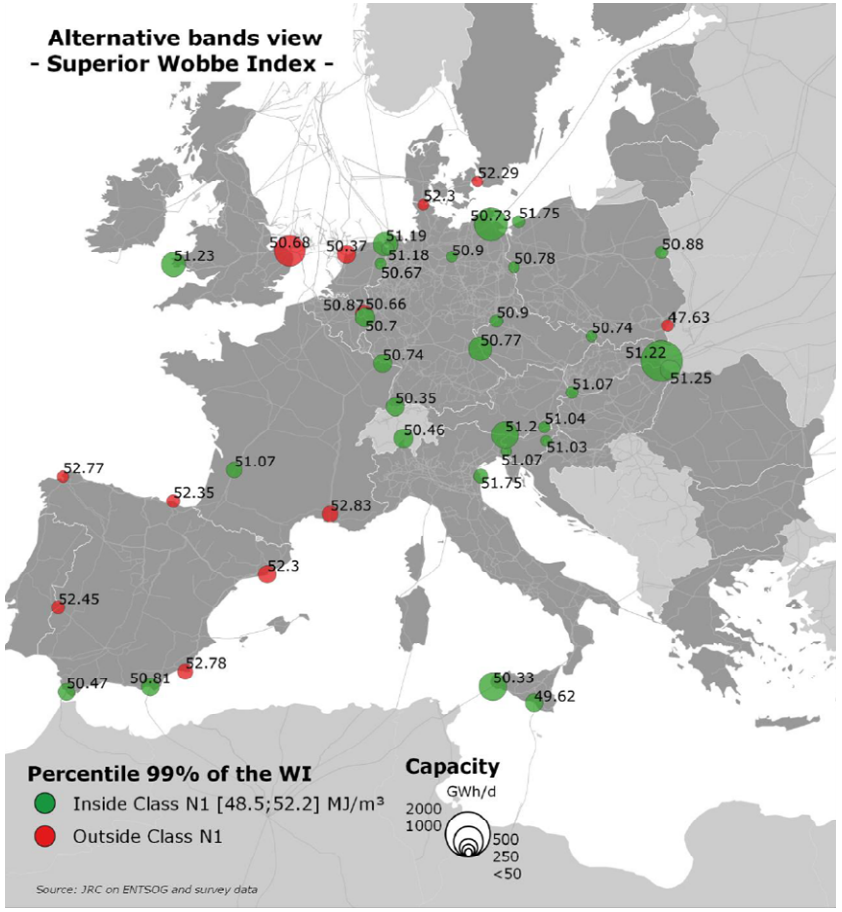
Real gas spec. Ws distributed in the EU:

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

Elements considered for the design of the testing programme in WP3:

- Statistical approach based on as real conditions as possible
- Investigating the worsening factors.
- Testing 100 appliances (only) compared to the > 200 M installed will necessarely have limitations.
- Optimise the test programme to get the best value from the work done → making some choice: getting insight on less probable situations or having consolidated conclusions on most probable scenarios?

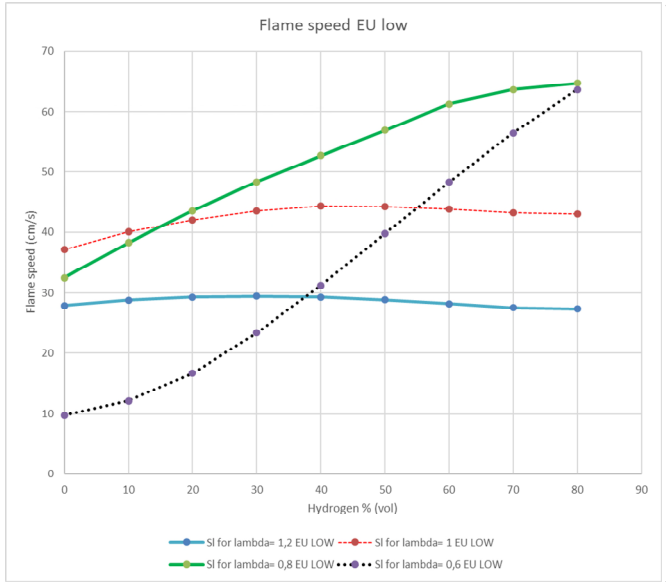
DISCLAIMER. JRC/ENTSOG 2019
The data source for the sensitivity analysis is public, gas quality data for 2015 and 2016 were provided by ENTSOG for the SFGas study on natural gas quality. These data sets correspond to a limited subset of all points.
The numbers on the graph are the measured 99th percentile 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.

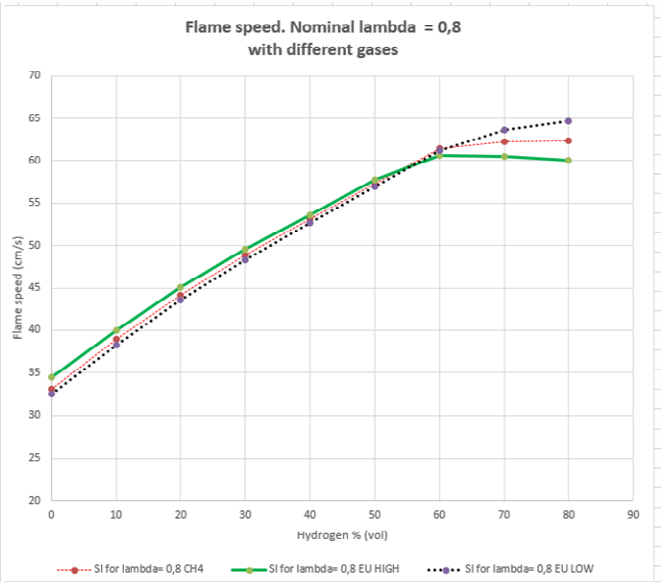


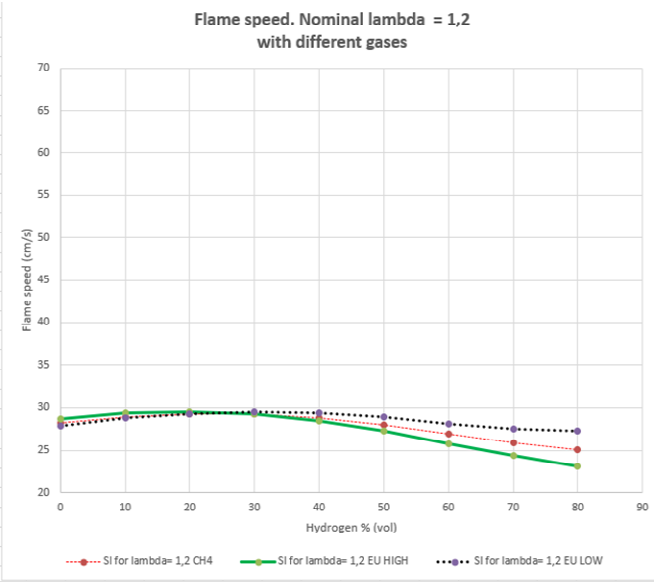
(*) *99% percentile* = 48,5 to 52,2 MJ/m3 (15/15) / **dWobbe = 3,7 MJ**

TEST GASES FOR THYGA : Short term tests

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



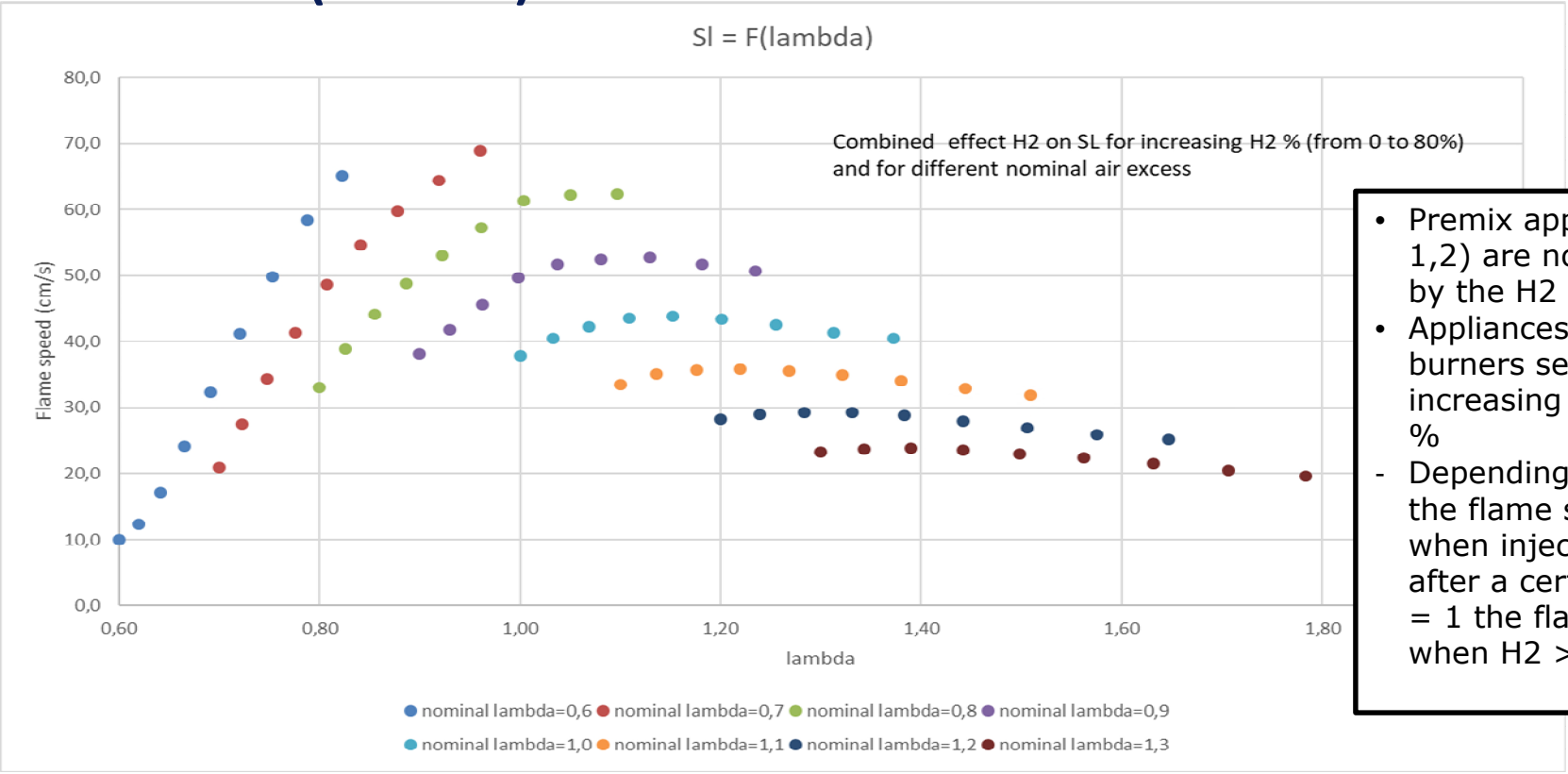




Justification of the testing proposal

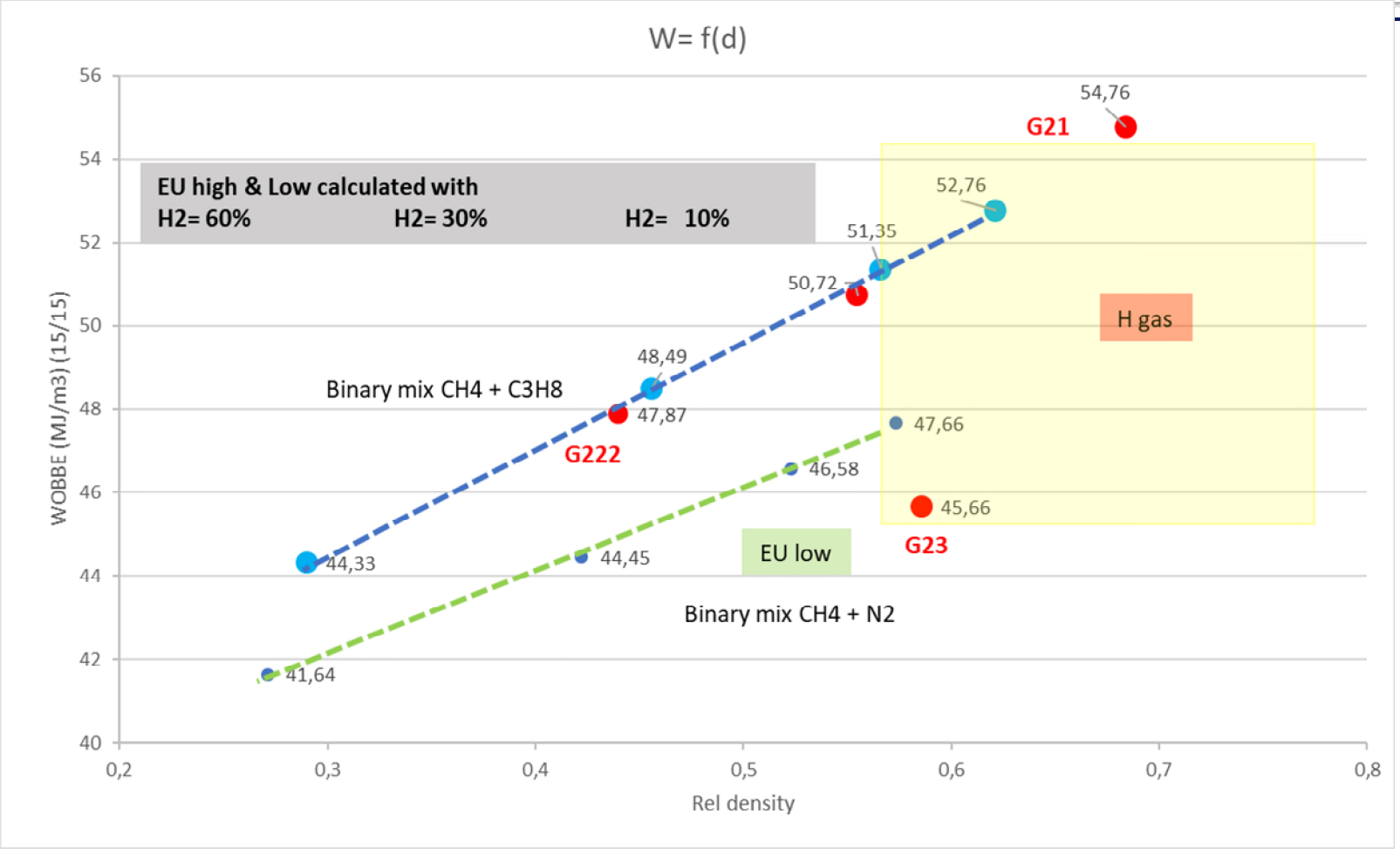
FLAME SPEED

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%)

TEST GASES FOR THyGA: Short term tests



Conclusion: Nominal gases chosen for the tests are *CH4, EU low, EU high* combined with H2. In addtion, tests will comprise various scenarions of adjustement with thoses gases (with/without H2) and the use of gases at the other extreme of the range (with and without H2)

TESTING APPROACH

Approach for testing

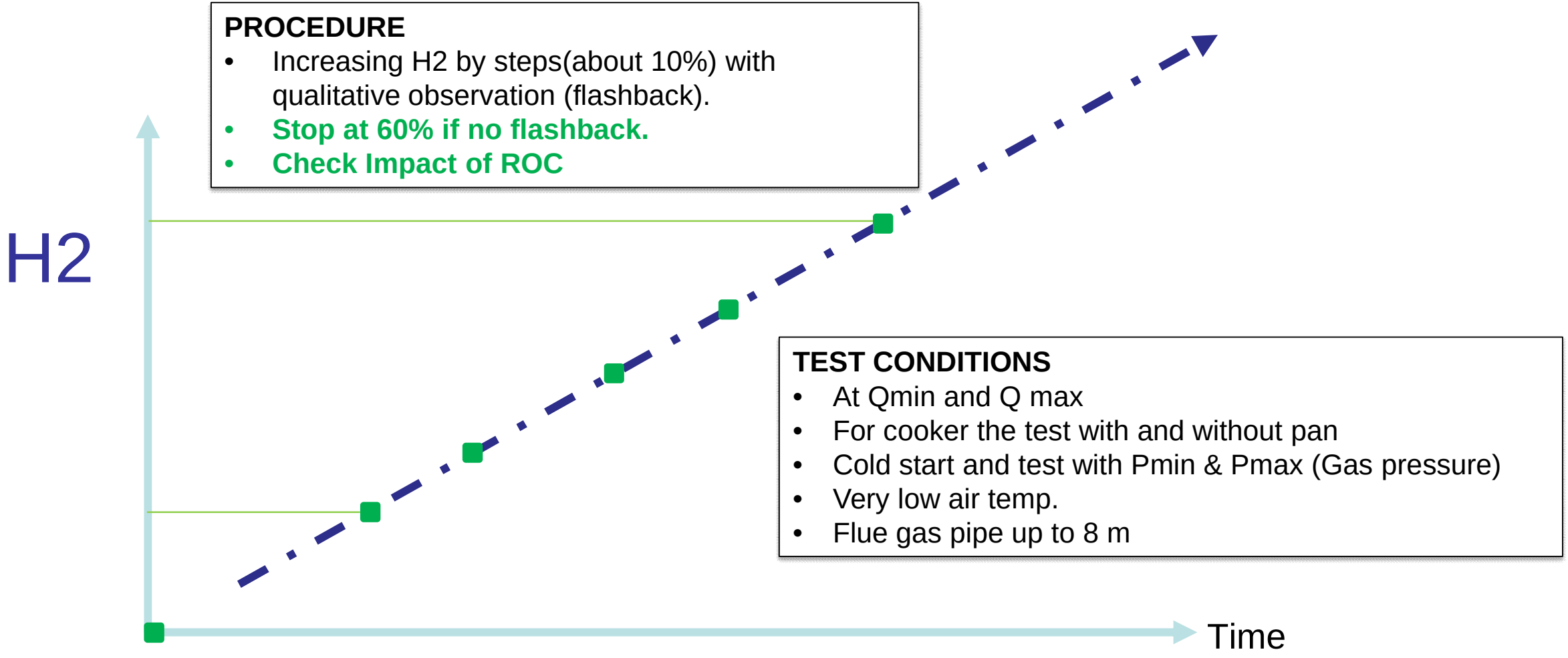
- PART 1 Detemination of flash back or other safety and operational issues (SAFETY)
- PART 2 Measurement efficiency and emissions (PERFORMANCES)
- PART 3 Testing of different adjustment scenarios

PART 1 SAFETY

Testing part 1 SAFETY. Increasing H2 until Flashback

PROCEDURE

- Increasing H2 by steps(about 10%) with qualitative observation (flashback).
- **Stop at 60% if no flashback.**
- **Check Impact of ROC**



TEST CONDITIONS

- At Qmin and Q max
- For cooker the test with and without pan
- Cold start and test with Pmin & Pmax (Gas pressure)
- Very low air temp.
- Flue gas pipe up to 8 m

Late ignition test and other safety test

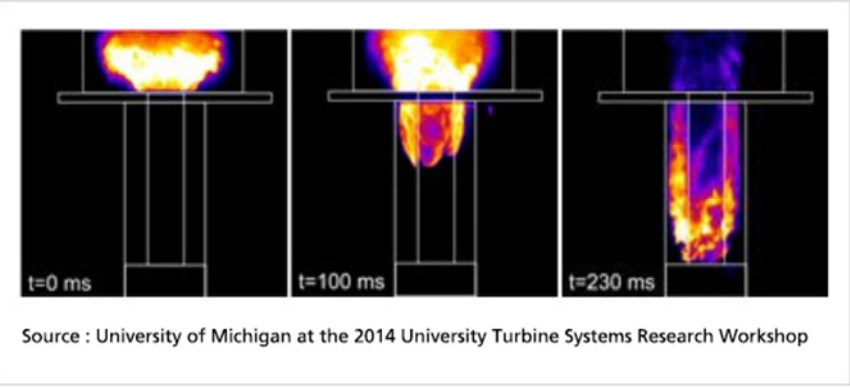
a) Impact of H2 on flame detection (optical, Temp)

b) Late ignition test (with NG/H2 blends) according product standards

Late ignition is presently investigated:

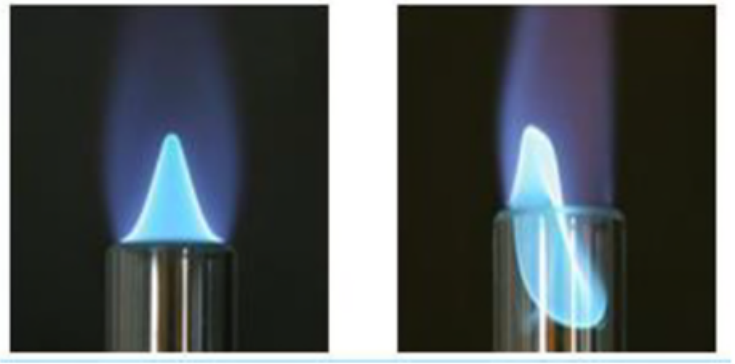
- Limited possibilities of testing in labs.
- Possible theoretical evaluation of the increased risk of Mixing H2 in NG
- Use of existing experience from other projects related to H2
- Appliance strategies in case of non-ignition

Flashback



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

FIGURE HIPS GERG PROJECT DGC



Picture THyGA application 2019

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 is possible)

Labs will also as far as possible film open flames and register the noise.

PART 2 PERFORMANCES

Testing part 2 PERFORMANCES.

Contractual scope (Grant Agreement)

- Low = <10% Vol.
- **Medium = 10-30% Vol. (Focus priority range)**
- High = 30-60% Vol

- **Efficiency**
- **Emissions (CO, NOx, CxHy, H2)**
- **Performances degradation (eg. loss of power)**

PART 3 ADJUSTMENT TESTS

Testing part 3 Adjustments

Appliance adjustment (for a given gas) (only few segments can be adjusted!)

Lessons from the project Gasqual *(http://www.gasqual.eu/)*

- Appliances that are adjustable are generally adjusted to G20 during production
- Appliances are delivered with instructions on O2 or CO2 % to be achieved for the servicing
- Discrepancies between the reality and the national regulation related to adjustment policies
- Adjustment is one of the most critical point impacting the safety of gas appliances when gas quality is changing
- Adjusting appliances to G20 whatever the gas is distributed seems to be the safest option (implemented in DK)
- Adjustment method to perform this have been developped

Only few segments are adjustable

Testing part 3

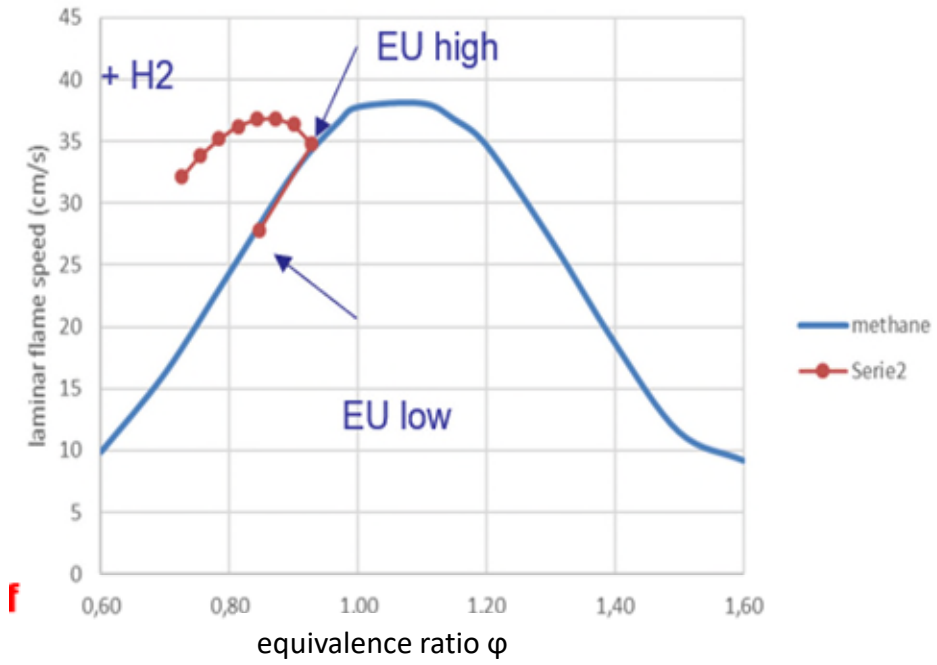
Test of the impact of adjustment (premix appliances)

Example:

ADJUSTMENT EU LOW -> Gas used= EU HIGH + H2

The flame speed changes first due to the change in the air excess.

It changes further with the addition of H2

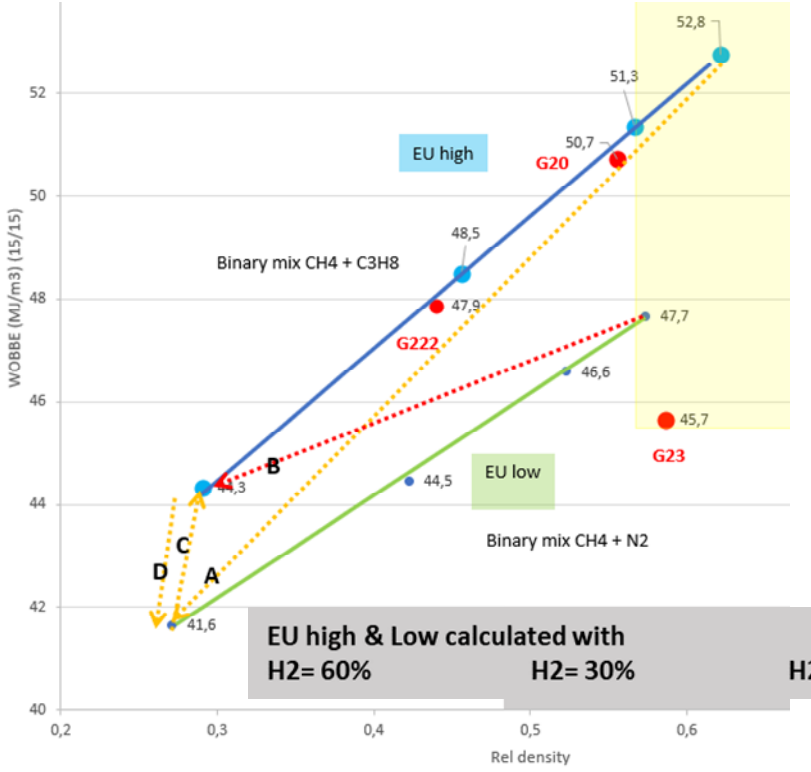


$$\varphi = \frac{\dot{V}_{air,,min}}{\dot{V}_{air,actual}} = \frac{1}{\lambda}.$$

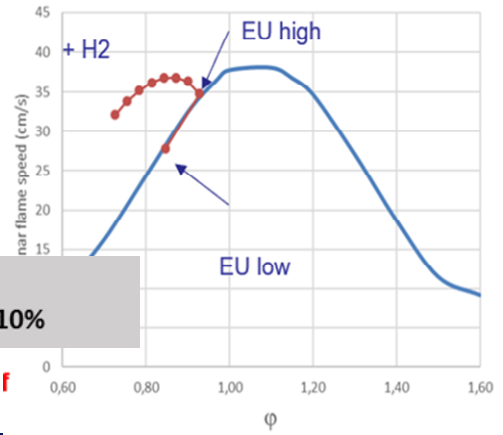
Testing part 3

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

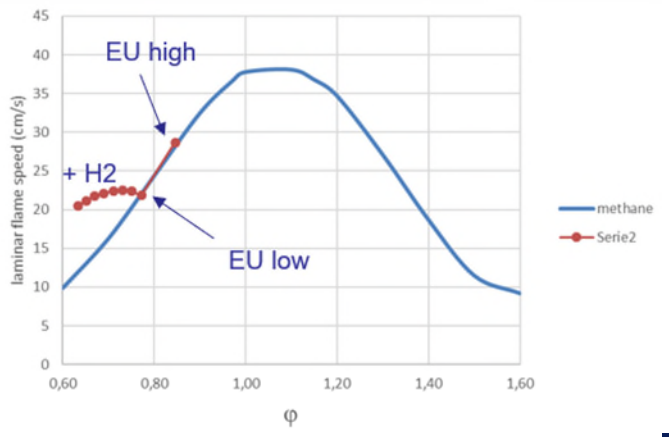
Investigation of Flame speed impact and or CO



B



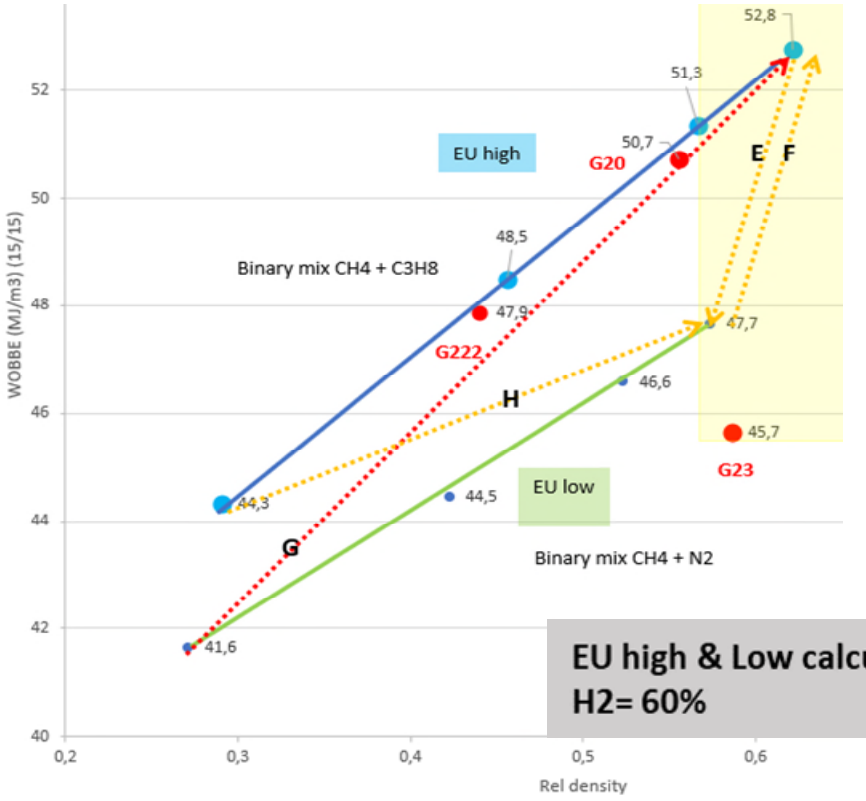
A



Testing part 3

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

Other adjustments tests with focus on CO



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

Testing part 3

Test of the impact of adjustment (premix appliances)

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	

LONG TERM TESTING FOR THYGA

- TEST GASES FOR LONG TERM WILL BE NATURAL GASES distributed **with addition of H2 (for costs reasons)**

- Exact protocol in development