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

Testing programme for hydrogen tolerance tests of domestic and commercial natural gas appliances

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List of abbreviations

CEN TC	Technical Committee (European Committee for Standardization)
CHP	combined heat and power
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
D	deliverable of this project
DGC	Dansk Gasteknisk Center; THyGA laboratory
EU	European Union
FB	flashback
Gas.be	Gas.be; THyGA laboratory
GWI	Gas- und Wärme-Institut Essen; THyGA laboratory
H_2	hydrogen
HP	heat pump
NOx	nitrogen oxides
O_2	oxygen
Qmin	minimal thermal load
Qmax	maximal thermal load
TC	technical committee
UHC	unburnt hydrocarbons
WP	work package

1 Objective and Scope

The **THyGA project** (‘**T**esting **Hy**drogen admixture for **G**as **A**pplications’) focusses on technical aspects and the regulatory framework concerning the potential operation of domestic and commercial end-user appliances with hydrogen / natural gas blends.

The core of the project is a broad experimental campaign with the aim to conduct up to 100 hydrogen tolerance tests. In addition, the technical status quo and present knowledge about hydrogen impact on domestic and commercial appliances are assessed and potential future developments of rules and standards are discussed. Also, mitigation strategies for coping with high levels of hydrogen admixture will be developed. By this broad approach, the project aims at investigating which levels of hydrogen blending impact the various appliance technologies and to which extent in order to identify the regime in which a safe, efficient, and low-polluting operation is possible.

The series of public reports by the THyGA project starts with several publications from work package 2, which sets the basis for the upcoming results and discussion of the experimental campaign as well as mitigation and standardisation topics.

The finalised reports from work package 2 are published online, e.g. on the project website[1], and cover the following topics:

D2.1 presents a segmentation of the markets of all relevant domestic and commercial natural gas-fired appliances used in Europe. Appliance categories are sorted by combustion technologies to create a reference system that structures the subsequent work on hydrogen tolerance including the preparation of laboratory tests and the acquisition and selection of appliances to test [FSCB21].

D2.2 explains the theoretical background for hydrogen/natural gas blends from the perspective of combustion theory. Central physical quantities are introduced and interrelationships between them are explained including diagrams as well as examples and discussion [LSCA20].

D2.3 provides first detailed insights on the various appliance technologies identified by the market segmentation. All technology categories are presented and working principles are explained including graphic material. First qualitative expectations on the appliance behaviour when combusting hydrogen / natural gas-blends are given based on the authors’ experience and knowledge during the first months of the THyGA project, i.e. before starting the laboratory test campaign. In addition to that, a literature meta-study has been conducted to gather the publicly available information in order to identify existing quantitative literature results relevant to the scope of the THyGA project [SFLB20].

D2.4 presents the impacts of hydrogen admixture to natural gas from the material science perspective. It focuses on the non-combustion related aspects of hydrogen admixture, including hydrogen embrittlement of metallic materials, chemical compatibility and leakage issues [BlBr20].

This report (D2.5) completes the series of public reports from work package 2. It explains the development of the test programme for gas-fired appliance tests with hydrogen admixture and especially describes the exchange between the THyGA partners and the external stakeholders. In addition, the process of acquisition of appliances to test and method of selecting appliances is reported.

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[1] For more information, please visit https://thyga-project.eu/

2 Development of the Appliance Test Protocol – exchange between THyGA consortium, manufacturers and associations

2.1 Consultation of stakeholders

From the beginning of the project (kick-off meeting), it has been decided to adjust the laboratory test timeline to make sure that all tests would be finished at least six months before the end of the project to ensure sufficient time for thorough analyses and reporting. For this purpose, some work was scheduled earlier than initially planned. The Covid-19 pandemic on the other hand side created some delays which need to be mitigated wherever possible during the project.

However, in order to make sure that the project timeline would be optimized, the topic of the definition of the test protocol and its relevance for the stakeholders has been tackled by task T2.5 since the beginning of the project.

- As illustrated in Figure 2-1, an **iterative approach** with many exchanges with partners and stakeholders has been put in motion to make sure the test protocol developed by the THyGA consortium answers the objectives of the project as well as the original call description and the expectations of the stakeholders.

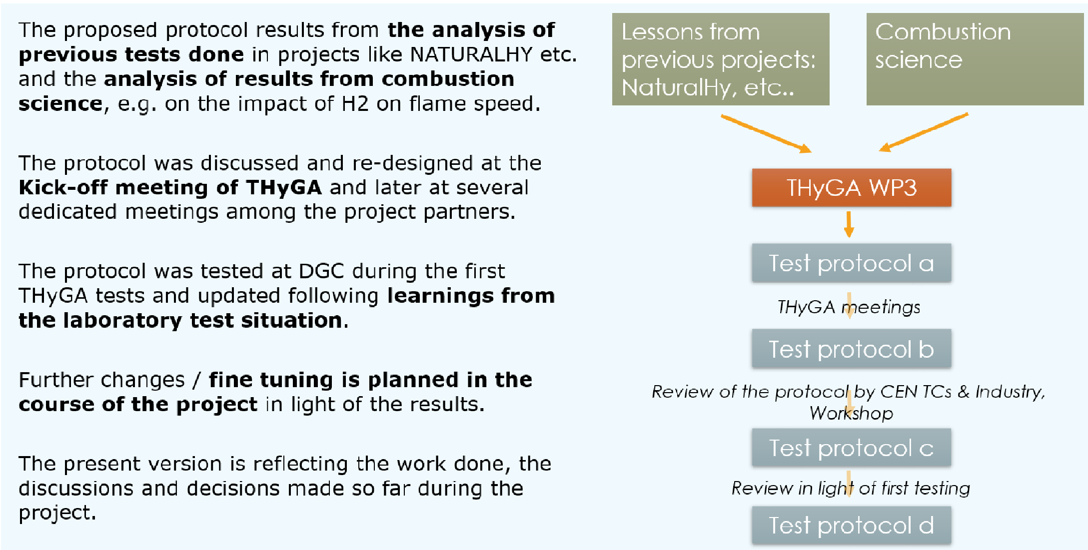

Figure 2-1 Method used to develop the test protocol

- Given the strategies proposed by most DSO/TSOs, the injection to hydrogen admixture levels higher than 30% seems technically and economically unlikely, from a grid's perspective. Thus, **THyGA proposes to put a focus on hydrogen rates below 30%** (more points of test), while also including test with hydrogen concentrations up to 60% (according to the Grant Agreement and FCH JU request).
- The **test protocol has been challenged by partners and external stakeholders, it will cover all points from the Grant Agreement but also include optional tests** that will provide

complementary information and will be performed according to simulated real-life situations (depending on agreement of respective manufacturer, availability of labs, budget, etc.).

FOCUS OF TESTS	MOST RELEVANT PARAMETERS
SAFETY • CO • Flashback • Overheating **EMISSIONS** • NOx • CO • CxHy **EFFICIENCY** • Flue gas Eff. • electr. consumption **OPERATION** • T(burner)	**1 GAS** • Initial Natural gas composition • H2 concentration (up to 60%) o Low = <10% Vol. o Medium = 10-30% Vol. o High = 30-60% Vol. (also 100% if possible) • Rate of change of H2 concentration **2 APPLIANCES** • Appliance adjustment (for a given gas) • Qmin / Qmax / On-off • Used / new appliances **3 TEST CONDITIONS** • Extreme conditions (air temp., overpressure, cold start) • Long term testing

Figure 2-2: Main elements of the test protocol including the focus areas of the laboratory tests as well as most relevant parameters.

2.2 Iterative process

The elaboration of the test protocol has followed several phases:

Phase 1. Preliminary protocol (January - May 2020)

This phase was based on:

1. A first **analysis of past projects** testing gas appliances with H_2/NG blends (Naturalhy and more).
2. An extended analysis of the effect of H_2, based on **calculations** (e.g. laminar flame velocity calculation) in order to determine the most crucial situations for H_2/NG blends. Calculation work included assessment of the Wobbe index, the density and laminar flame speed for different gas mixes. The theoretical considerations were reported in D2.2 [LSCA20].
3. The integration of the conclusions in a **preliminary test programme** inspired by a similar project (GASQUAL, impact of gas quality on domestic appliances).
4. First **discussions** with all partners (end of January 2020) during the kick-off meeting.

The preliminary protocol has been subject to several discussions within the THyGA consortium (two meetings between all partners, and three meetings within WP3) and was sent to the stakeholders (mainly manufacturers and associations from the advisory panel group of the project), with the aim to **receive feedback of the Industry** on THyGA's work proposal.

Phase 2. Protocol discussion with the stakeholders (May 2020 and later)

The protocol was presented during a first public event workshop (1st THyGA Workshop 6th of May 2020 [1stw20]) before being discussed in more detail in a workshop including only stakeholders from the **advisory panel group** (19th of May 2020).

The draft test protocol document had been sent to this group but also to technical committees beforehand to gather as many feedbacks as possible. The following technical committees (TC) from the CEN initiative, the European Committee for Standardization, were contacted by the THyGA consortium:

- TC48 (Domestic gas-fired water heaters)
- TC49 (cooking appliances)
- TC58 (combustion control)
- TC62 (independent room heater)
- TC106 (catering)
- TC109 (central heating boilers)
- TC131 (forced draught burners)
- TC238 (test gases, appliance categories, etc.)[2]

The detailed points of the discussion and how they were implemented as well as the minutes of the meeting with the advisory panel group are given in the annex (chapter 8).

Phase 3. Protocol for laboratory use (June 2020 and later): Protocol for testing

The testing protocol has been implemented in terms of a practical tool for testing (test sheets & reports) developed in Microsoft Excel format. The first tests have started in 2020 at DGC, GAS.BE and GWI for testing/validation of the protocol.

The results have been discussed between the labs and a number of improvements as well as corrections of the protocol were carried out in order to take into account the lessons learned from the laboratory testing experiences.

At the beginning of the testing phase of the project, each new test has brought new information that allowed the project partners to optimize the protocol in order to get the best information from the resources allocated. This typically resulted in optimisation of work flows and sharpening the focus on tests that yield the maximum added value to the project.

The project partners developed a testing structure which reached a stable state at the end of 2020 and contains the key components for the THyGA tests that will not be modified for the majority of appliance technology segments.

This version of the protocol was also described and shared with 10 “external labs”[3] for additional discussions with and feedback from international experienced laboratories outside the project group.

Phase 4. Further protocol improvements (from December 2020)

There are no doubts that the testing will shed light on criteria that are in the scope of THyGA, but the testing is also open for new questions arising from the test results or exchanges with stakeholders (not

[2] Official liaison with THyGA, through WP4

[3] «External labs» are laboratories (research centers, universities, manufacturers’ laboratories) that are not directly partners of the project but expressed their interest to use the THyGA test protocol in their facilities, on their own funds. If suitable testing conditions are provided, work package 3 may potentially be able to include these results to expand the data basis generated in the THyGA labs e.g. in terms of additional appliance types, enhanced variety of tested brands, materials, etc.

anticipated impacts, need to modify durations, etc.). Therefore, the THyGA partners decided to keep some flexibility for potential further adaptation of the protocol; such adaptions will most probably be minor adjustments to the existing protocol and developments of operational details on some tests or laboratory situations.

The discussions of the test protocol have so far been based on two internal documents

- A PowerPoint presentation of the protocol targeting labs for easy understanding of the testing that has been improved (versioning) from the beginning of the project (part of deliverable D3.1 "Test protocol for all appliances to be tested" (confidential)).
- An excel sheet used as the tool for the testing and reporting and that includes a number or automated calculations (submitted under "D3.2 Reporting templates for laboratories")

2.3 Details of the testing protocol

The testing programme includes the following points, they include mandatory tests (scope of the Grant Agreement) and additional tests according to technologies, possibilities in the laboratories, demands from the manufacturers and budget.

PART 1 SAFETY

1.1 SAFETY- EMISSIONS and EFFICIENCY with CH_4 (Note that for cooker, efficiency is treated apart due to the test procedure, see below) - *Mandatory*

1.2 SAFETY- EMISSIONS and EFFICIENCY with gas mixture "EUlow" (Note that for cooker, efficiency is treated apart due to the test procedure- see below) - *Additional*

1.3 (test initially focusing on cooking appliances, merged with 1.2)

1.4 EXTREME CONDITIONS - Cold start. - *Additional*

1.5 EXTREME CONDITIONS - Hot start (possibly connected to a previous test). - *Additional*

1.6 EXTREME CONDITIONS - Low air temperature (-10°C). - *Additional*

1.7 EXTREME CONDITIONS - Flue gas pipe length. - *Additional*

1.8 ROC (PLUG FLOW) - *Additional*

1.9 Impact of H_2 on FLAME DETECTION, measurement of the Ionization signal (to be done with 1.1) - *Additional*

1.10 FLASHBACK ANALYSIS - In case flashback is observed - *Additional*

PART 2 PERFORMANCES

2.1 PERFORMANCES (efficiency) with CH_4 (limited range for H_2 from manufacturer's decision) - *Mandatory*

2.2 PERFORMANCES with CH_4 (extended range for H_2) - *Additional*

2.3 PERFORMANCES (efficiency) with gas mixture "EUlow", for cookers only - *Additional*

2.4 UHC and H_2 emission at start/stop - *Additional*

PART 3 OPERATION and SAFETY UNDER ADJUSTMENT CONDITIONS

ONLY FOR APPLIANCES THAT CAN BE ADJUSTED.

3.1 ADJUSTMENT A (mostly to see FB & CO) - *Mandatory*

3.2 ADJUSTMENT B (mostly to see FB & CO) - *Mandatory*

3.4 ADJUSTMENT H (mostly to see FB & CO) - *Mandatory*

3.3 ADJUSTMENT G (mostly to see FB & CO) - *Mandatory*

PART 4 OTHER TEST

4.1 Delayed ignition test - *Additional*

4.2 Soundness - *Additional*

4.3 Quick variation Qmin-Qmax, shut-off condition (cookers and fires only). Qualitative test (observation) - *Additional*

4.4 Overheat. Measurement of the temperature- *Additional*

4.X Other test to check more parameters (open) - *Additional*

2.4 Conclusion

The **large number of interactions among experts allowed for intense knowledge exchange** and led to a high awareness of the projects' activities within companies, institutes and committees from the field across Europe. The gathered inputs were implemented into the work programme of the project wherever possible. The intense project phase of test protocol development consequently consumed a large amount of time dedicated to meetings for each involved partner. However, a positive consequence was that this methodology favoured communication on the objective of the project and -already- led to successful dissemination on THyGA's test protocol.

- **Many manufacturers expressed interest in providing appliances**
- A group of laboratories ("**external labs"**) also considers to use the THyGA protocol in their own premises which could help to gather more test results and thus, enhance significance of the accumulated results.

3 Acquisition of Appliances for Testing – Involvement of Manufacturers

A central challenge for the preparation of the selection of appliances for testing (task 2.6) was to acquire a broad choice of potential test objects covering the full range of appliance technologies identified [FSCB21] and described [SFLB20] in previous reports of this project. The resulting fundament of available appliances allows the THyGA partners to pick representative test objects for the different market segments based on a variety of technical criteria.

The communication with manufacturers from the various market segments was started by widely distributing the invitations to the THyGA **online workshops** with the aim to reach a broad audience including appliance manufacturers. Newsletters and emails as well as the project website and the GERG website and the social network LinkedIn were used to maximise the range of the invitation flyers. As a result, more than 100 participants attended the first public workshop, and the presented documents were spread by email afterwards and published via the project website. For the two public workshops held half a year later, several hundred registrations and almost 500 active participants were counted, while additional registrations were only limited by technical boundary conditions of the webinar service. The proportion of participants from the manufacturing industry in the second and third webinar accounted for 21% [BBSM20] and 27% [LeSM20], respectively.

Once interested manufacturers were identified based on the feedback received by email, phone or web-meetings, a **survey** was sent to the respective companies to collect information on the types of appliances they were willing to deliver to one of the THyGA test laboratories for experiments. Responsible persons on the part of the manufacturers were queried and some basic information about the THyGA project was provided for company-internal communication. Companies were also asked to indicate limitations – if any – that would forbid the use of high hydrogen admixture levels up to 60%. The manufacturers were informed that not all appliances offered could be tested within the THyGA project, and that the choice of appliances would be based on the most relevant expected results on hydrogen impact on end-use technologies. The manufacturers were allowed to mark one or several THyGA laboratories which they would prefer to cooperate with. Finally, a text box for comments was added for the manufacturers to add some more detailed information to the survey.

Accompanied by numerous communication actions by the THyGA partners and the manufacturers, questions on further details were clarified and the survey feedbacks were summarised and assessed. At this point the criteria described in the following chapter were applied. In any case of doubt, web-conferences between the THyGA laboratories were held to discuss possible decisions and find solutions to all remaining questions that were relevant for joint decision-making

4 Method for the Selection of Appliances for Testing

The preparation for the final selection of appliances for the laboratory tests was started in task 2.1 of the project, i.e. by performing a market segmentation of gas-fired appliances across Europe. The goal of that task was to create a reference system of typical technology classes with respect to the various domestic and commercial use cases. The result of the task was a table of 56 market segments, numbered by a three-digit number, with the first digit indicating the main markets boilers, water heaters, cooking appliances etc. and the two remaining digits numbering the sub-categories concerning their technological specifications, such as burner type. The resulting table is shown in Table 4-1 (result of task 2.1). [FSCB21]

Table 4-1 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.

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 (former EN 483)	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)			1,125
201	WATER HEATERS	instantaneous open flued	partial pre-mix/atmos.	EN 26	43,242
202		instantaneous room sealed	partial pre-mix/fanned		38,796
203		storage, open flued	partial pre-mix/atmos.	EN 89	5,397
204		storage, room-sealed	partial pre-mix/fan-assisted		2,292
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		cavity burner "tubular" (ovens, 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		fryers	pre-mix burner	EN 203-2-4	unknown
407		salamanders / rotisseries	ceramic 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		Independent gas-fired convection heaters type C	heating & decoration, balanced	EN 613	1,839
503		Decorative fuel-effect 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		Internal combustion engine			40.8
603		Micro gas turbine			0.5
604		PEM Fuel Cell			5
605		SO Fuel Cell			2.7
701	HP	engine HP	Heating	EN 16905	373
702		adsorption		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		infrared radiant heaters (former EN 777-1)	non-domestic, tube radiant heaters	EN 416	
805		air heaters (former EN 1020)	non-domestic, forced convection, fan, <300kW	EN 17082	1,000
806		air heaters (former EN 525)	non-domestic, forced convection, <300kW	EN 17082	
807		air heaters <70kW (former EN778)	Ducted warm air; forced convection air heaters	EN 17082	
808		domestic washing machines		EN 1518	very small
809		domestic dryers		EN 1518	very small

Planning of experiments

For the planning of the experiments to be conducted within the THyGA project the above presented market segments of gas-fired appliances and their estimated population in the field were taken into account.

However, in order to design a meaningful test campaign that allows statements for the situation of installed appliance stock in the future (2030 and onwards) the following considerations have been made:

- Representability of the market segments in terms of appliance population in the field
- Expected sensitivity of technologies concerning hydrogen admixture
- Sales trends, expected developments on the market
- Broadness of the range of different designs / products per segment on the market
- Availability of appliances for testing
- Complexity of tests in some cases, such as large ceiling-hung heaters

The project partners assessed the market segmentation table with its estimated appliance populations for Europe and discussed the test programme. For a first, general classification of the appliance sensitivities to hydrogen admixture a three-level rating system

(1) low sensitivity,

(2) medium sensitivity,

(3) high sensitivity

was applied based on the experts knowledge and expectations reported in D2.3 [SFLB20]. The main aspects considered were safety impacts by hydrogen admixture as well as operational effects.

For some market segments, depending on available data and knowledge, market evolution trends were taken into account. For some technologies that were identified to vanish from the market, the assessment led to a lower prioritisation of laboratory tests or lower number of tests planned. In some cases, the project decided not to test as a priority the technologies with population numbers almost negligible in in the field and not or almost not existing on the market.

Subsequently, for the precise distribution of the appliance technologies and/or market segments to the laboratory capacities available among the THyGA project partners, additional points were considered, including:

- Field of expertise / experience concerning specific appliance types in the labs
- Equipment of the labs
- Capacities of the labs concerning personnel and project budget

The partners decided to organise about 2/3 of the maximum planned number of tests in a first wave of experiments and leave some flexibility to react on the results received from the laboratories in the further course of the project. In this way, depending on what will be learned about the hydrogen impact on the most crucial appliance technologies, some capacities are saved that allow the project to realise additional tests on technology segments that prove to be critical for the use with hydrogen / natural gas blends.

The project partners finally combined the results of their assessments of technology segments, expected hydrogen impacts, etc. with the available products acquired by the stakeholder participation process (i.e. survey). For most market segments, an oversupply of appliances was available. Due to this fact, the partners were able to choose scientifically interesting combinations of appliances to be tested, e.g. comprising different burner designs or materials, or different control mechanisms within the same appliance category.

5 Conclusion and Outlook

The market segmentation from the previous deliverable (D2.1, [FSCB21]), as well as combustion science considerations (D2.2, [LSCA20]), and the appliance technology assessment concerning hydrogen impact (D2.3, [SFLB20]) set the basis for task 2.5 leading to the definition of a test programme for appliance tests with hydrogen admixture (this report, D2.5). The test programme was designed to include as many as possible technologies from relevant market segments for the subsequent laboratory tests conducted in work package 3. With the aim to find an ideal utilisation of the laboratory capacities and project resources the testing programme does not solely rely on the estimated appliance population numbers (Table 4-1). Instead, further criteria were developed to design a test programme suitable for tackling the most urgent research questions concerning the impacts of hydrogen admixture for all addressed market segments. The additional criteria were implemented in terms of weighting factors to create a priority list for each of the head market segments (boilers, water heaters, cooking appliances, catering equipment, local space heaters, combined heat and power systems, heat pumps, other) based on the present state of the art knowledge from [LSCA20, SFLB20]. The resulting prioritised technology list served as input for the following project step.

The selection of specific appliances for the tests was made in task 2.6 (confidential report) as the final step of work package 2. This final selection chooses precisely those technologies and technology combinations that were identified to be the most crucial research subjects in terms of expected impact of hydrogen admixture. Once the suitable appliances from the market are chosen, a process of communication with manufacturers and THyGA laboratories starts with the aim to acquire the selected test objects and assign them to the testing laboratories that are prepared to perform the pre-defined tests. Testing conditions, test protocols, definition of test gases, etc. are prepared among all involved THyGA partners.

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[SFLB20] SCHAFFERT, JOHANNES ; FISCHER, PHILIPP ; LEICHER, JÖRG ; BURMEISTER, FRANK ; FLAYYIH, MUSTAFA ; CIGARIDA, HRISTINA ; ALBUS, ROLF ; GÖRNER, KLAUS ; ET AL.: *THyGA project: Impact of hydrogen admixture on combustion processes – Part II: Practice*, *Testing Hydrogen admixture for Gas Applications (THyGA); EU project, grant agreement no. 874983* (Project Report - Deliverable D2.3). https://thyga-project.eu/ : Gas- und Wärme-Institut Essen e.V. (GWI), ENGIE, DVGW-EBI, GAS.BE, DGC, 2020

8 Annex 1: Minutes of the web-conference on test protocol (19th of May 2020)

List of attendees (as indicated by participants): Patrick Milin, Helene Pierre, Robert Judd, Lars Jorgensen, Giacomo Silvestri, Jairo Soto Rey, Johannes Schaffert, Valentia D'Acunti, Roald Bac, Ella Cooper, Wilfried Linke, Hristina Cigarida, Frank Burmeister, Maurizio Beghi, Sebastiano Temperato, Jean Schweitzer, Salvador Ochoa (BSH), Luis Galiano (APPLiA), Titouan Fabiani (GERG), Marco Turchi, Alejandro Cabarga, Danny Peacock, Marcel Fraterman, Kris de Wit, Fabio Spano, Ole Björn Bohms, Paul Glanville, Krishnaveni Krishnaramanujam, Andrea Manini, Salvador Ochoa (BSH), Mindert van Rij, Simon Bower, Flavio Chiavetti, A. Gaipo (BSH), Steve Sutton

Comments sent before the workshop

Overall, the input is very constructive and useful. We shall try to incorporate as much as possible in the test programme. There are however some constrains:

- Budget allocated for the work to be done. The increase of the number of test or increase of test duration will result in the reduction of the number of appliances tested. So if we add more tests or increase the duration this will lead to contractual issues that would need to be solved.
- What nominal natural gas to be used as reference

NOTE THAT THE PROTOCOL DISCUSSED APPLIES TO WP3 ONLY AND NOT TO WP4. The testing programme & gas to be used in WP3 has been designed according the following points:

- Main testing based on statistical approach based on as real conditions as possible
- Additional (and less extensive) testing with worsening factors to check what will happen in case the conditions are deviating from known range of variations.
- Keeping in mind that testing 100 appliances (only) compared to the > 200 M installed will necessarily have limitations, THyGA (nor other project) cannot bring a guarantee that the conclusions will apply to 100% of installed appliances.
- Optimizing the test programme to get the best value from the work done --> making some choice = getting insight for trends on less probable situations and having consolidated conclusions on most probable scenarios?

	THY_WP3_009_Test protocol_simple 02c				
		TC COMMENTS	**ANSWER THyGA**	**see also**	**ACTION**
		INPUT TC109/WG1 adhoc group meeting on H2/THyGA experimental protocol			
LINE	**Slide Nr**	**1) A clear specification of the gas type -.the normal distribution gas (NDG) is needed.**			
A1		The normal distribution fossil base gas that appliance is expected to burn safely at normal operating conditions must have a clear specification:	TEST IN WP3 are assuming that gas distributed in the EU are 100% percentile from JRC /ENTSOG study. In practice the gas mix will be made with EU High and EU Low gas by mixture with addition of Nitrogen (N_2) and Propane (C_3H_8) (+ possibly a bit of butane, so to optimize costs when using LPG). And the EU	Gases for testing WP3	
A2		A Wobbe index between 48.5 and 52.2 MJ/m3 (15/15) with a probability of 98 %			

			gas quality will be delimited by two gases EU high and EU low defined respectively with CH4 + C3H8 and CH4 + N2. Some test/calculations will be done to check the sensitivity of the result to the tolerance of the gas mix and to see what will be the trend when gas quality rises out of the border delimited by EU high and EU low. Note also that the testing will be an iterative process where the test protocol may vary in the light of the results obtained.		
A3		A maximum saturated higher hydrocarbon content of 7% (by volume) propane equivalent with a probability of 98%	As a result we don not intend to add more requirements on gas used, but if there are important factors that may play a role in one or the other result we will of course be open to include those within the constraints of the project.		
A4		A maximum unsaturated higher hydro carbon content of 0.5% (by volume) in total with a probability of 98%			
A5		A maximum CO_2 content of 2% (by volume) with a probability of 98%	We expect CO2 having the same impact on combustion than N2. So this may not be relevant		
A6		The maximum added hydrogen indicated in % by volume must have a probability of 98%.	We suppose this comment is about the accuracy of the target H2 to be reached by labs compared to the value given in the protocol?-(tolerance on the target value of H2). At the moment we cannot give an exact number for this tolerance as some labs are still working is setting/tuning their gas mixing test rigs. In any case the gas used for testing will be analyzed accurately and this is the most important point. Almost all tests will be done with several % of H2 allowing for interpolation: In order to be cost effective we shall try not to put to stringent tolerances on the exact H2 used for testing as this can be very much time		

			consuming in practice and not needed when we can interpolate.		
A7		2) **A clear indication of the technologies covered must be indicated**.			
A8		Assuring the safety of an appliance one of the key factors is making sure that the appliance is running on appropriate gas air ratio. There are different technologies used for assuring this gas air ratio. An evaluation of the suitability appliances for other gas types than they are initially designed for, requires a risk analyses based on the technology used. The technologies covered in the THYGA proposal are:	Note that THyGA intend also to includes the mentioned technologies in existing segments or sub-segments. The best would be to indicate in a segment the sub-segment variations to be tested. (action WP2?)	Segmentation	Segmentation / sub-segmentation in WP2
A9		1. Appliances using atmospheric partially premixed burners using a venturi injector combination.			
A10		2. Fully premixed appliances using a pneumatic gas air ratio controller (PGAR)			
A11					
A12		However other technologies are in the field as well such as:			
A13		1. Partially premixed burners using venturi injector mechanism and a fan.			
A14		2. Fully premixed burners using a fan for the air supply and a nozzle for the gas supply			
A15		3. Appliances using a non-premixed jet burner also known as forced draught burner			
A16		4. Electronic gas air ratio controllers using for example mass flow sensors or combustion feedback signals.			

A17		For each technology the risk analysis must identify the appropriate test protocol needed to verify that the risks are mitigated properly. Or alternatively these technologies must be excluded from the scope of the study	The sentence "the appropriate test protocol needed to verify that the risks are **mitigated** properly" is not clear. The testing in WP3 is to evaluate the impact of H2 on the appliance, so the test protocol is to simulate what is going to happen on a real installation and there is no mitigation here. Do you mean **assessed?** WP4 is to bring information to the certification this comment would be relevant. Therefore we will asap also develop the test programme for WP 4 and start also for WP 5. The test protocol covers the risk analysis with the different percentage of H2 in laboratories We will not do the "risk analysis" with separate test protocol for every technology (the testing protocols should be as similar as possible), but there will be specific part of testing for all technology following as far as possible the testing methods from the relevant standards.		
A18		**3) The installation instructions shall be followed to ensure the safety of the user. This includes the instructions for adjustment of the settings of the appliance using the NDG. It must be assumed that this setting will be done either at the NDG having the highest Wobbe index or the NDG having the lowest Wobbe index. In both cases the appliance must be safe.**			
A19		This means that for example fully premixed appliances using a pneumatic gas air ratio controller (PGAR) typically need to be tested at both a the maximum lambda setting and the minimum lambda setting.	Yes this is well covered by the "adjustment tests". Safety is concerned with the minimum and maximum levels of lambda and Wobbe index with the study and the tests are planned at those levels with the different appliances in practice. We may also add some test to check what is going on if the appliances are not adjusted correctly (e.g. 10% CO2 instead of 9%) This situation may already be extrapolated for the test programme proposed (we will need to see/check this)	Adjustment	
A20		Fully premixed appliances using a pneumatic gas air ratio controller (PGAR) the setting of the build in pressure regulator may drift over time due to wear and tear. This risk is mitigated by the instructions that generally require a verification of the setting of the PGAR during installation and maintenance. In the installation and maintenance instructions the specific verification instruction for that			

		appliance is given. This installation and maintenance instruction is part of the appliance. Both the packaging and the appliance must carry a warning that the instructions for installation and maintenance must be followed.			
A21		Different kind of instructions are found:			
A22		1. A CO2 level measured in the flue at minimum and maximum heat input. If the CO2 level is outside a specified range an adjustment must be made and it must be verified that the CO2 level is now withing the specified range at both heat inputs.			
A23		2. A O2 level measured in the flue at minimum and maximum heat input. If the O2 level is outside a specified range an adjustment must be made and it must be verified that the O2 level is now withing the specified range at both heat inputs.			
A24		3. A verification the pressure of the “zero pressure regulator at minimum and maximum heat input. If the pressure is outside a specified range an adjustment must be made and it must be verified that the pressure is now withing the specified range at both heat inputs.			
A25		4. A verification the pressure of the “zero pressure regulator at minimum and maximum heat input. If the pressure is outside a specified range the PGAR or parts of it must be replaced.			
A26		When investigation the suitability of an appliance for other types of gases than those it has been designed the installation instructions that mitigate the risk of drift over time must be followed an a verification must be made that the appliance remains safe at both ends of the acceptable range indicated in the installation instructions using the whole range of gases the appliance is investigated to be suitable for.			

A27		This means that at least two settings of the appliance must be investigated with a setting resulting in the highest lambda according to the installation instructions and the type of gas used, and a setting resulting in the lowest lambda according to the installation instructions and the type of gas used.			
A28		This setting depends on the kind of installation and maintenance instruction used. For example an appliance using instruction on the O2 level:			
A29		· The low lambda setting is found using the gas with the Highest Wobbe of the gas type investigated and setting the appliance at the highest O2 level still acceptable in the installation instructions.			
A30		· The high lambda setting is found using the gas with the lowest Wobbe (and maximum hydrogen concentration) of the gas type investigated and setting the appliance at the lowest O2 level still acceptable in the installation instructions.			
A31		All safety tests must be performed at both settings.			
A32		**4) Testing for combustion stability and smooth ignition limit gases must be used that stress the appliance with a sufficient safety margin beyond the normal foreseeable operating conditions. A headroom of 10% in the lambda must be ensured compared to the foreseeable minimum and maximum lambda given the type of gas suggested. These stressed limit conditions are needed to ensure safety under normal operating conditions.**			
A33		This 10% headroom is also mentioned in the soon to be published PAS 4444 for hydrogen appliances. This 10% headroom is needed assuming the appliance is tested at "reference conditions" as is the common practice is in the EN standards.	WP3 is to test the hydrogen with the EU gas in the different composition and to check H2 impact.		
A34		For pneumatic appliances this 10% headroom can be archived using:		Gases for testing WP3	Extend the test programme to check trends when going above & Below the range EU high _ EU low (add test) (e.g. the proposed 10%
A35		1) A High Wobbe limit gas with a Wobbe index that is 10% higher than the maximum Wobbe index of 52,2 MJ/m3,	This section and headroom principle is mostly dealing with certification (WP4) and less for the evaluation the impact of hydrogen on installed appliances. This said we are also intending to test out of the range EU low-EU		

			high for some test to check what would be the trends. OK for 10%		
A36		2) A low Wobbe limit gas that has a Wobbe index that is 10% lower that minimum base Wobbe index with the maximum amount of hydrogen added. (Adding 23% additional hydrogen on top of the maximum hydrogen added to NDG with the lowest Wobbe index has probably more or less the same effect.)	The certification of appliances (WP4) shall bring a guarantee that the safety of the user is not compromised. The test of WP3 - whatever we are testing – will never be able to give any guarantee due to the numerous limitations ("only" 100 appliances tested compared to > 200 M installed; mostly new appliances, etc…) So we are using a statistical approach based on real gas found in the EU and not adding headroom (on Wobbe **for standard test in WP3**), this will give a more realistic indication of the stock of appliances that may giving issues. **This said we will also test some appliances in extremes conditions (Pressure, temperature, Wobbe in WP3** and WP4 will certainly also give some testing investigating new limit gases.		
A37		Note: Performing a test at using the low lambda setting of the appliance in combination with the NGD that results in the lowest Lambda in Combination with 10% recirculation of the flue gases, is already a tests that demonstrates a 10% head room on the low lambda side.			
A38		If the appliance is tested at the extreme external conditions that result in the theoretical highest and lowest lambda, an additional headroom of 5% is sufficient. This additional 5% is used in the draft version of the EN 15502 amendment for appliances using an adaptive combustion control function. An example of an extreme conditions could be a combustion air temperature of -10 degrees or +40 degrees, while having a gas temperature of 20 degrees.	Very low air temperature will be tested, very high temperature is not planned to be tested		Discuss the possibility of a test at T_amb = 40°C

A39		Of course the elevated CO levels that are acceptable for limit gas testing (typical 1000 ppm DAF) are acceptable at these stressed conditions.	Yes 1000 ppm seems to be reasonable value for extreme/stressed conditions. The evaluation of the results is planned to be done in an harmonized way for all appliances. We have not yet defined this in the very detail.	Thresholds for evaluation	
A40		5) **A suitability of the materials used is in relation to hydrogen is needed. Key points are some metals and elastomers and rubbers used in fittings ,**			
A41		A risk analysis on using gases with high H2 content seems to be missing. PAS 4444 suggests detonation tests on casings that excludes related safety risks a clear specification on the odorization of the gas seems to be missing as the hydrogen may dilute the odorant.	In THyGA Project, it is planned to investigate the tightness and leakage of the hydrogen in the indoor installation and a long-term test is to be done with the different used components from the different countries. The "detonation tests" if this means delayed ignition test; we are discussing this, and tests are already in test protocol, there are safety issues related to this test that are to be discussed. "Odorization of the gas" is a more broad discussion that is not in the scope of THyGA	delayed ignition	
		Safety test			
B1		How to detect flashback when it is not possible to see the flame? (evolution of CO/CO2 in burnt gases?)	This was discussed by labs and some common understanding was proposed by manufacturers in the project.	Flashback	
B2		Warning: only 5 min steps were used during the first safety (flashback test). But ceramic burners have a long thermal inertia. 30 min would be more adequate.	We would not suggest to do it systematically for all burners (cost), but this can be done with ceramic burners.		Adapt the stabilization type to the specifications of the appliance
B3		Is it possible to check the impact of safety times?	This is covered by the discussion on delayed ignition	delayed ingnition	
B4		Do we plan to test appliances at minimum pressure?	Yes	Pressure	

B5		Used burner (partially premix with pressure regulator?) may be interested to test as they might use different technology than current appliances.	See above comment, we shall integrate as many relevant appliances as possible. In case of used appliances this may however be a problem	Old /new appliances	
B6		Do we plan to use an incomplete combustion gas for the tests, such as CH4+propane?	This is maybe a topic for WP4		Topic for WP4?
B8		**Performance test**			
B9		In case of a flashback on an appliance, do we plan to have a safety margin to perform performance test? (=if flashback occur at 35%, will we test it at 30% or at a lower percentage of H2?)	Yes this is the proposal in the latest test sheet	Flashback	
B10		For decorative appliances (=fireplace), do we have a specific test on how the flame will look like?	Not a test but the flame appearance shall be commented, This is also valid for the other technologies, where any change will be noted and recorded (film/photo, etc…)		
B11		Flame ionization is important to check.	Will be when it is possible	Ionisation	
		INPUT ARISTON			
C1		1. Your suggestion for safety and performances tests are clear and it easy to apply it to boiler. Do you take in account also a kind of adjustment for other appliances like water heaters? How do you would manage these products?	Yes the protocol first version is very much based on boilers, but we are now working at adapting it to other appliances (e.g. efficiency) the protocol should be usable for all appliances including water heaters.		Test protocols (mainly integrated in the data sheets) development
C2		2. For performances tests we think that it is important to understand the H2% upper limit for different technologies and in this way understand which are the most promising technologies and which are critical. So according this position we would not stop the test at 30% for those technologies that are able to work with higher H2%,	yes indeed, we plan to go as high as possible so we will challenge the 30% in most tests to find the upper limit	Gases for testing WP3	

C3		3. We expect as possible output of THyGA project a map of existing technologies in relation to hydrogen use, but to do this you should collect the same technology from different manufacturers, otherwise we don't get a mapping but a simple product test. Are you thinking about something like this?	We use a segmentation based on combustion (burners and controls) from the previous Gasqual project. We will test several appliances per segment trying to have a wide diversity of appliances, manufacturers and features so it may not be "technology" as you see it but we think it will be relevant to give a global conclusions on types of appliances per segment. Do you agree with that or do you see other problems within segments?	Segmentation	
C4		4. Of course, we are aware and we don't expect that these tests will realize a complete and exhaustive analysis of the existing old products in field.	At the moment we expect that some of the appliances that will be tested will be used appliances, we are also checking if we can have two versions of the same appliance (used and unused)	Segmentation and list of appliances for testing	
C5		5. About use of hydrogen in field, we don't expect that appliances will be supplied with a fixed H2 quantity over time, do you think it makes sense to introduce a possible life test in which H2 quantity changes over time from 0% to a max %?	We have some long-term tests (~2 years) on some appliances with X% of H2 (X to be defined, but variating) but given the cost only 5 appliances will be tested that way. We have to make sure to identify the sensitive appliances.	ROC	
		INPUT Roald Bac (Bosch):			
D1	s7	•Focus Operation: Ad - Acoustic noises	Yes you are right : Noise to be measured for FB conditions	Flashback	
D2	s7	•Parameter Test conditions: Ad -Min load with max flue resistance, -blocked flue.	We have a test with flue pipe of different size. We have added blocked flue		
D3	s10	R. Bac (Bosch): L-gas? H-gas is meant here.	Yes H-gas, this was a mistake		Correct the slides THY_WP3_009_Test protocol_simple 02c

D4	s13	R. Bac (Bosch): Study shows that the other components in the gas other then CH4 is affecting strongly the results when H2-injection is studied. Limit gasses of the EN437 should be considered once H2 is added (Study is available if needed). So e.g. 30% H2 in G20 should also be checked with the limit gasses as mentioned in the EN437 + the additional 30% Hydrogen. Today we test with limit gases in order to ensure a certain safety margin to the circumstances in the field. How is it approached in this investigation?	WE agree with you, but at constant air excess the flame speed is not very much impacted by the gas composition, but the impact on flame speed of gas composition when the appliance is not readjusted to keep the air ratio constant can be very important and can add to the H2 impact for atmospheric appliances especially. I the testing we test various scenarios including adjustment with and without H2 in the gas and later use with gas with different % of H2.	Gases for testing WP3	
D5	s17	•At which setting of the appliance? If it concerns safety, it should be tested on worst allowed appliance setting since it is known that a certain amount of the boilers today is not running on reference/ nominal conditions.	See the slides with adjustment	Adjustments	
D6		•It has to be considered an appliance installed in an area with a NG quality at the lower end + tolerances for adjustment + bad maintenance and then add the H2 fluctuating as described up to 60%. The same has to be done for the other end, meaning upper limit of NG.	Yes I think that again the adjustment is covering those scenarios	Adjustments	
D7	s17	•Use Two times max flue length (resistance), 80/75dgrC, nom CO2.	We have different flue gas length testing but all test are at 40/60	Flue gas pipe	
D8	s19	R. Bac (Bosch): At the end the study should also reveal the effect on lower heat input of the appliances. E.g. a combination boiler which will not achieve the 55dgrC for domestic hot water.	Yes we evaluate the decrease of performance especially for cooking & hot water production, etc..		
D9	s21	R. Bac (Bosch): Performance test At which setting of the appliance? –2 times max flue length, 80/75ºC, nom CO2. And 35/30ºC	We plan to do the test at nom 40/60 with 1 meter chimney. We don not expect water temperature to play an important role. Do you have references showing this? We could verify this through tests when needed.	Flue gas pipe	
D10	s24	•Late (Delated) ignition to be tested in Part 1. Very important to see for each appliance how that will affect the appliance/system.	We agree and are aware of the importance	delayed ignition	

D11	s24	•Burner temperature is measured, but what about component temperatures close to the burner e.g. ionization pin which might degraded due to higher temperatures. This is not part of Task 2.4.	We measure all we can, but shall not interact with the appliance, so we will need some support from the manufacturers to instrument the appliances or the components	Ionisation	
D12	s31	R. Bac (Bosch): If E and F are not tested because it is done in the GASQUAL study, then it make sense to share the results in the THyGA team and ask the members if they are okay with the findings.	The GASQUAL report is public so there is no problem to share. We are not sure we shall start a debate on Gasqual results in THYGA. We don't have resource to that and it is not really in the scope. (E & F is not including H2)		
D13	s33	R. Bac (Bosch): use 2x max flue length (restrictor) to simulate partly pollution		Flue gas pipe	
D14	s34	R. Bac (Bosch): Study in the Netherlands shows strong effects in SL based upon gas composition (other than Hydrogen).	Yes when air ratio is changed. (see above) but not at constant air ratio	Gases for testing WP3	
D15	s35	• Cold start. Tested with min flue length. Appliance to be cooled till 10-15 °C.	We will cool at T_amb. As we have no other alternative		
D16	s35	•Ambient conditions: A variation of temperature, pressure (gas, air) and humidity has to be considered in a fluctuation which reflects the typical operation range of our products in that climate zone	This can probably not be done (cost & equipment from the labs). Is there some evidence that this may change the results?		
D17	s36	TOC: R. Bac (Bosch): while the appliance is running, these tests will not reveal much new insight. Better might be a scenario where an appliance is adjusted in the field to nominal O2 on high H2, and then check what the effect will be once the H2 will go back to 0%.	OK noted, protocol adjusted consequently	ROC	
D18	s37	R. Bac (Bosch); good the have an overview of the different burner types (flat ceramic / cylindrical / ..) for each appliance type (premix / ..).	Noted. This should be 1) in the sub-segmentation 2) in the reports indicating details about the technologies tested	Segmentation	
D19	s38	Ionization signal is used for flame detection as well as combustion control (Intelligent Combustion Control systems). How hydrogen is affecting the signal should be tested under all mentioned conditions (gas quality (incl. limit gasses) environmental and system conditions, lifetime) .„Measure" according installation manual of application and consult manufacturer upfront.	Yes this has to be done in close relation with the manufacturer.	Ionisation	

D20	s39	•Flash back: definition necessary what do we understand by flashback, + acceptance criteria.	We have had a workshop on this to harmonize views	Flashback	
D21	s39	•Important parameters (loads/ratio/temps burner/heatcell/..) need to be set in worst case condition. (e.g. Tested with maximum (concentric) flue gas length)	Test will be made with 1 meter chimney and additional tests with up to 6 meters for some appliances	Flue gas pipe	
		Valentina D'Acunti (Immergas) :			
E1		P= 17 mbar is the lower pressure level of testing boilers. Why 15 mbar?	This was used in GASQUAL, we could possibly change to 17 mbar, but 15 mbar was the value agreed so far	Pressure	
E2		Why making the difference between used or unused appliance? The aim is to verify the behavior of a boiler with an adjustment for a given gas and that switching on for a different gas?	Yes but aging of appliances may worsen the sensitivity to H2	Old /new appliances	
E3		About safety aspects: a delay ignition should be performed, after a delay ignition a visual inspection and a gas circuit soundness should be undertaken	We agree and are aware of the importance	delayed ignition	Add soundness test after delayed ignition
E4		In Test conditions, standard temperature conditions should be introduced:	Yes, agree	Test conditions	Give clear instructions on standard test conditions
		Mems AG:			
F1	s7	Test conditions: More? -> dynamic (fast) changes in flow: side-effects like flame extinction (safety issue)?	Yes this is included (ROC)	ROC	
F2	s29	What is the alternative here compared to previous slide?	This was a mistake		Correct the slides THY_WP3_009_Test protocol_simple 02c
F3	s47	Tolerance for H2 % in testing 2% is a bit high if you want to achieve H2 steps of 5%.Otherwise, jumps in H2 percentage can be as high as 9% (e.g. change from nominally 30% to 35% could effectively be 28% to 37%).	This is correct, let discuss with the lab what is feasible		Adapt the tolerance to what is feasible in labs
		TC 49 Domestic cooking			
G1	s 7	Is it foreseen to check CO2 emissions as well?	It will be measured		

G2		In the field „Safety“, the leakage check is not mentioned, why?	It will be done for some		clarify in protocol
G3		The variation in the output power should be checked as well. In theory, a certain burner will slightly reduce the output power as long as H2% is increased.	It will be done (is planned)		
G4	s10	100% within EN 437 limits? Or in some cases the Ws is outside this range (i.e. 52.83 in the picture)?	True, we were not aware of this we will ask EU if this is a mistake.		ask Kris de Wit
G5	s13	Natural Gas used for long term test: will it be periodically analyzed to check its variation during test session?	Yes we will follow if there is any trend /change by monitoring measurements		
G6	s17	It is suggested to preheat 30 minutes to have the appliance at steady temperature conditions	Yes there is a preheat before all tests, is adapted to the appliance type	Test conditions	To specify in the protocol
G7	s18	At each step, to perform also: Quick variation Qmin-Qmax Shut-off condition	To be discussed for addition. So it could be Qmin-Qmax with highest H2 possible. Can you precise what you mean with shut off conditions		Open discussion
G8	s19	Metal plate on the burner (simulating griddle), overheating of the burner	To be discussed for addition. Do you mean having a TC on a metal plate that we place on the burner?	Overheating of hob burners	Open discussion and details of test to be decided
G9	s20	How would be flashback evaluated? According to EN 30-1-1? In cold conditions, or hot conditions or both? With and without a pot on the burner? The temperature of the burner has an important influence on the flashback conditions, as well as on the CO emissions. Therefore, the test conditions have to be clearly defined.	Both in hot and cold with and without the pot	Flashback	
G10	s21	How NOx will be measured in household cooking appliances? There is no such test in EN 30-1-1.	We will measure as for the other component in flue gas with the sampling system used for cookers. We are not interested in absolute value of emissions but trends in evolution when adding H2		
G11	s22	The ignition performance, with increased H2 concentration is not checked? Ignition should be smooth, both in cold and hot conditions.	To be discussed for addition, we have only planned a cold start and not a hot start, but this is cheap and easy to implement		Open discussion
G12	s23	Regarding flashback, the test pressures (maximum and minimum) should be also evaluated.	Yes it will- it is planned		

G13	s24	The consideration about going >30% sounds wise. But please note that the CO_2 reduction with max. 30% of H_2 will probably be low.	Yes 30% H_2 is only 10% energy....		
G14	s25	In addition we suggest to evaluate measurement of NOx	Yes it is planned		
G16	s26	For the sake of reproducibility, it would be better to start always from cold conditions, and check always after a certain time (i.e. 20 min). Then increase the H_2 % and start again from cold.	This will be very much time consuming = expensive so it is unlikely to be done, but we will do cold start testing		
G18	s27	The power of a burner, as well as the emissions, change depending on the temperature of the burner. We recommend to follow the normalized test conditions in EN 30-1-1	We will follow En30 as much as possible, but sometimes we will need to shorten and simplify in order to have the most cost effective work		
G20	s28	It has very few sense to check emissions (CO, CO_2) and efficiency at Qmin. Regarding Qmax, we shall point out that the power of the burner is expected to decrease with increased H_2%. It is recommended to evaluate how the power changes. The right comparison in terms of emissions is to be achieved always at the same output power.	Yes Power decrease will be one of the main measurement here. We will do test at Qmin for the first cooker and decide to simplify/remove tests when those are not relevant. We agree that the power decrease will be the main consequence to measure. For the emission we see what you mean, we measure under nominal conditions. We give the emission in mg/kWh so they relate to the heat input (this way your concern is covered I guess?)		
G22	s29	Leakage test is a very important safety test. In our opinion it should also be part of the „standard tests“.	Ok we will see if we can make it is a systematic way		Discuss if leakage shall be a systematic test
G24	s30	Why about the test conditions for the leakage test? The method according to EN 30-1-1, could it still be valid?	Yes we agree we shall use / adapt the existing methods		Clarify leakage test
G25	s31	CO_2 is typically not measured for household cooking appliances on the field, sometimes the CO inside the kitchen environment is measured, but it shall be noted that it is influenced by the kitchen dimension and air ventilation.	Ok		

G26	s32	Are adjustments for domestic cooking considered? We could adjust the bypass inside gas tap to regulate the lower flow rate (minimum) and replace the injector	This is possible we have not considered this. What situation would be checked here (wrong injector?)		Shall we also have adjustment test with cookers
G27	s33	Which measurements are part of the short term test? (relates to used/unused)	For use/unused appliances. At the moment we don not have tests	Old /new appliances	
G28	s34	Sooting gas is G21, we suggest to find an equivalent.	I suggest this is part of WP4 as we do not have sooting test for NG/H2 mix		WP4 discussion?
G29	s35	Domestic cooking appliances typically work at ambient temperature.	OK, this will only be tested at Tamb, the test with very cold temp are for appliances taking air outside the house		
G30	s36	Minimum pressure test in EN 30-1-1 is at 17 mbar + a minimum flame check done at 14mbar (70% of nominal pressure).	OK	gas pressure	To be decided
G31	s37	In Russia and Baltic countries the predominant nominal pressure is 13mbar.			
G32	s38	(related to ionization signal) Which can be the impact of hydrogen on thermocouples used as flame safety devices in terms of durability, signal generation, etc.	This will be part of Long term test. Are most of cookers equipped with TC for flame safety devices (other technologies used? Appliances without saftey device?)		Choosing a cooker with TC for flame safety device for long term test
G33	s39	Flashback can be detected with a thermocouple close to the burner	Yes perfect, we will suggest this as much as possible	Flashback	
G34	s40	Which limits to be considered? The same of CEN or lower considering that Hydrogen can introduce more critical conditions.	To be discussed	Thresholds for evaluation	
G35	s41	Which pressure to be considered? The same of CEN or higher considering that Hydrogen can introduce more critical conditions	See comment/line G30	gas pressure	To be decided
G36	s42	Test conditions will measure humidity too? Please consider preheating (30 minutes) and use of iron plates. See comments in slide 17. From 23%, we suggest 10 minutes waiting time instead of 5.	**Air Humidity**: yes we will measure. Iron plate testing , to be discussed see also point/line G8	Overheating of hob burners	
G37	s44	Further suggestion: decreasing approach à start from 60% and go back to 23% step by step? Can it be more valuable?	It was proposed (by DGC as well), but it was decided to do it the other way round (increase)		Re-discuss in light of the first test done

G38	s46	If flashback occurs, it's suggested to repeat the test sequence to confirm the result with a second iteration.	Agreed		Add this test in the protocol
G39	s47	Typically flashback is influenced by air draught (i.e. laboratory door open) in the lab environment around the open flame burners. It's suggested to have no air draught of the test labs in this project in order to have repeatable results.	Yes agree I shall make this clear in the instructions	Test condition	Make test condition clear
G40	s48	99% H2 is in EN 437 not EN 237.	OK to be corrected		Correct the slides THY_WP3_009_Test protocol_simple 02c
		EHI			
H1		The flue temperature raise due to H2 is an important test to add to the protocol. If the burner temperatures rises due to H2 combustion, how big is the awaited increase and will this influence the flue system which is mainly made of plastics?	I guess this remark is for boilers and water heaters mostly? We will measure the T_flue		
H2		slide 47: the reference to the EN 237 seems wrong as the title is "Liquid petroleum products - Petrol - Determination of low lead concentrations by atomic absorption spectrometry EN 237:2004. But if the EN 437 is meant then it must be stated that this is the latest revision draft. The current version of the EN 437 does not contain requirements for H2.	Yes mistake see above. TC49		Correct the slides THY_WP3_009_Test protocol_simple 02c
H3		Forced draught burners are not integrated in the test program. Is there any reason?	They are!	Segmentation WP2	
H4		Will there be new requirements for components, like gas valves, e.g. lower leakage rates?	THYGA can only make suggestions and or recommendations based on testing results obtained in WP3 and investigations in WP4		WP4. Kris can you look at this questions?

Questions/Answers

In the following text, external questions to the THyGA partners raised during the workshop are printed in blue color, answers are printed in black.

CO thresholds
Mindert van Rij (Kiwa): the classic way is to test extreme conditions and 1000 PPM or 300PPM at normal conditions. Some thinking in TC109 on CO levels could be used in the post-analysis, Mindert will send us the TC109 table.

Old/new appliances
Wilfried Linke (BDH/EHI): to test only old appliances makes no sense as these appliances will disappear from the market. To test only current available appliances should be the majority as these appliances will stay in the market for about 15-25 years. One should concentrate on the technics used rather than the use/not used criteria. BDH & EHI can offer help to select the relevant appliances. Majority of appliances that will be tested will be new appliances.

Delayed ignition
Mindert van Rij (Kiwa) on delayed ignition : there is a max safety time according to the volume of the combustion chamber (difference between few KW and ~100skW). The manufacturer designs the delayed ignition time but there is no harmonized safety time.
Alejandro Cabarga (BSH): for cooking appliances, EN 30-1-1 has safety times, you should apply them rather than inventing new methods. This value remains relevant for blending.
Maurizio Beghi (Electrolux): good opportunity to check the relevance of the standards with blends (position of the sensor and impact on the sensing of the flame?)
Marcel Fraterman (thermoCet): We do delayed ignition testing on decorative balanced flue glass fronted fires in our own lab. cold start max gas flow till max explosion limits up to 60 seconds drop off time thermocouple flame safety
Robert Judd can raise the question with DNVGL UK in Groningen. Also Future Fuels again in Australia. We will use the standard as basis but our scope is not exactly the standard's since we want to have a vision on what will happen on the field ; we will have some different approaches sometimes.

Roald Bac (Bosch): important for the test results to clarify the specifications of the appliance that is tested (delayed ignition time) to make sur that we can compare the relevant appliances between themselves. The project will be as explicit as possible within confidentiality limits

Conclusion THyGA: we will use the input received and evaluate if the present standards are also applicable to NG/H2 mix. (validity of standards) (note after the meeting: this is rather a WP4 activity?) The report shall be extensively describing the appliances tested (still respecting confidentiality)

Gas pressure
Mindert van Rij (Kiwa): The standards give explanation of the max pressure to be used according to the installation conditions. We are in a real situation, the question is why should we male difference between cooker and boilers for example.
Roald Bac (Bosch): a link to the standards is necessary to ensure the safety aspects

Alejandro Cabarga (BSH): for cooking appliances P_min should be 17mbar
Fabio Spano (Electrolux): but in EN 30-1-1 there is also a test at 14mbar

Alejandro Cabarga (BSH): new version of EN 30-1-1 will not use 14 mbar any more, as far as I remember
Salvador Ochoa (BSH): Regarding ENE 30 tests, there is even one at half nominal heat input which is approx. 5 mbar (CO test)
Alejandro Cabarga (BSH): 17mbar should be the correct value. Since this is a flashback test, we can test both at 14mbar and 17mbar to make sure we don't forget some points.
Fabio Spano (Electrolux): Anyway test at 14mbar is kept in new EN 30-1-1, just keep track of this pressure for a test in this standard
Alejandro Cabarga (BSH): Fabio, you are right, but it is a very specific test that checks if the flame is extinguished with a pressure 70% lower than the normal one.

Marcel Fraterman (thermoCet): local heating products are not always fitted pressure regulators. just follow EN437. Pmax 2nd family 30mbar

Appliance categories having as index	Test gas	p_n	p_{min}	p_{max}
1st family 1a	G 110 G 112	8	6	15
2nd family 2H	G 20, G 21, G 222, G 23	20	17	25
2nd family 2L	G 25, G 26, G 27	25	20	30
2nd family 2E	G 20, G 21, G 222, G 231	20	17	25
2nd family 2N [d]	G 20, G 21, G 222, G 231, G 25, G 26, G 27[a]	20	17	30
	G 25, G 26, G 27	25	20	30
3rd family 3B/P	G 30, G 31, G 32	29 [b]	25	35
	G 30, G 31, G 32	50	42,5	57,5
3rd family 3P	G 31, G 32	37	25	45
	G 31, G 32	50	42,5	57,5
3rd family 3B [c]	G 30, G 31, G 32	29	20	35

a For test pressures corresponding to gases distributed nationally or locally, refer to Table B.5.
b Appliances of this category may be used, without adjustment, at the specified supply pressures of 28 mbar to 30 mbar.
c The tests with G 31 and G 32 are carried out at the normal pressure only (p_n = 29 mbar), these test gases being more severe than any gas distributed. This condition covers the normal variations in the gas supply.
d See definition in 6.1.2.2.

Conclusion THyGA: we will use the EN437 (17-25 mbar) for all appliance and will make few tests at lower pressure 14 mbar to test sensitivity of the parameter.

<u>Overall Test conditions</u>
Wilfried Linke (BDH/EHI): the conditions in real-life will have different impacts on appliances (open windows for cookers).
Conclusion THyGA: We will try to make some tests to check that (influence of wind speed)

<u>Plug Flow</u>
Paul Glanville (GTI): Does it need to be plug flow to represent the worst case? It seems true plug flow is unlikely in the field. Yes, this is intended as a worst case that could happen in reality

<u>Additional tests / flashback</u>
Fabio Spano (Electrolux): On/off test: what happens when the movement of the flow is going to zero, qualitative tests (observation of what happens).
Maurizio Beghi (Electrolux): we have a dynamic condition at this point (air/gas stability and then the flashback can occur when we reduce to zero the pressure of the gas in the venturi, the flame speed is

suddenly reduced). Not dangerous (gas is going off but noisy and not acceptable behavior for the appliance.
Lars Jorgensen (DGC) : we observed the phenomenon during the 1st test
Wilfried Linke (BDH/EHI): can also happen with boilers (sound at shut down of the appliance)
Conclusion THyGA: we include the test in the protocol (qualitative and make note of the observations

New test / overheat burners
Fabio/Maurizio (Electrolux): To measure what is the difference on the burner side when overheating with blends, emulating worst operation conditions. Fabio will send some elements to make this test.
Alejandro Cabarga (BSH): in general if you add H2 the temp of the open flame should increase.... how can this be assessed? In some conditions, this could have an effect for the user (destroy pans). The project will consider that (probe in the flame?)
Salvador Ochoa (BSH): Theoretically, also the radiative properties of the flame would change
Stéphane Carpentier (ENGIE): With flame speed increase, the flame might stabilize closer to the burner and overheat it, which could be problematic with aluminum burners. The test with metal plate could reveal this problem, maybe.
Conclusion THyGA: Manufacturers will send more details on the testing with the circular plate. We will include the test in one of the first cooker test and in the light of the results we will see if it shall be extended to the other cookers. Simple test would also be included on one of the appliances to measure temperature in the flame with different % of H2 (not systematic)

Test sheet
Some manufacturers (Bosch) would like to have the test sheet to make their own tests.
Conclusion THyGA: OK, it is relevant, we will send the test sheet once in a version more finalized to the labs that want to test their own appliances with the same protocol

Wilfried Linke (BDH/EHI): at part load, there is a phenomena on draught burners that should be looked at. **Wilfried Linke/Frank Burmeister will come with a proposal**
Alejandro Cabarga (BSH): questions from TC49 on leakage tests that are not included in the protocol. TC49 thinks that this topic is very important and needs to be addressed. Some specific tests are done on leakage by the project but the topic is not closed on the tests themselves.
Conclusion THYGA: We are opened to proposals from TC49. We will certainly include a leakage test.

Marcel Fraterman (thermoCet): for decorative flame fires visibility of flame is essential and also the "soot" number.
Conclusion THYGA: We plan to have visual observations and evaluate in general if H2 impacts the function for which the appliance is designed. This means visual observation, possible noise or decrease of performances due e.g. to lower power. Soot will be checked for cookers & decorative heaters (though it is expected that H2 will reduce the problem)
Alejandro Cabarga (BSH): visibility of the flames is also very important for open burners in cookers
Conclusion THYGA: see above

Review of "THY_WP3_015_Compilation feedback from TC and answers 01"
Fabio Spano (Electrolux)::
1) Adjustment of Qmin
2) Nozzle change

Fabio Spano (Electrolux): will there be adjustment test with cookers? Adjustment on cookers. This could be:

3) Adjustment of Qmin
4) Nozzle change

Conclusion THYGA: Appliances will be adjusted to Qmin according the standard, but we don't plan to test appliances with wrong nozzles in WP3. WP5 could possibly look at optimizing nozzles for NG/H2 mix.

Alejandro Cabarga (BSH): answer to comment "G32", should we give an answer now? à most use thermocouple (ionization exist also). Safety device is compulsory (= no appliances without) New question arising after the meeting: Does this also apply to installed appliances? If not when became this compulsory? (age of installed appliances that have no safety device to know if we shall consider some for the testing?)

Conclusion THYGA:

<u>We were probably not able to address all comments from "THY_WP3_015_Compilation feedback from TC and answers 01", but we believe 95% of those were discussed. If there is remaining points that need a discussion we encourage everybody to contact us.</u>