THyGA WP4

Certification & Standardization: workshop

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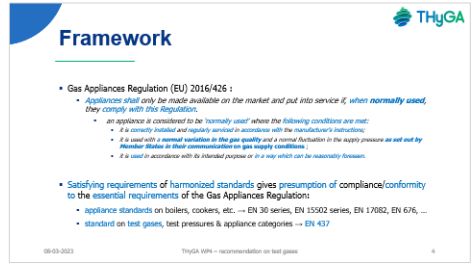
Objectives of workshop

- A **WORKshop**, not just a presentation.
- **Check thoughts** on **test gases**.
- Now that the results of the testing (WP3) are available, it is time to **couple** the **outcome of** the **testing to** the **identified risks of H_2NG supply**.
- To do so, **check** if **all risks** are well **identified**.
- Comment: **overlap** with **ongoing work in parallel!**

Deliverables

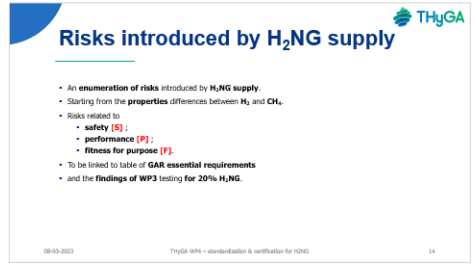
NEW

- D4.3 – **thoughts** on **test gases and**
  - proposing reference and limit gases ;
  - based on current approach regarding reference and limit gases ;



NEW

- D4.3 – … **support** for **H_2NG risk analysis** and **assessment** of **gas appliance standards** based on
  - a general risk identification regarding safety, performance and fitness for purpose ;
  - the results and findings from THyGA WP3 testing ;
  - the conclusions of existing WP2 (D2.2 and D2.3) and WP4 deliverables ;
  - the exchanges with relevant stakeholders → workshop on 08/03 AM ;
  - and linked to the corresponding GAR (EU) 2016/426 essential requirements.



Framework

- Gas Appliances Regulation (EU) 2016/426 :
  - *Appliances shall only be made available on the market and put into service if, when* ***normally used****, they comply with this Regulation.*
    - *an appliance is considered to be 'normally used' where the following conditions are met:*
      - *it is correctly installed and regularly serviced in accordance with the manufacturer's instructions;*
      - *it is used with a* ***normal variation in the gas quality*** *and a normal fluctuation in the supply pressure* ***as set out by Member States in their communication*** **on gas supply conditions** ;
      - *it is used in accordance with its intended purpose or in a way which can be reasonably foreseen.*

- Satisfying requirements of harmonized standards gives presumption of compliance/conformity to the essential requirements of the Gas Appliances Regulation:
  - appliance standards on boilers, cookers, etc. → EN 30 series, EN 15502 series, EN 17082, EN 676, …
  - standard on test gases, test pressures & appliance categories → EN 437

EN 437

- Definitions:
  - **gas family**: group of gaseous fuels with **similar burning behaviour** linked together by a **range of Wobbe indices**

  - **gas group** (like H, E, L): specified range of Wobbe index **within** that of the **family concerned**
    - *Note 1 to entry: This range is determined on the general principle that appliances using this gas group operate safely when burning all gases within this range without adjustment.*
    - *Note 2 to entry: **Adjustment** of the appliance may be **permitted** in accordance with the special national or local conditions that apply in some countries.*
  - **appliance category**: means of identifying the gas families and/or gas groups for which a gas appliance is **designed to operate safely** and to the **desired performance level**.

EN 437

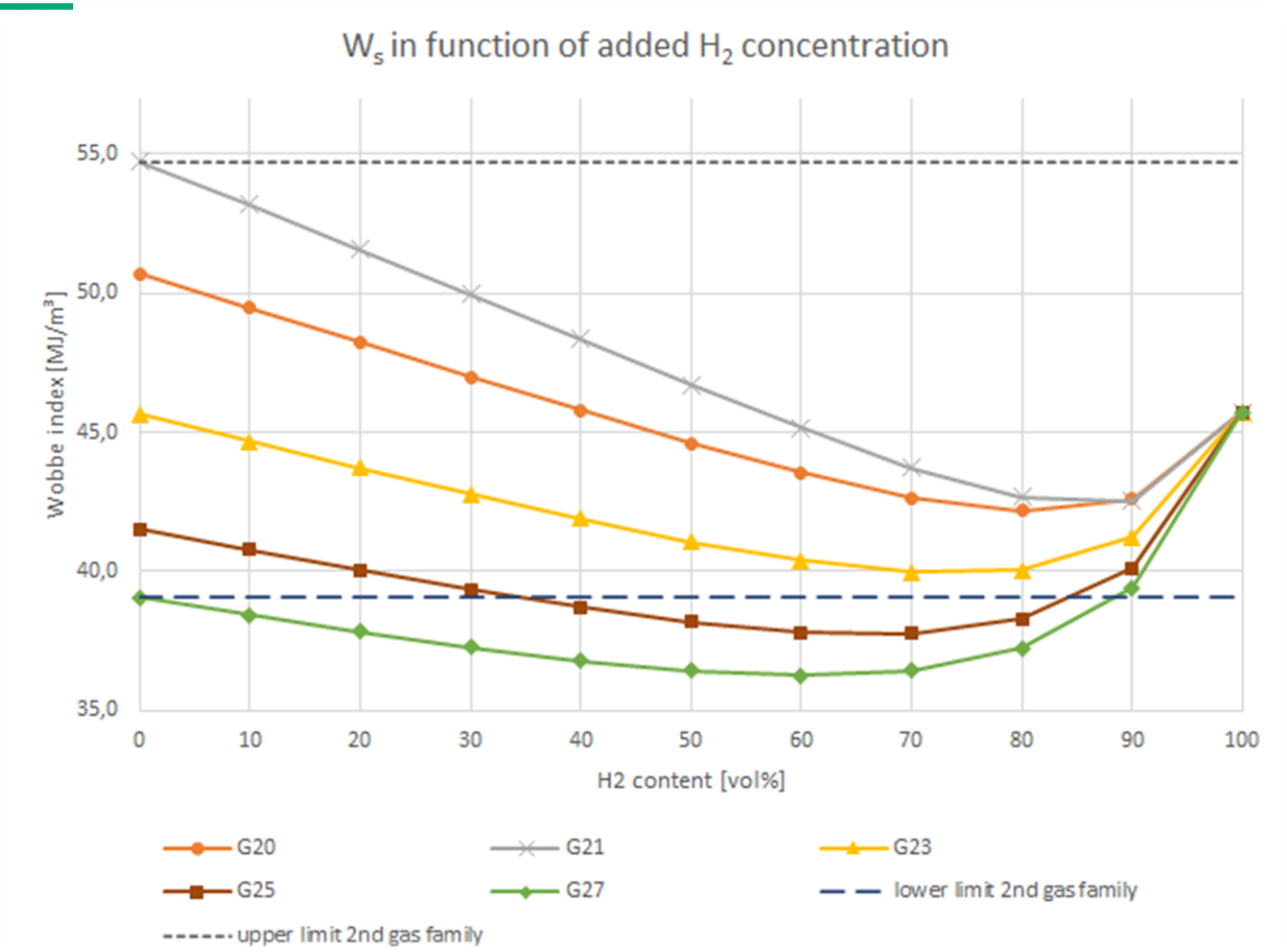
- Definitions:
  - **test gas**: gases intended for the **verification** of the **operational characteristics** of gas appliances
    - *Note 1 to entry: Test gases include reference and limit gases.*
  - **reference gas**: test gas with which **appliances operate under nominal conditions** when they are supplied at the corresponding normal pressure
  - **limit gas**: test gas **representative** of the **extreme variations** in the **characteristics of the gases for which** appliances have been **designed**

EN 437 – comments for H_2NG supply

- Definitions:
  - **gas family**: group of gaseous fuels with similar burning behaviour linked together by a range of Wobbe indices
    - similar burning behaviour:
      - probably **OK up to 20 % H_2 (?)**
    - linked together by a range of Wobbe indices:
      - **OK for H-gas** as natural gas family range (**2nd family**) ranges from **39,1 up to 54,7 MJ/m³** and **H_2** has WI of **45,88 MJ/m³**
      - but **not necessarily for L-gas**

2nd gas family **OK for H-gas** up to 20 % H_2 based on similar burning behaviour and current 2nd family WI range

WI of H_2NG admixtures



EN 437 – comments for H_2NG supply

- Definitions:
  - **gas group** (like H, E, L): specified range of Wobbe index within that of the family concerned
    - *Note 1 to entry: This range is determined on the general principle that **appliances using this gas group operate safely when burning all gases within this range without adjustment**.*
    - *Note 2 to entry: **Adjustment of the appliance** may be **permitted** in accordance with the special national or local conditions that apply **in some countries**.*

Taking in account a min. W_S of 46,44 MJ/m³

- H group (45,7 – 54,7 MJ/m³): WI stays <u>always</u> within range up to 7 % H2
  E group (40,9 – 54,7 MJ/m³): WI stays <u>always</u> within range up to 60 % H2

Or limit the min. Wobbe index of NG?
Or increase the Wobbe index range?

gas group limits do not need to change if H_2 limited to above concentrations; defining new gas groups can obviously overcome the issue.

EN 437 – comments for H_2NG supply

- Definitions:
  - **appliance category**: means of identifying the gas families and/or gas groups for which a gas appliance is designed to **operate safely and to the desired performance level**
    - **fluctuating H_2 concentrations may compromise** the above definition as it
      - **widens the potential WI range** of the gases supplied to the appliance
      - **relevant H_2 presence increases existing risks** (cf. light-back, delayed ignition, …)

e.g. CEN/TC109 proposal

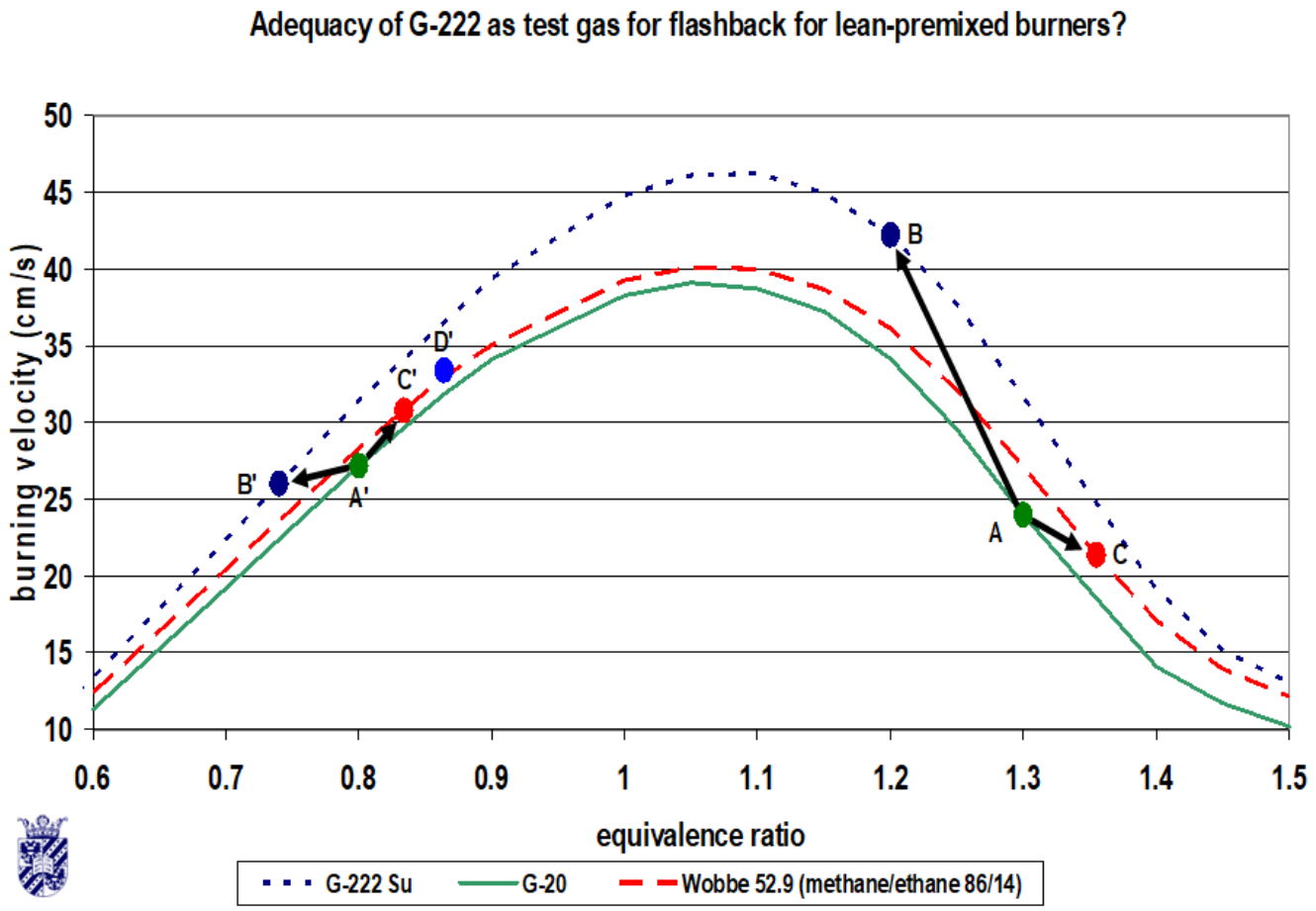
The appliance category needs to limit the H_2 concentration → generally defined (e.g. I_{2H} includes H_2 varying between 0 and 20 %) or a supplementary identification on a max. acceptable H_2 concentration the appliance is designed for.

EN 437 – comments for H_2NG supply

- Test gases: **limit gases**
  - test gas representative of the **extreme variations in the characteristics of the gases for which appliances have been designed**
  - current limit gases (for group H):
    - G21 87 % CH4 + 13 % C3H8 → incomplete combustion and sooting limit gas
    - G222 77 % CH4 + 23 % H2 → light-back limit gas
    - G23 92,5 % CH4 + 7,5 % N2 → flame lift limit gas
    - G24 68 % CH4 + 12 % C3H8 + 20 % H2 → overheating limit gas
  - **G21** and **G23** to be maintained as H_2 concentration may vary from 0% to m concentration
  - **light-back limit gas**: distinction between technologies
    - **fully (lean) premixed burners**: covered with **G21 or G24 (?)**
    - **partial premixed burners + fully premixed burners with constant λ**: for **20% H_2NG** 65 % CH_4 + 35 % H_2 (= **G22**)
  - **overheating limit gas**: G24 overload + flame speed → OK for fully premixed burners, but what about others? **(?)**

Same flame speed increase to be calculated as between G20 and G222?

EN 437 – comments for H_2NG supply



EN 437 – comments for H2(NG) use

- Test gases: **reference gas**
  - test gas with which **appliances operate under nominal conditions when they are supplied at the corresponding normal pressure**
  - current reference gas (for groups H and E):
    - G20 100% CH4 → used for assessing most of risks apart from extreme variations in characteristics of gases the appliance has been designed for
  - H_2 presence may impact risks assessed with G20 ⇒ need for a 2nd reference gas
  - 2nd ref. gas: CH_4 with max. H_2 concentration

But what about nominal settings? Specific for each ref. gas or 1 setting for both?

Risks introduced by H_2NG supply

- An **enumeration of risks** introduced by **H_2NG supply**.
- Starting from the **properties** differences between **H_2** and **CH_4**.
- Risks related to
  - **safety [S]** ;
  - **performance [P]** ;
  - **fitness for purpose [F]**.
- To be linked to table of **GAR essential requirements**
- and the **findings of WP3** testing **for 20% H_2NG**.

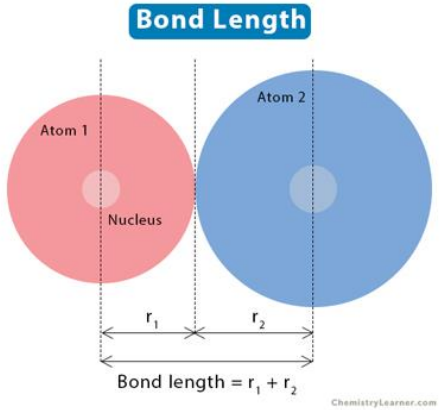
Properties H_2 vs. CH_4

Property	Unit	CH_4	H_2
Atomic radius	Å	H 0,25 C 0,70	H 0,25
Bond length	Å	1,09 (C-H bond)	0,74
Gross Calorific Value	MJ/m³	37,78	12,1
Net Calorific Value	MJ/m³	34,02	10,2
Relative density	-	0,56	0,07
Wobbe index (using GCV)	MJ/m³	50,72	45,88
Laminar flame speed at λ = 1	cm/s	38,6	209,8
Adiabatic flame temperature λ = 1	°C	1.946	2.101
Flammability range in air	vol%	5 - 15	4 - 75
Min. air quantity for complete comb.	m³/m³	9,52	2,38
Min. ignition energy	mJ	0,28	0,02
Auto-ignition temperature	°C	595	560
Dewpoint temperature at λ = 1	°C	59	72
Explosion pressure (stoichiometric mixture)	bar	8	
Methane number	-	100	0
100 year GWP	x CO_2	28	11
Other	-	-	pale blue flame

15/15°C and 1013,25 mbar

Significantly different properties of H2 introduces **risks** for **appliances not designed for** supply with gases containing **relevant H2 concentrations**!

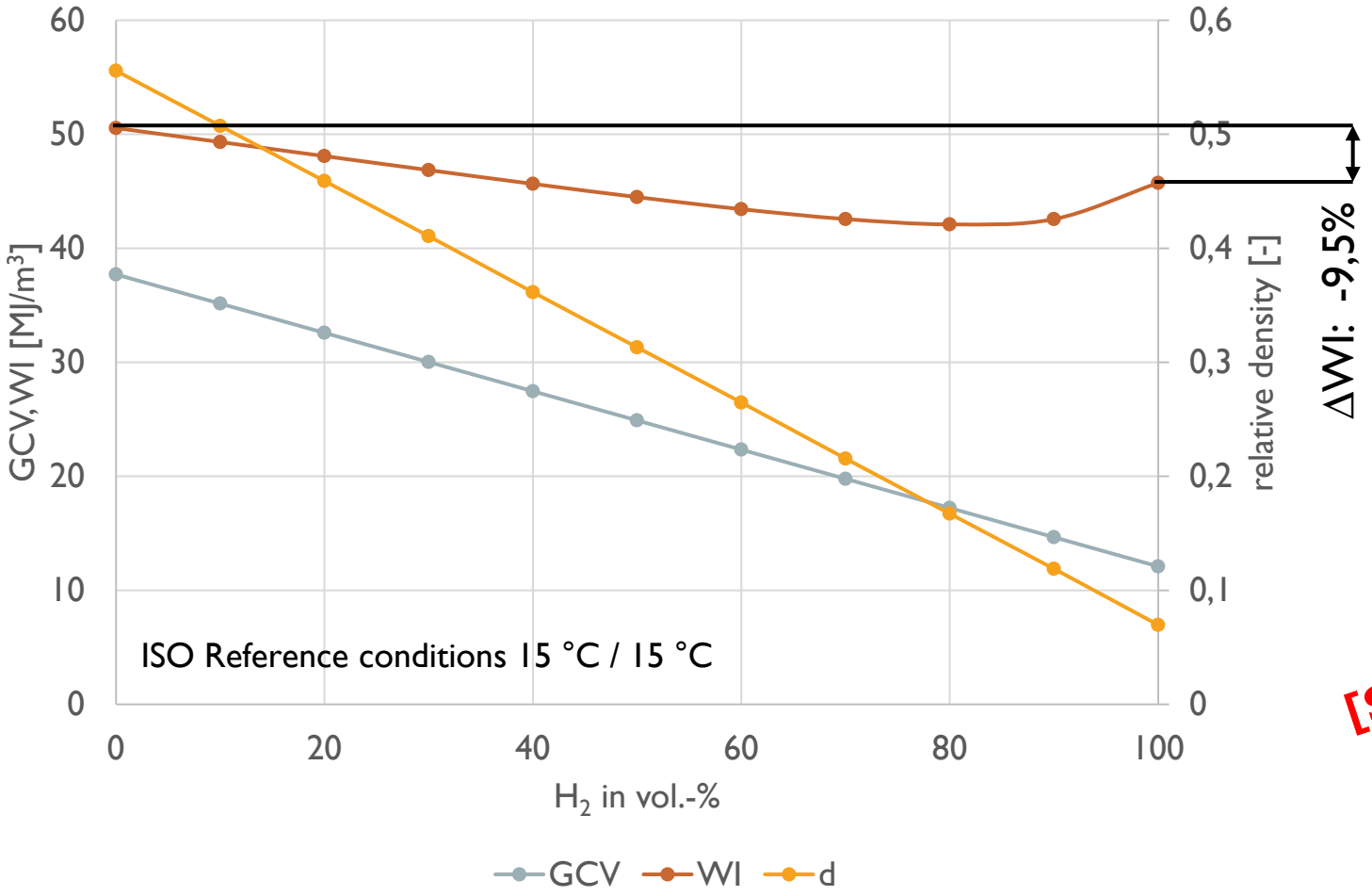
Impact + risk: atomic radius & bond length



- atomic radius: H 0,25 vs. C 0,70 Å
- bond length: 0,74 vs. 1,09 Å (of 1 C-H bond, but CH_4 forms a tetrahedron)
- impact
  - H_2 is much smaller molecule
- risk (cf. THyGA D3.7 on tightness testing)
  - unburnt gas leakage: CH_4 tight $\Rightarrow$ H_2 tight and at low pressures, the potential permeation of gas through the material can be neglected
  - unburnt gas leakage: **higher flow rate** through a hole $\rightarrow$ however, when gas flow is regular and smooth, essentially at low pressures, the difference between leakage rates in methane and hydrogen decreases to about 1,2 $\Rightarrow$ max. leakage rates to be evaluated in view of avoiding dangerous accumulation of unburned gas

[S]

Impact + risk: Wobbe index

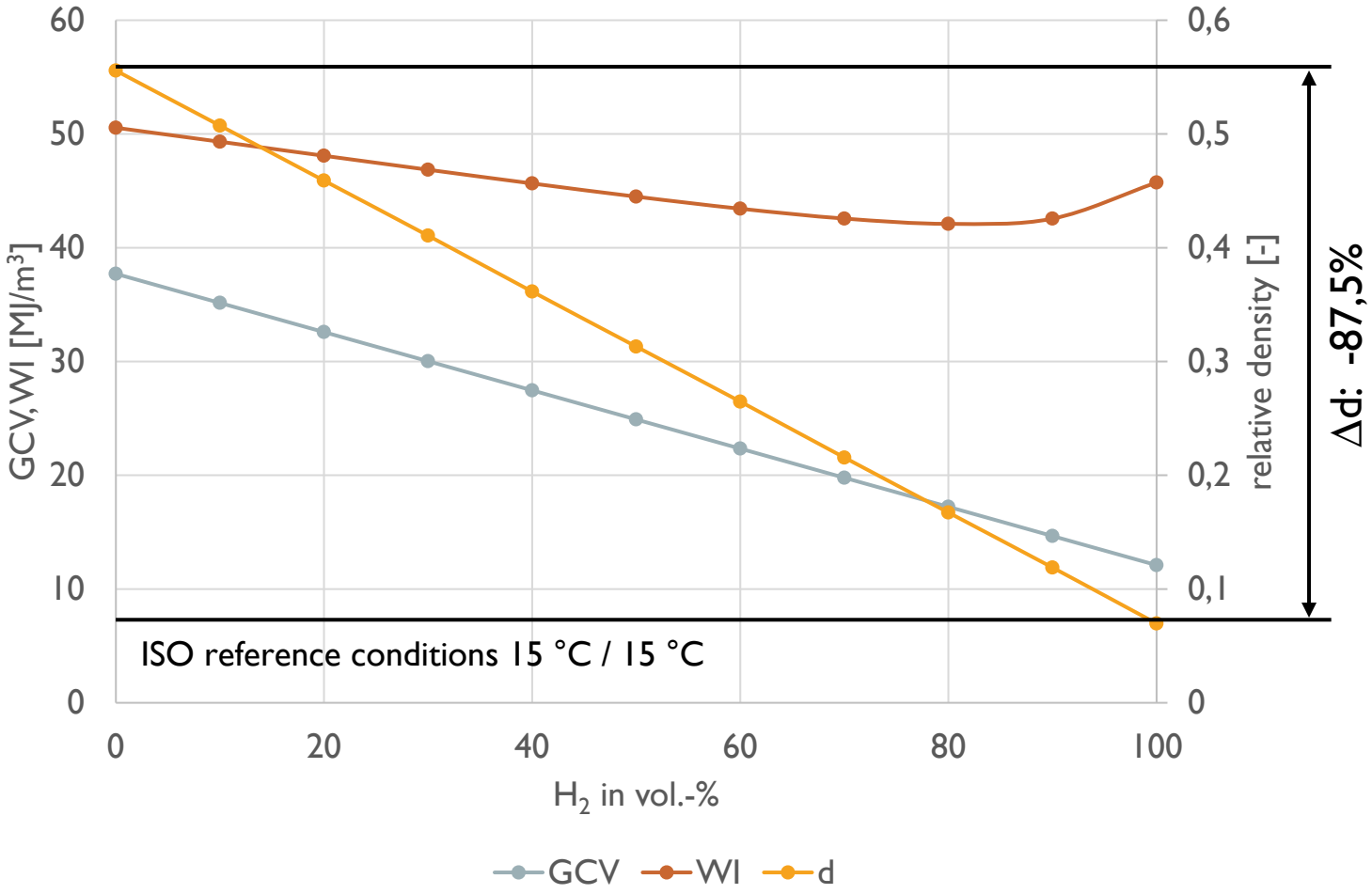


- lower Wobbe index
- impact
  - **lower heat output** under same conditions
  - H_2NG with varying H_2 % : **widens local WI range**
- risk

[F]
  - **insufficient heat output** (→ unfit for purpose)

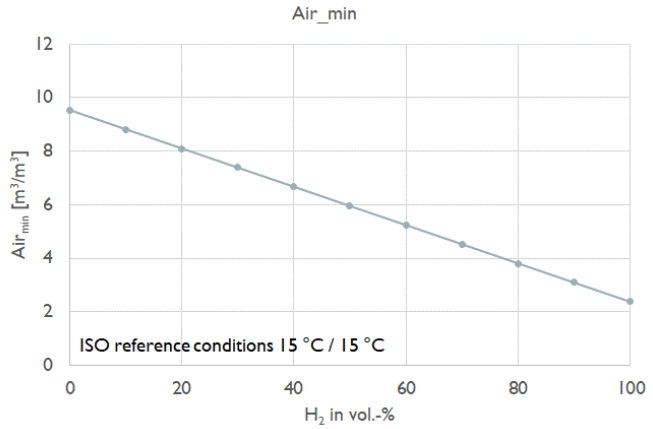
[S, F, P]
  - H_2NG with varying H_2 concentrations: may **complicate/compromise onsite adjustment**

Impact + risk: relative density



- much lower relative density
- impact
  - **stratification/separation of gases** in standstill conditions
- risk
  - **startup with high H_2 concentrations** (e.g. due to vertical pipework) **[S, F]**
  - *any risk specific to C_{11} appliances ? **[?]***
  - *no risk for delayed ignition as limited time prevents stratification? **[?]***

Impact + risk: min. air requirement



- significantly lower min. air requirement for complete combustion: 2,38 vs. 9,52 m³/m³
- impact
  - λ increase (without combustion control)
- risk

[S, F]
- flame lift/instability ⇒ CO increase or safety shutdown

[P]
- lower efficiency

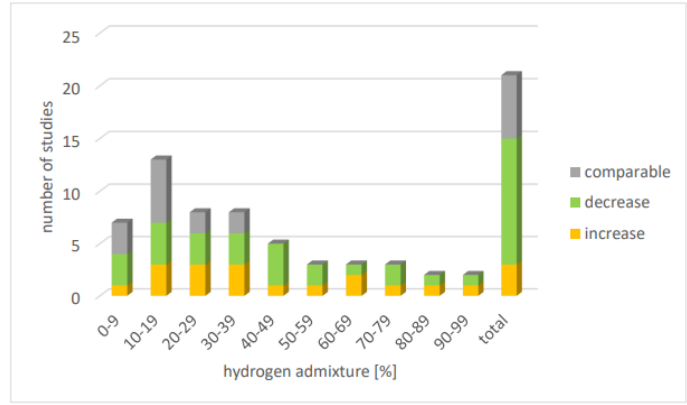
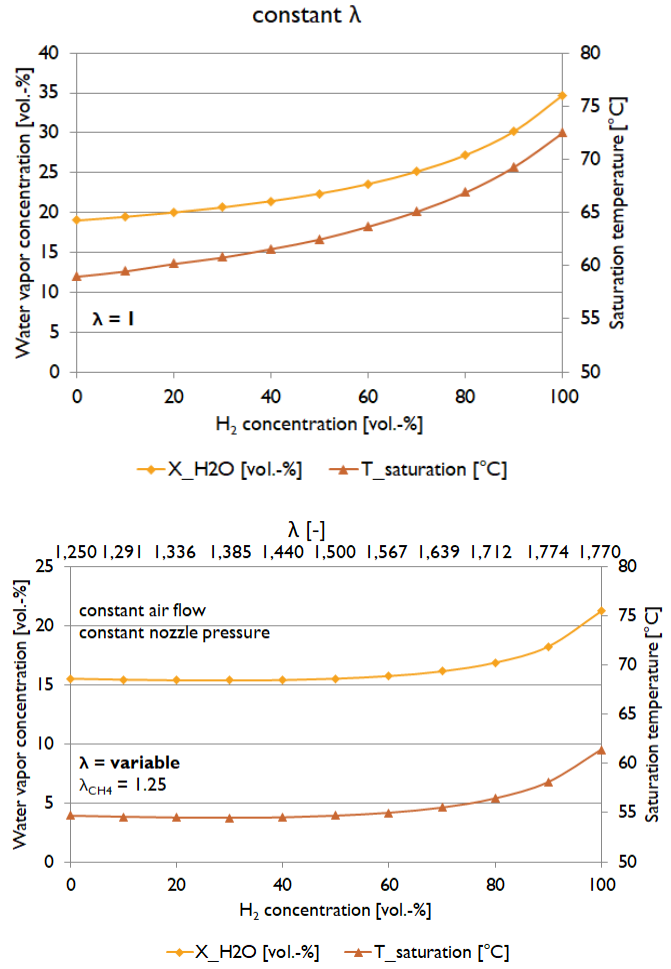


Figure 3-7 Overview of CO emission results in reported literature

Impact + risk: dewpoint temperature

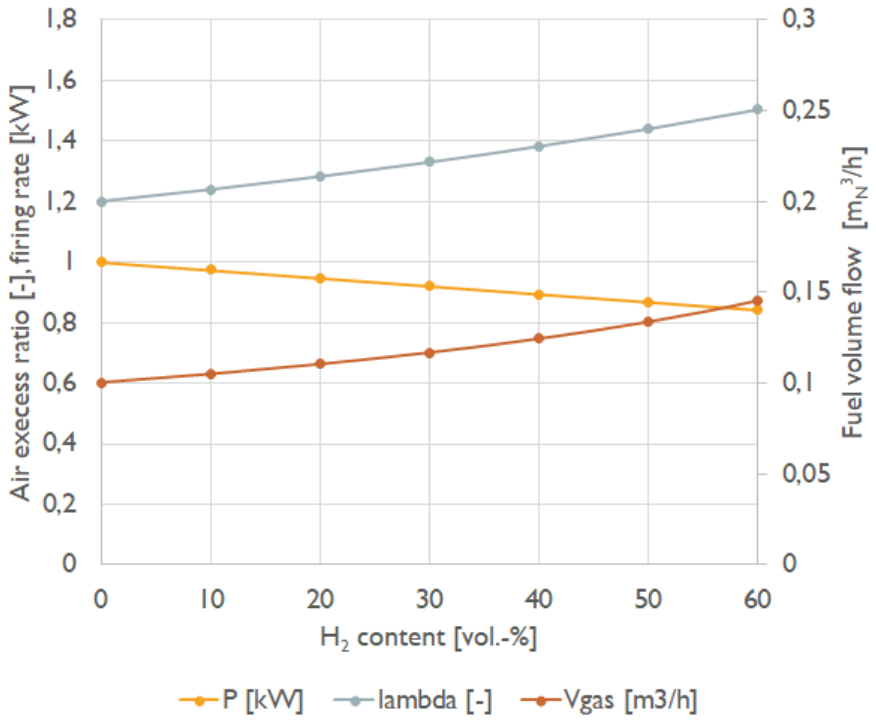


- higher dewpoint temperature
- impact
  - condensation at higher temperature with constant λ
- risk

[P,F]

  - appliances with combustion control: condensation at places in appliances/combustion products evacuation not designed for condensation
  - condensation with higher water circuit temperatures for appliances with combustion control ⇒ higher seasonal efficiency

Impact + risk: fuel volume flow



- higher fuel volume flow
- impact
  - higher fuel volume flow + same air flow = **higher combustion products flow**
- risk

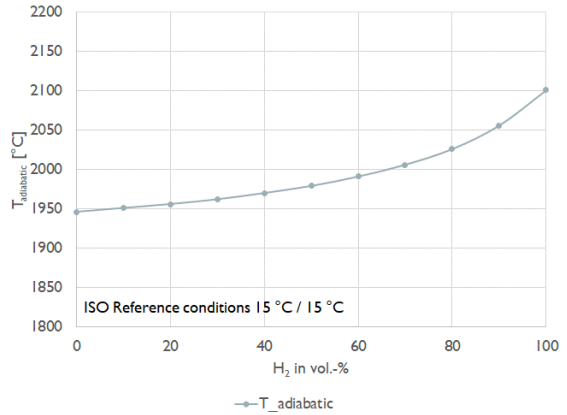
[S, F]
  - **inappropriate TTB position** on B_{11BS} appliances
  - *any further risk on inappropriate combustion products evacuation? **[?]***

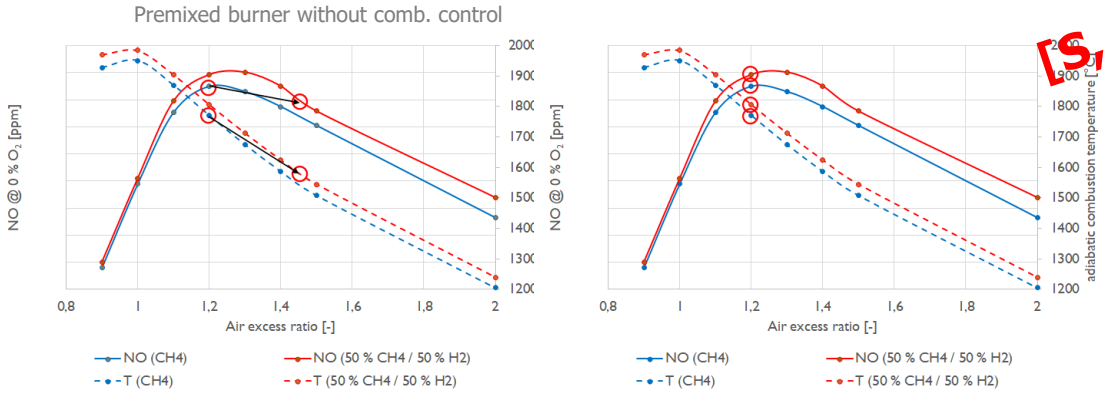
Impact + risk: combustion products temp.

- lower combustion products temperature due to lower heat output and, for appliances without combustion control, higher λ
- impact
  - **lower combustion products temperature ⇒ reduced natural draught**
- risk
  - [S, F] **condensation at points not designed for condensation**
  - [S, F] **inappropriate combustion products evacuations** for B11/C11 appliances
- comment
  - lower combustion products temperature may be (partially) neutralized by higher flame temperature

Still to be checked on consistency with THyGA test results.

Impact + risk: flame temp.





- higher flame temperature
- impact
  - thermal NO_x formation increase
  - higher surrounding surface temperature
  - higher combustion product temperature
- risk

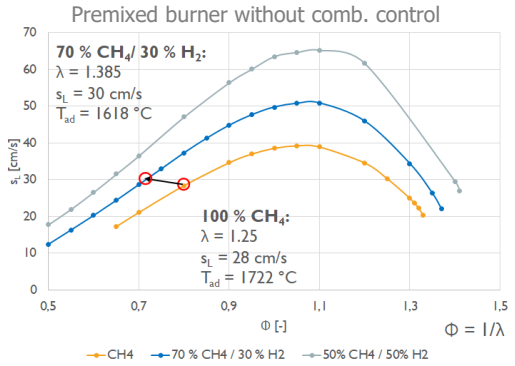
[P]
  - NO_x emissions exceeding limit values

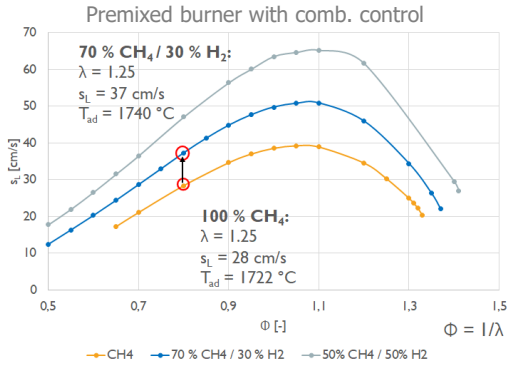
[S, F]
  - material detoriation

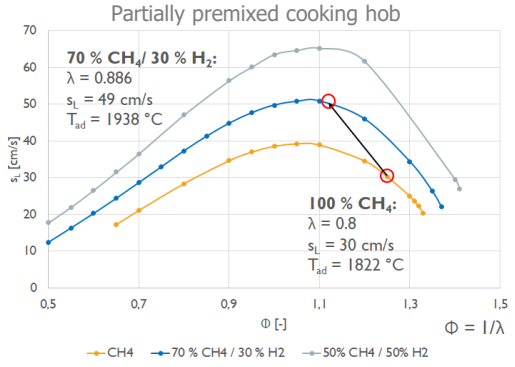
comment

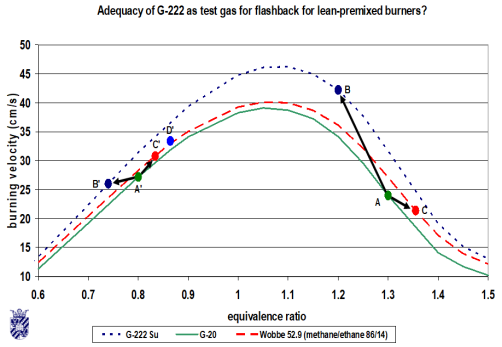
- NO_x emission increase may be neutralized by λ increase on appliances without burner control (cf. see concerned slide)

Impact + risk: flame speed









- higher flame speed
- impact
  - faster propagation of flame front ⇒ disturbed equilibrium between flame speed and gas flow speed
- risk
  - light-back for partially premixed appliances and appliances with combustion control [S, F]
  - Material deterioration [S, F]
- comment
  - for appliances equipped with full-premixed burners it seems more appropriate to use gases containing higher hydrocarbons to asses the light-back risk (cf. thoughts on test gases)

Impact + risk: carbon content

- zero carbon content
- impact
  - less CO and CO_2
- risk
  - none
- comment
  - CO may increase due to flame lift/instability caused by an increasing λ (see concerned slide)

Impact + risk: flame colour

- pale blue flame
- impact
  - nearly invisible in daylight
- risk
  - [S, F] appliances without flame safety device: flame status not visible for user
  - [F] no flame detection by optical flame safety device (cf. fitness for purpose)
  - [F] unsatisfactory flame pattern for decorative fuel effect appliances (cf. fitness for purpose)

Impact + risk: explosion violence

- higher explosion violence
- impact
  - **higher explosion violence → higher forces** on walls of 'closed' spaces
- risk
  - **appliance's integrity** and **user injury** due to **ignition** of **accumulated unburned gas** → e.g. **delayed ignition** or any inappropriate evacuation after burner stop

[S, F]

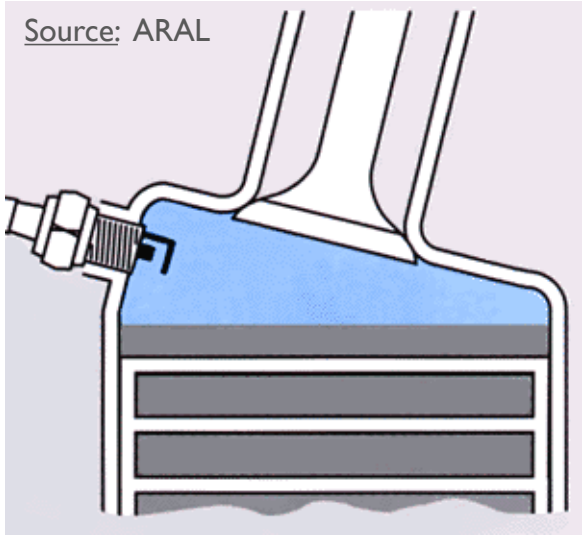
Test results:

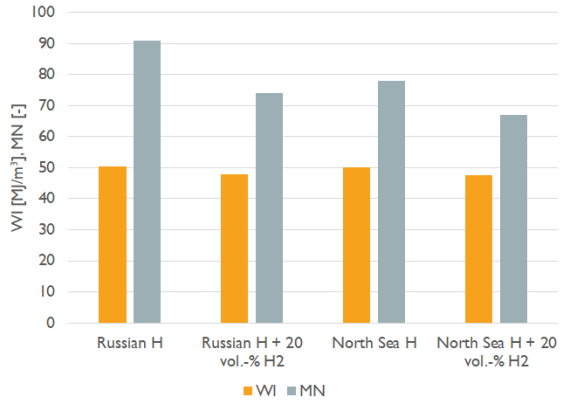
Test No.	Boiler setting: Gas	Boiler setting: CO2 [%] O2 [%] Max-Min	Boiler setting: CO DAF [ppm] Max-Min	Test gas	CO2 [%] O2 [%] Max-Min	CO DAF [ppm] Max-Min	delayed ignition time [s]: 1	2	3	4	5	6
1	G20	**CO2: 8,7-8,4** O2: 5,4-5,9	CO: 155-8	G20	CO2: 8,7-8,4 O2: 5,4-5,9	CO: 155-8						
2	G20	**CO2: 8,7-8,4** O2: 5,4-5,9	CO: 155-8	G20 +30%H2	CO2: 6,9-6,6 O2: 7,0-8,0	CO: 29-2						
3	G20 +30%H2	**CO2: 8,7-8,4** O2: 3,8-4,4	CO: 192-6	G20 +30%H2	CO2: 8,6-8,4 O2: 4,2-5,1	CO: 192-6						
4	G20 +30%H2	**CO2: 8,7-8,4** O2: 3,8-4,4	CO: 192-6	G20	CO2: 10,6-10,4 O2: 2,3-3,0	CO: 678-27						

- smooth ignition
- small detonation
- noisy detonation without damages
- very noisy detonation without damages
- boiler deterioration - hazard for user
- No ignition

Note:
an external timer has been connected between the burner control and the igniter in order to delay the ignition of the gas/air mixture inside the combustion chamber from 1s to Ignition Safety Time [TSA].

Impact + risk: methane number





- methane number = 0!
- impact
  - H_2NG: lower methane number
- risk
  - knocking of reciprocating engines

[S, F]

Impact + risk: other

- chemical impact on materials: sufficient input
- flammability range: wide range → rich mixtures **[?]**
- flame radiation & emissivity: lower emissivity **[?]**
- flame length
- ionization current: sufficient input
- GCV/NCV ratio **[?]**
- unburnt H_2 emissions: sufficient input
- pressure drop **[?]**
- ventilation: installation related

Impact + risk: literature

D2.3 - Impact of hydrogen admixture on combustion processes – part II: practice

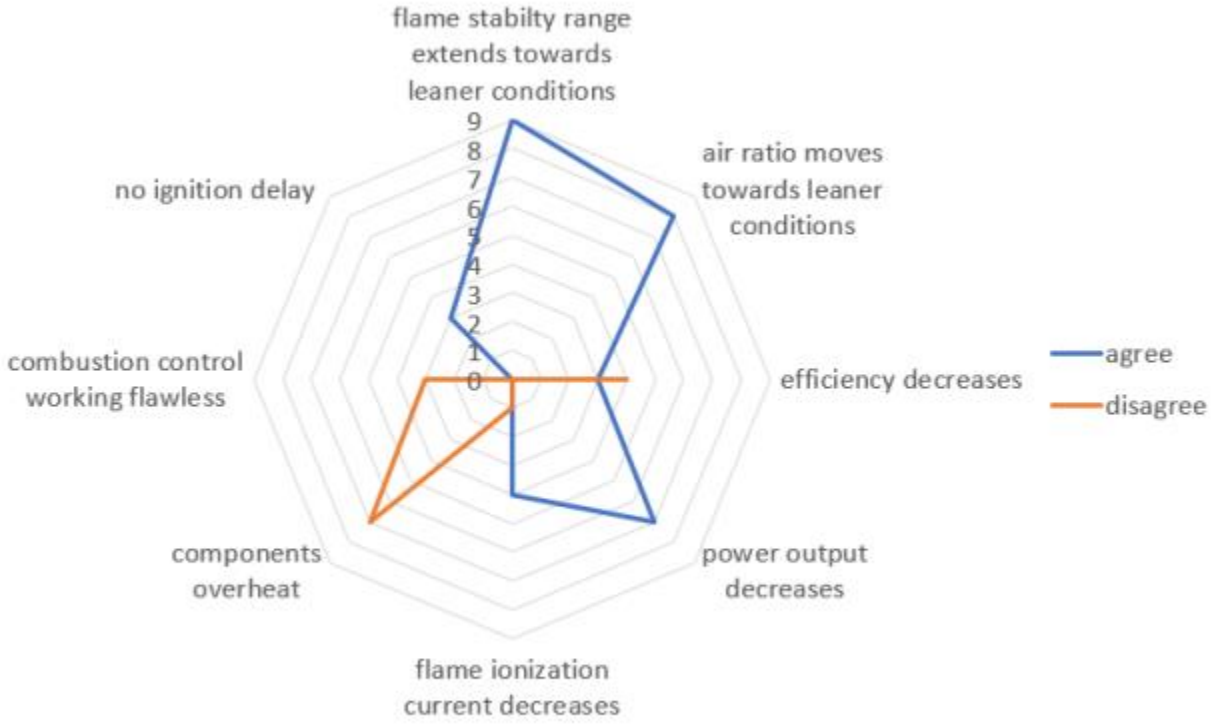


Figure 3-5 Collection of statements on operational issues when admixing hydrogen to various types of natural gas fired burners

Link with GAR essential requirements

GAR Essential requirement		RISK DUE TO H2NG SUPPLY	THyGA outcome of tests/analyses for 20% H2NG
N°	Requirement		
1	GENERAL REQUIREMENTS		
1.1	Appliances shall be so designed and constructed as to operate safely and present no danger to persons, domestic animals or property, when normally used.	...	...
		...	...
	Fittings shall be so designed and constructed as to fulfil correctly their intended purpose when incorporated into an appliance or assembled to constitute an appliance.	...	...
1.2	The manufacturer is under an obligation to analyse the risks in order to identify those which apply to his appliance or fitting. He shall then design and construct it taking into account its risk assessment.	...	...
1.3	In selecting the most appropriate solutions, the manufacturer shall apply the principles set out below, in the following order:		
	(a) eliminate or reduce risks as far as possible (inherently safe design and construction);	...	...
	(b) take the necessary protection measures in relation to risks that cannot be eliminated;	...	...
	(c) inform users of the residual risks due to any shortcomings of the protection measures adopted and indicate whether any particular precautions are required.	...	...
1.4	When designing and constructing the appliance, and when drafting the instructions, the manufacturer shall envisage not only the intended use of the appliance, but also the reasonably foreseeable uses.	...	...
1.5	All appliances shall:		
	(a) be accompanied by instructions for installation intended for the installer;	...	...
	(b) be accompanied by instructions for use and servicing, intended for the user;	...	...
	(c) bear appropriate warning notices, which shall also appear on the packaging.	...	...
1.6.1	The instructions ...	...	...

TO BE COMPLETED FOR DELIVERABLE D4.3

THyGA

END