Hy4Heat

Mark Neller

Arup+ Hy4Heat Programme Director


CHURCH HOUSE
12

Agenda

- 10.30am Welcome
- 10.35am BEIS Innovation, Policy and Hy4Heat
- 11.20am Panel Q&A
- 11.35am Industrial and Commercial Hydrogen Appliances
- 11.45am BREAK
- 12.00pm Standards and Certification
- 12.15pm Safety Assessment
- 12.30pm Hydrogen Appliance Development
- 1.15pm Panel Q&A
- 1.30pm NETWORKING LUNCH

BEIS Innovation, Policy and Hy4Heat

SPEAKERS

- Mark Taylor, BEIS Deputy Director, Innovation
- Richard Leyland, BEIS Deputy Director, Policy
- Heidi Genoni, Arup+ Hy4Heat Programme Manager

PANEL Q&A

Joined by

- Mark Crowther, Arup+ Technical Director (Kiwa)

Dr Mark Taylor

BEIS Deputy Director, Energy Innovation

Hy4Heat

Professor Mark Taylor FIMA
Deputy Director, Energy Innovation
Science and Innovation for Climate and Energy

Hy4Heat Engagement Event
9th March 2020

Department for
Business, Energy
& Industrial Strategy

The Climate Change Act is the basis for UK action to cut emissions

Long-term target

The UK Climate Change Act commits the UK to an at least **80% reduction in Greenhouse Gas** (GHGs) **emissions** in 2050 compared to 1990 levels.

Government **is now committed to net zero** by 2050.

Carbon budgets

The Act requires that we cap GHG emissions over **successive 5 year periods.**

Scrutiny

The Act established an independent **Committee on Climate Change (CCC).**

BEIS Energy Innovation Programme

The overall aim of the BEIS Energy Innovation Programme is to accelerate the commercialisation of innovative cheap, clean, and reliable energy technologies by the mid 2020s and 2030s.

- Within each theme the budget is allocated to a mix of development and demonstration projects focused on specific objectives, underpinned by a programme of open, cross-cutting support
- This programme has a steep spend trajectory to 2021, and will be challenging to deliver in the compressed time frame
- Over £300m of the £505m announced so far

£180m Nuclear
Driving down costs and building new UK supply chains and skills

£15m Renewables
Driving down the cost of low carbon electricity at scale

£100m Industry
Low carbon options for industry, lowering energy costs

£90m Built Environment
More cost effective energy efficiency and low carbon heating

£70m Smart Systems
Scaling up flexibility and looking for new storage options

£50m Cross Cutting
Supporting disruptive innovations (particularly for SMEs), including using innovative finance.

First of a Kind	Description	BEIS Funding £m
Carbon Capture **Tata CCUD**	Demonstrate carbon capture and utilisation at key industrial site in the UK	**4.2**
Offshore wind **Magnomatics**	Successful test of 500kW Generator using magnetic gearing to demonstrate efficiency savings in Wind Turbine Generation	**1.1**
Hydrogen Boilers	Worcester-Bosch successfully demonstrate a hydrogen ready boiler	**0.75**
Second Life EV batteries	Nissan developing second life EV plant in Sunderland after Warwick University successfully developed world leading sorting and grading technology	**0.9**
Energy Storage at Scale	Liquid Air Energy Storage to provide grid services	**10**
Plastic waste recycling **Recycling Technologies**	Changing the story of waste plastic. Producing Plaxx a hydrocarbon product, meeting the commercial specifications of an industrial burner fuel. 7 million tonnes by 2027. Total, Mars and Nestlé join forces with project to develop Chemical Recycling of Plastics in France	**0.7**
Gigastack - Hydrogen production from offshore wind	To develop a semi-automated factory for the production of a new generation of electrolyser producing them at a rate 10x greater than the largest factory today	**7.5**
Fuel switching technologies for the glass sector	Multi-partner study looking at the possibility of fuel switching to sources such as biofuels, hydrogen and electricity	**7.1**
HyNet North West	Hydrogen energy and Carbon Capture, Usage and Storage project in North West of England.	**13.2**
Piclo	Independent market place for trading flexibility online. November 2019: UKPN announced biggest ever flexibility auction (170MW) using Piclo platform	**0.4**
Grid connected hot water tanks. Mixergy	Demand response enabled energy efficient hot water tanks. First hot water product with National Grid approval. Secured British Gas contract	**0.3**
Battery Energy Storage Systems. **PowerVault**	Using the GridFLEX™ platform PV offer grid supporting services and customers can sell electricity back to the grid when it is under stress	**0.58**

Policy drivers and context

HEAT STRATEGY

Assessing heat decarbonisation approaches to meet 2050 targets

- Electrification (heat pumps, hybrid heat pumps with gas boilers);
- Decarbonisation of gas grid (hydrogen, biomethane, heat networks)
- Not clear which approach(es) will work best at scale and offer the most cost effective long term answers. Likely a range of approaches will be needed to meet diverse consumer needs.

CCUS

Exploring pathways to deploy CCUS at scale in 2030s

- HMG wants the UK to become global CCUS technology leader and work internationally to bring about global cost reductions
- Ambition is to have "the option of deploying CCUS at scale during the 2030s, subject to costs coming down sufficiently"
- Interest in broad role for CCUS including low carbon hydrogen production at scale

HYDROGEN ECONOMY

Developing a strategic approach for UK

- Improved understanding of potential to meet Clean Growth goals, with appropriate time horizons
- Whole system perspective – starting with detailed understanding of potential in each sector
- Building relationships and identifying opportunities to unlock deployment of low carbon hydrogen in UK context

UK Housing

- We have a varied housing stock with many dating back to the industrial revolution
- 80% of the current building stock will still be in use in 2050
- 85% of homes are currently supplied by natural gas through the gas grid

Whole House Retrofit Competition (£9.7m)

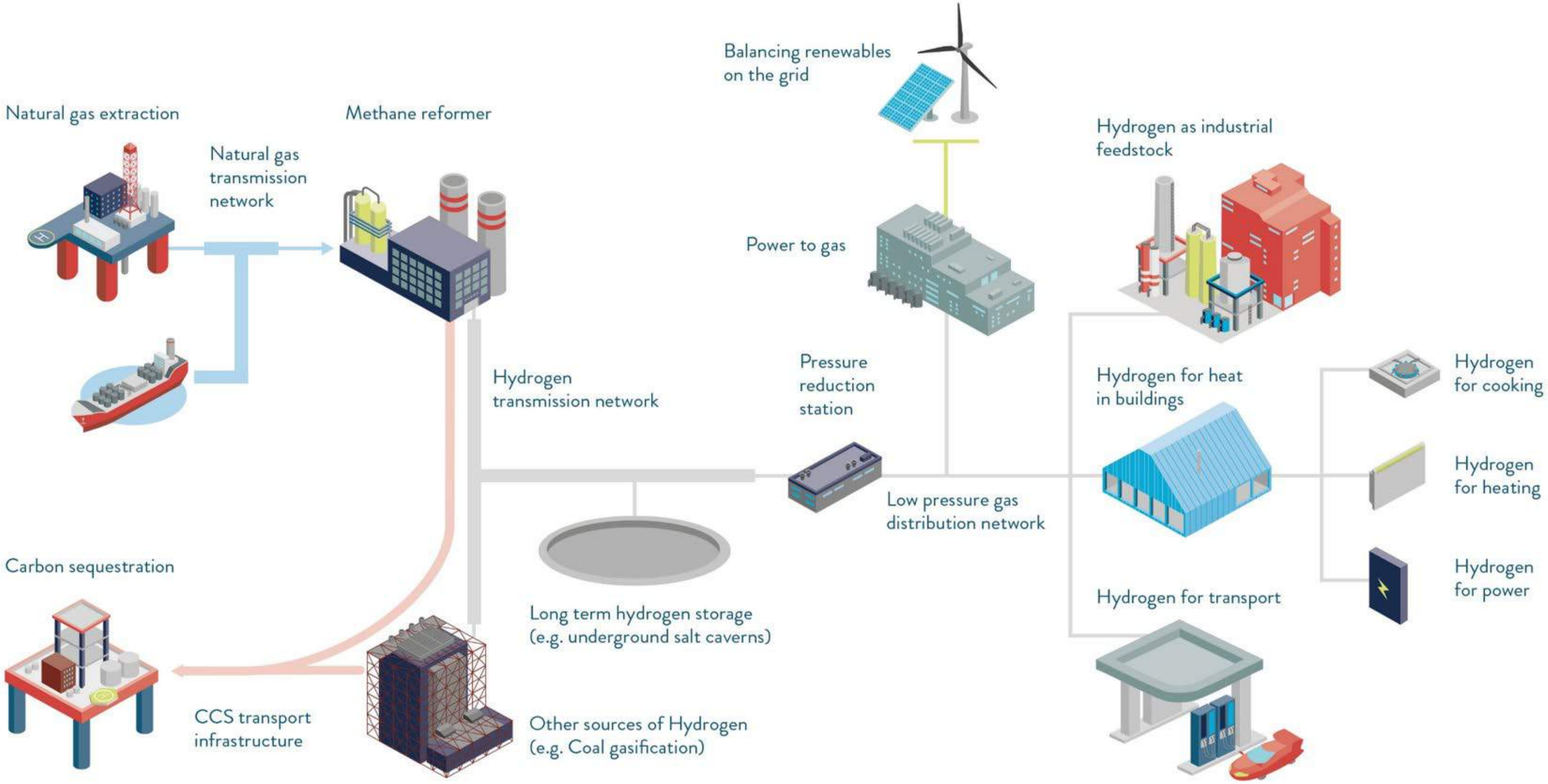
Aim: to demonstrate cost reduction in the deep retrofitting of buildings through innovative approaches to retrofit at scale

Outputs: Each project will work to deliver:

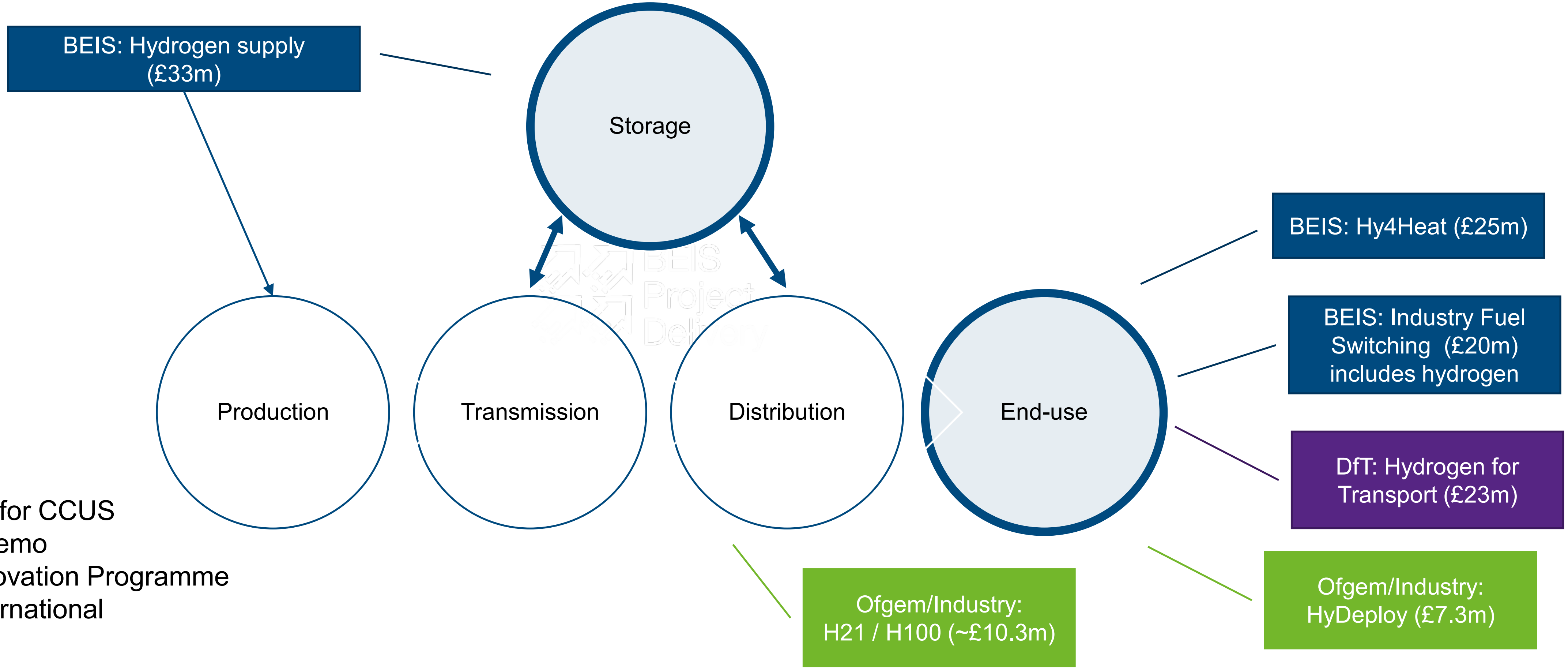
- Demand and cost reduction with ‘fabric first’ approach
- Focus on process innovations
- evidence on deployment roadmap
- in-situ performance measurement pre- and post retrofit
- improvements in the health and well-being of occupants

Learning: expect ‘learning by doing’ and demonstration in practice.

Hydrogen Economy



Hydrogen pathway



BEIS: £54m funding for CCUS

- £20m for CCU Demo
- £24m CCUS Innovation Programme
- £10m CCUS International Collaboration

Hydrogen Networks – HyNTS and H21

HyNTS Led by National Grid

Feasibility of using hydrogen in the National Transmission System

Investigating use of the isle of grain to supply London & the South East

Investigating blending and deblending in the Aberdeen area

H100 – Led bySGN

Examining the feasibility of converting 300 homes and businesses to 100% hydrogen

Researching the impact of distributing and using hydrogen.

Developing a safety case for the use of hydrogen

HyNet – Led by Cadent

Currently building technical, cost and practical evidence to inform heat and carbon capture policy

Developing hydrogen and carbon capture infrastructure, aiming for first deployment by 2026 subject to funding

H21 NIC – Led by Northern gas networks

Undertaking testing programme to provide quantified safety evidence comparing natural gas with 100% hydrogen in distribution networks

Confirm potential changes in background leakage levels

Consequence testing to understand changes to safety risk under background leakage conditions

Assessing impact of failures and operational repair

Industry & CCS Competitions

- 1 Market Assessment Study Delivered
- 36 Feasibility and FEED Studies Delivered
- 48 "Final Studies" in Delivery or in Award Process

Hydrogen Supply (£33 million)
Aim: identify solutions to produce zero or low carbon hydrogen
Phase 1 → Feasibility Studies → 13 studies complete
Phase 2 → Demonstration → 5 projects in delivery

Industrial Fuel Switching (£20 million)
Aim: Identify methods to move industry from fossil fuels to low/zero carbon sources
Phase 1 → complete → 1 market engagement study
Phase 2 → Feasibility Studies → 7 studies completed
Phase 3 → Demonstration → 4 projects in delivery

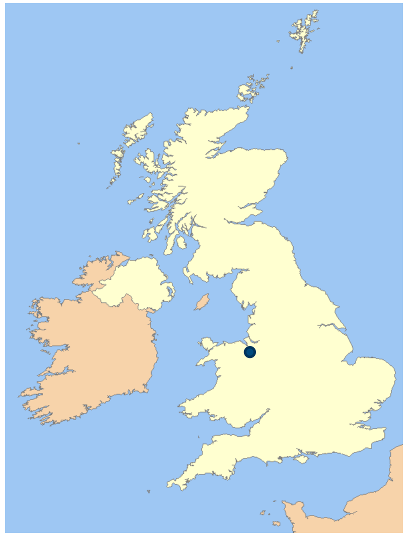
CCUS Innovation (£22 million)
Aim: achieve significant cost reduction against state of the art CCUS technology
Phase 1 → Demonstration → 7 projects in delivery

Industrial Energy Efficiency Accelerator (£10 million)
Aim: Develop solutions already close to commercialisation to reduce energy costs for UK industry
Phase 1 → 7 projects in delivery
Phase 2 → 8 projects in delivery, 1 in award process

ACT CCS International (£13 million)
Aim: Fund CCUS projects as part of consortium with 9 European countries
ACT 1→ 5 projects awarded, finishing 2020
ACT 2 → 10 projects awarded, finish Sept. 2022

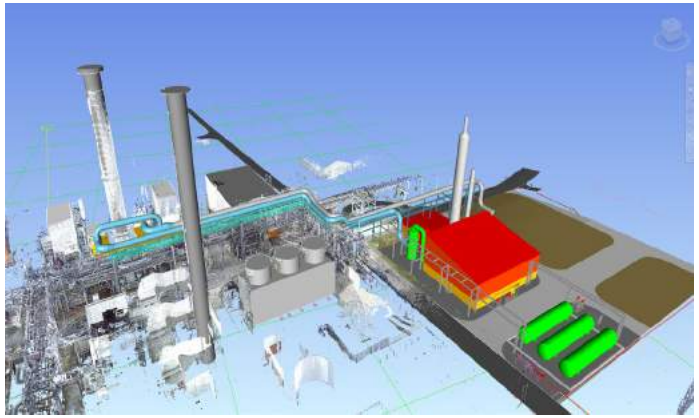
CCU Demonstration (£5 million)
Aim: Identify methods to move industry from fossil fuels to low/zero carbon sources
Phase 1 → Feasibility → 14 feasibility studies Complete
Phase 2 → FEED → 2 studies Complete
Phase 3a → 1 project in delivery

Tata Chemicals Europe: Carbon Capture & Utilisation Demonstration



Headline
Largest Industrial size CCU project in the UK, capturing 40,000 te of CO_2 from gas fired CHP and use in manufacturing of pharmaceutical grade sodium bicarbonate for export markets

Key Outcome
Capture, liquefaction, purification and reuse of 40,000 te of CO_2 from power plant and use as key raw material for manufacturing thus reducing carbon emissions by 11% which is equivalent to removing c22,000 cars from the environment



Work includes

- Construction of CCU plant utilising advanced amine technology
- Liquefaction , purification to food quality standards
- Use in sodium bicarbonate plant, eliminating CO_2 imports and enabling business growth in export markets

Hydrogen Supply Competition - BEIS

- **£33 million (increased from £20m)**
- Identify how to supply low cost, low carbon hydrogen at scale at a reduced cost at a lower carbon intensity
- Run over two phases
  - £5m Feasibility – 13 projects split into three key areas; Low Carbon; Zero Carbon; and Storage, the reports are all live
  - £28m Demonstration – 5 successful projects completing March 2021

Lead Company	Demonstration Project
Cranfield University	Build a 1.5MW pilot demonstration with potential for high capture rates based on hydrogen production technology from GTI
Progressive Energy Limited	Developing the FEED for JM's GHR Auto-Thermal Reformer Hydrogen Plant located on Stanlow Oil Refinery
Pale Blue Dot Energy	Acorn Hydrogen Project: pre-FEED on producing hydrogen using GHR at St Fergus to supply the gas grid
ITM Power Ltd	Gigastack – Build a prototype of a larger cell and scaled up production of electrolysers, working with Orsted and Philip 66 to develop a 100MW electrolyser
Environmental Resources Management Limited (ERM)	Dolphyn – Detailed design for a 2MW pilot, producing hydrogen from floating offshore wind

Industrial Fuel Switching Programme - BEIS

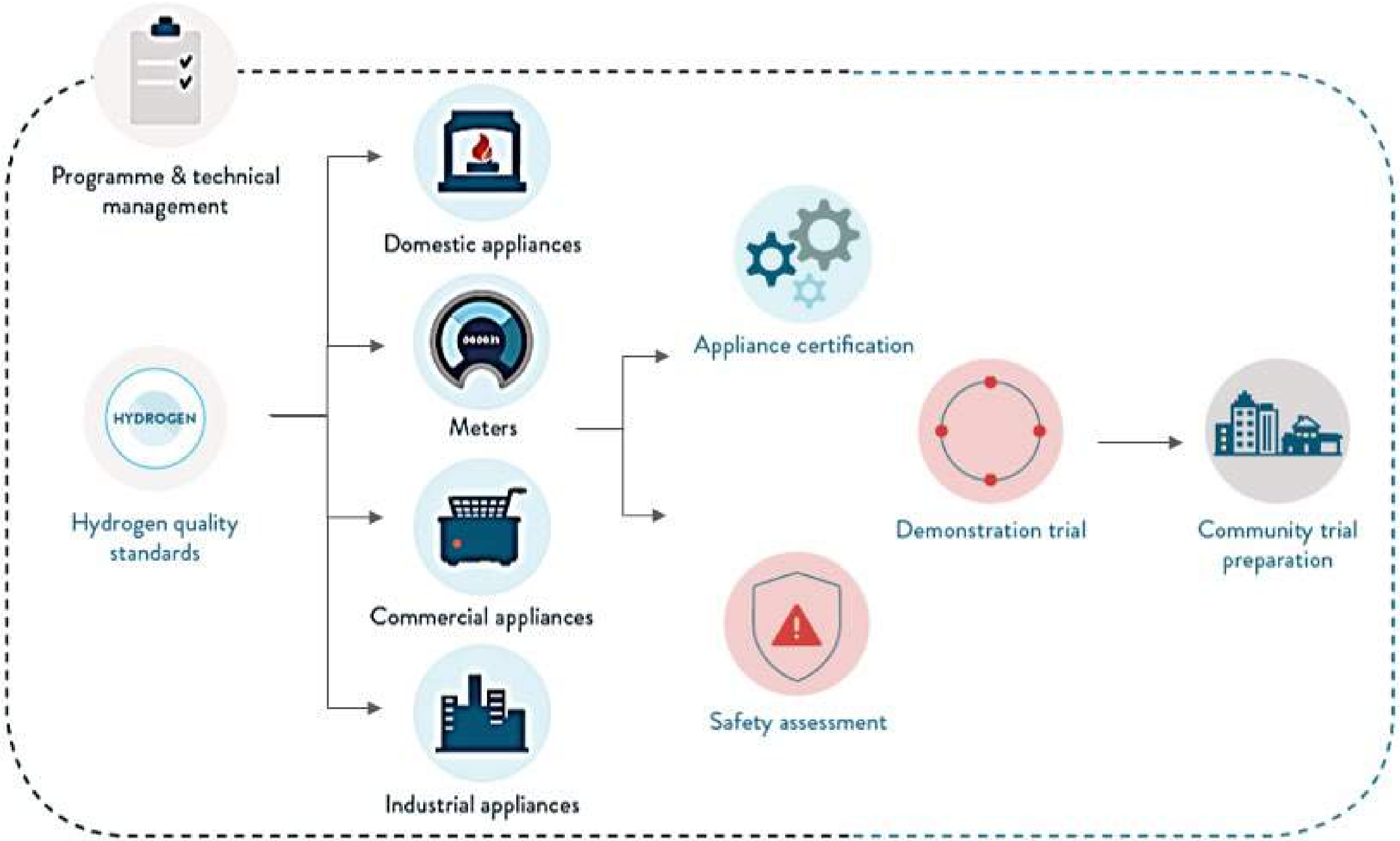
- **£20 million competition**
- Enabling the development of industrial processes to switch to fuel switching to low carbon fuels (including hydrogen, biomass and electricity)
- Run over three phases
  - £200k Market Engagement and techno-economic study
  - £2m Feasibility – 7 projects over a range of industrial processes from a distillery to the glass sector
  - £17.5m Demonstration – 4 successful projects completing March 2021

Lead Company	Project Title w/short description
Progressive Energy Ltd	HyNet North West – looking at testing a range of hydrogen industrial use opportunities across the North West and developing a hydrogen CHP
Mineral Products Association	Testing switching UK cement production to operate on low carbon fuels including hydrogen, biomass and electrification
Glass Futures Ltd	Trialling the potential for the glass sector to use alternative fuels across the sector
British Lime Association	Testing the use of hydrogen in the high calcium lime sector

Hy4Heat mission

To establish if it is technically possible, safe and convenient to replace natural gas (methane) with hydrogen in residential and commercial buildings and gas appliances

This will help enable the government to determine whether to proceed to a community trial

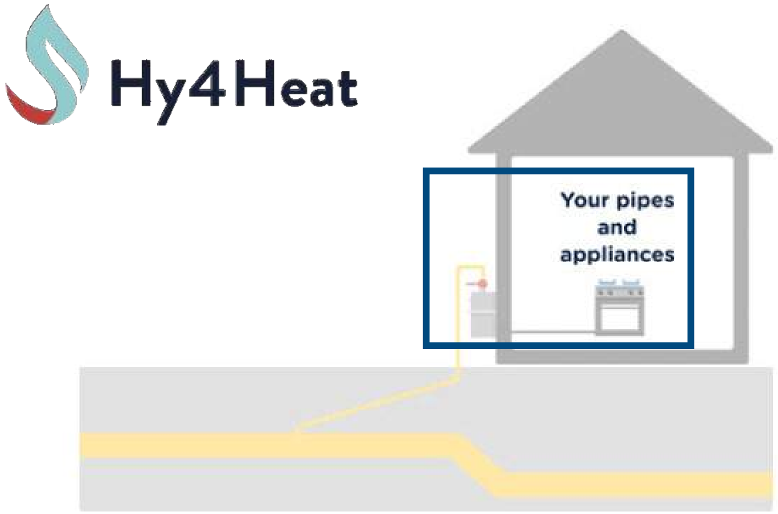


Hy4Heat programme work packages

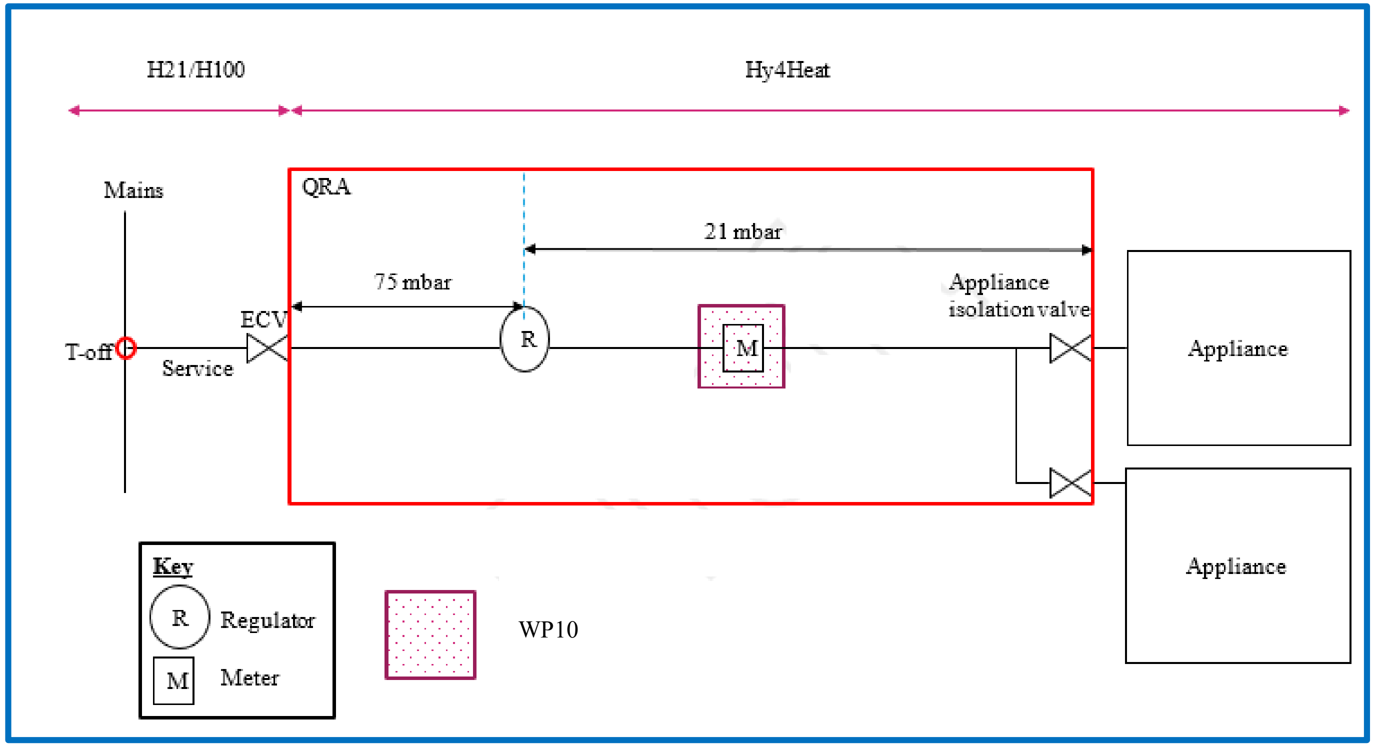
Hy4Heat

Department for Business, Energy & Industrial Strategy

Safety Assessment Scope



Scope Boundary



Dispersion Experiments in 2-storey Property

Dispersion and accumulation of methane and hydrogen in a 2 storey property

- To test and compare the movement and accumulation of methane and hydrogen in a typical 2-storey domestic property for a range of gas leaks
- Improve our understanding of gas dispersion and therefore our quantification of the risk from leaks of both gases
- This will allow us to better quantify the range of possible gas concentrations close to likely sources of ignition for both gases

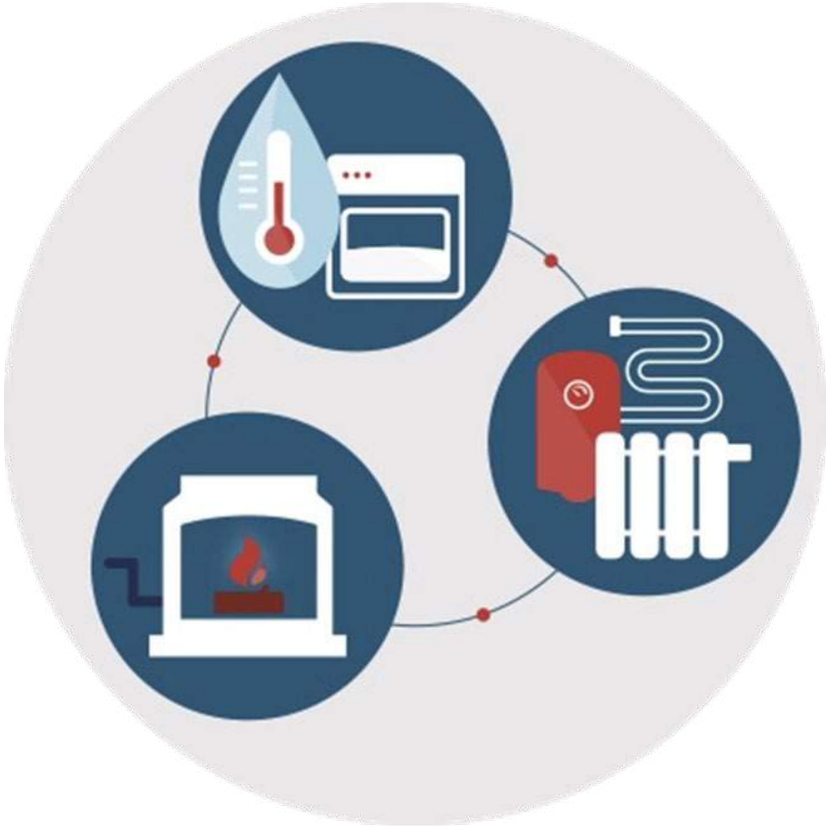
Dispersion → Explosion → Structural response → Human injury

Hy4Heat

Department for Business, Energy & Industrial Strategy

Three demonstration facilities

- **Outdoors moveable demonstration showroom** with operational appliances using hydrogen
- **Exhibition showroom** stands *(for display purposes only)* indoors at exhibitions and industry events
- **Portable cooking demonstration** (chef demo) unit to enable cooking demonstrations at various locations using a hydrogen fuelled hob



Hy4Heat

Conclusions

- We have commissioned significant work, much of which is well underway, and is considerably advancing our knowledge base:

Appliances / devices:
- Domestic boilers, fires, cookers
- Commercial
- Smart meters

Safety case:
- QRA
- Safety assessments

Hydrogen standards
- Purity, colorant and odorant
- IGEM reference standard

Certification guidance
- BSI / PAS 4444

Research reports:
- Industrial appliances
- Commercial appliances

Cross-cutting new outputs
- Hydrogen Knowledge Centre
- Competency Framework with Energy and Utility Skills

- Now focusing on pulling this learning together to provide a robust safety case annex and high-quality demonstration outputs, able to show hydrogen as a safe and pragmatic solution for heat decarbonisation

Hy4Heat

Richard Leyland

BEIS Policy

Hy4Heat

Heidi Genoni

Arup+ Hy4Heat Programme Manager

Hy4Heat

demonstrating
hydrogen for heat

Hy4Heat's Mission

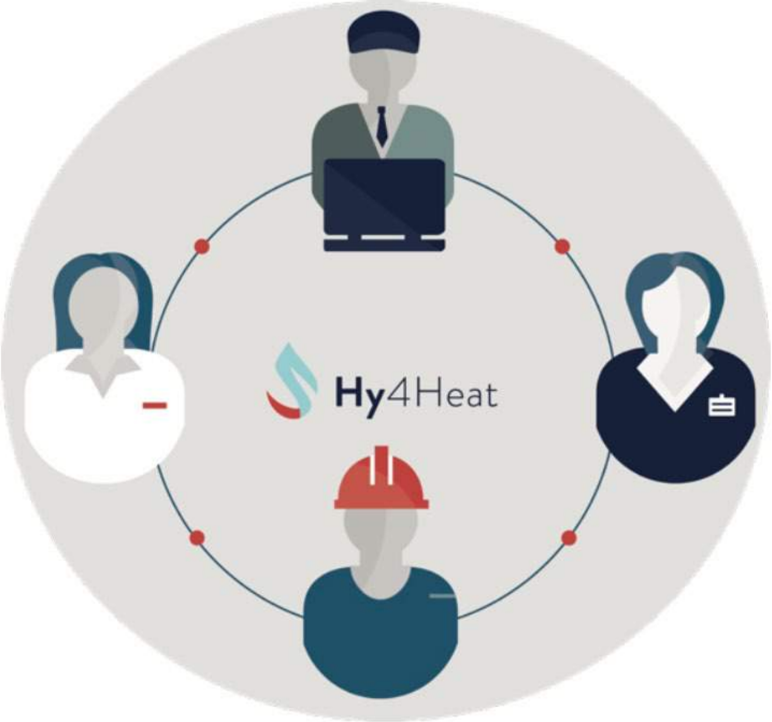
To establish if it is technically possible, safe and convenient to replace natural gas (methane) with hydrogen in residential and commercial buildings and gas appliances

This will help enable the government to determine whether to proceed to a community trial

Our Approach

- Collaborative
- Impartial
- Evidence based
- Stakeholder focused

- Open & transparent
- Engagement & dialogue
- Flexible in approach
- Philosophy of 'like for like' innovation & hydrogen ready



Hy4Heat Success

- Evidence that the technologies are feasible (e.g. certified hydrogen appliances etc.)
- Evidence that it is safe to use hydrogen in our homes (i.e. safety assessment based on experimental results and empirical data)
- Evidence of initial consumer acceptance – demonstrations

Department for Business, Energy & Industrial Strategy

Hy4Heat

Organisation

Department for Business, Energy & Industrial Strategy

Hy4Heat – demonstrating hydrogen for heat

Hydrogen Coordination Group
- Gas Distribution Network Operators
- National Grid
- IGEM
- Ofgem

Advisory Panel
- Independents, industry experts & academics
- Ofgem
- Health & Safety Executive
- Gas Distribution Network representative

WP 2 – Hydrogen Quality Standard
- IGEM
- DNV GL

WP 3 – Appliance Certification
- BSI

WP 4 – Domestic Appliances
- Baxi
- Worcester Bosch
- Clean Burner Systems
- Hycookers (Consortium led by Enertek)
- Hyfires (Consortium led by Enertek)
- Samad Power

WP 5 – Commercial Appliances
- ERM

WP 10 – Meters
- MeteRSit
- Pietro Fiorentini

WP 6 – Industrial Appliances
- Element Energy

WP 7 – Safety Assessment
- DNV GL
- Steer Energy

WP 8 – Demonstration Facilities

WP 9 – Community Trial Preparation

NPL National Physical Laboratory

Legendfires

ARUP

Solid Power

Falcon

Pietro Fiorentini

Steer Energy

kiwa

Advisian
Worley Group

Cadent
Your Gas Network

IGEM
Institution of Gas Engineers & Managers

Progressive energy

Loughborough University

NORTEK GLOBAL HVAC

WORGAS
A Beckett Company

ERM

Health & Safety Laboratory

Northern Gas Networks

Teddington Bemasan
part of the Teddington Group

WORCESTER BOSCH

Cardiff University
Prifysgol Caerdydd

Hy4Heat

CAG Consulting Ltd

SGN
Your gas. Our network.

Wales&West Utilities

Clean Burner Systems

GlenDimplex
Heating & Ventilation

technopolis |group|

Department for Business, Energy & Industrial Strategy

DNV·GL

GAZCO
Fire Your Imagination

valor

University of Leeds

Brunel University London

POWRMATIC

bsi.

Samad Power Ltd

ofgem

Enertek International

MeteRSit

element energy

BAXI

Charlton & Jenrick Ltd
Best of British fires, fireplaces & stoves

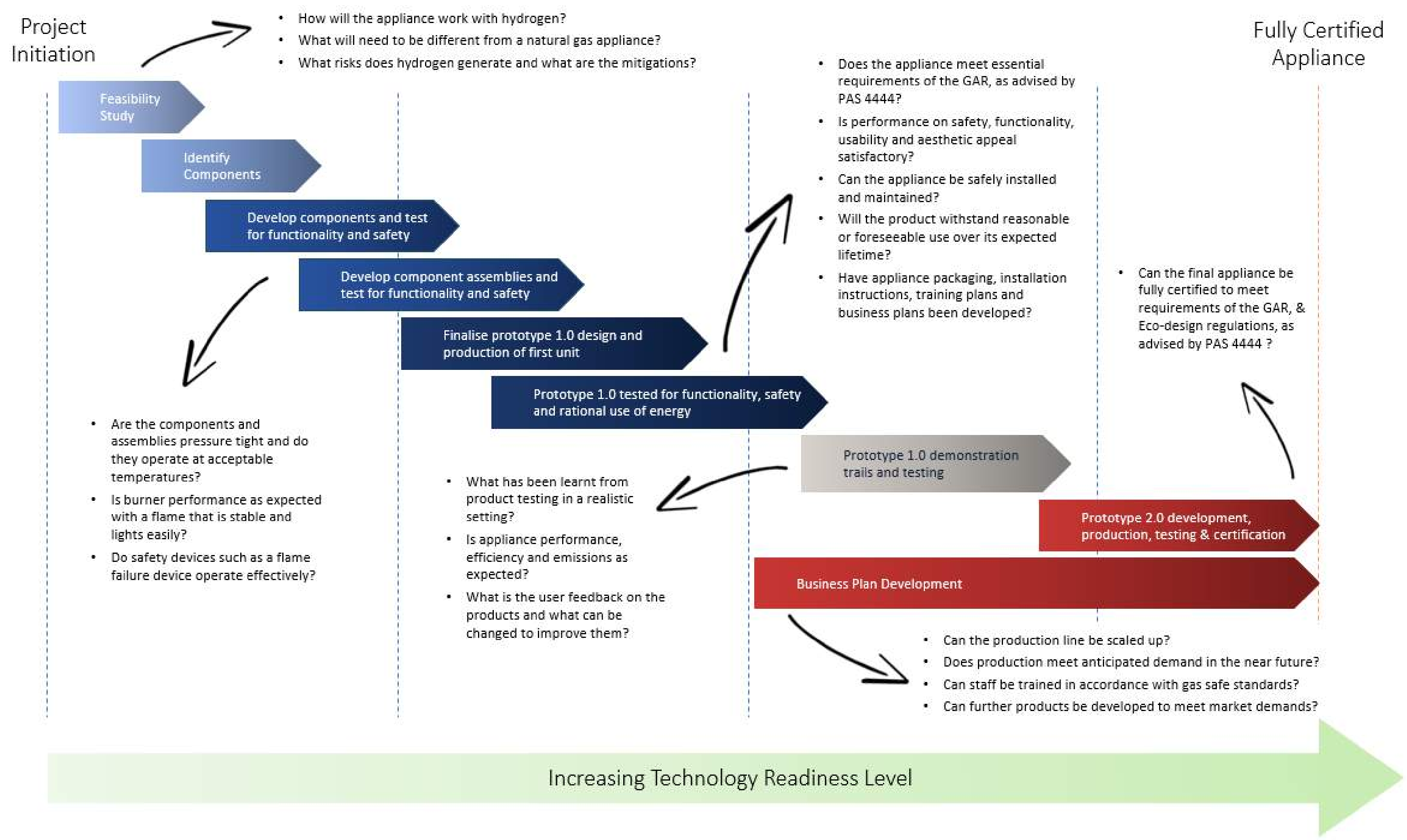
Birmingham Burner (Walsall) Limited

Almaas Technologies Limited

Overview of Work Packages and Progress

Work package	Progress	Work package	Progress
Programme Management	✓	Commercial market review + appliances	✓
Quality & Standards (IGEM, purity etc)	✓	Industrial market review	✓
Certification of appliances (BSI PAS4444)	✓	Safety Assessment incl. experimental testing	✓
Domestic appliances + ancillary systems components	✓	Demonstration trials	✓
Metering (SMETS2)	✓	Preparations for community trials	✓

Accelerating Innovation - The Appliance Development Pathway



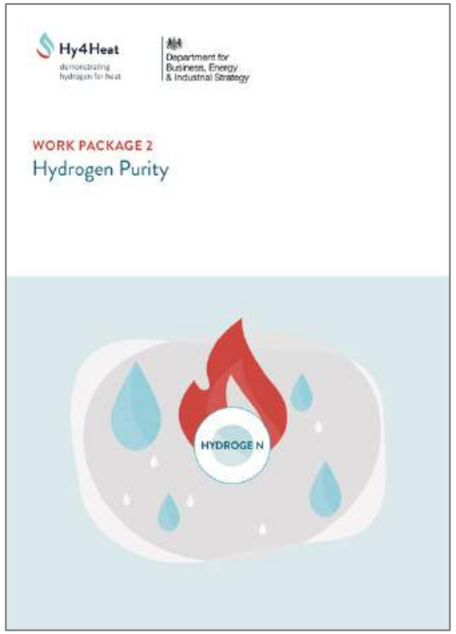
What To Look Forward To In The Next 12 Months…

- Showcasing the prototype hydrogen appliances in a home setting (e.g. kitchen, living room, bathroom, + cooking demos etc.)
- Evidence and disseminating knowledge – safety is critical
- Preparing for potential community trials

- Keep… - engaging – collaborating – delivering

Sharing Information

- www.hy4heat.info
- Newsletters / updates / tweets
- Key documentation e.g. ITTs, guidance notes etc.
- Reports



Hy4Heat

Panel Discussion

To Ask A Question Use 'slido' Or Put Your Hand Up

Join at: **slido.com**
Event Code: #Hy4Heat

wifi: CHW-guest

pass: Westminster1

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Industrial and Commercial Appliances

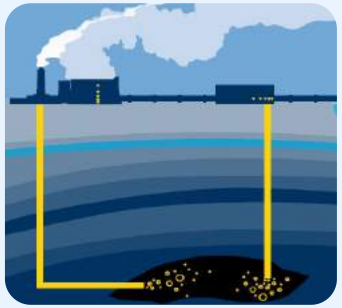
Industrial and Commercial Research

SPEAKERS

- Emrah Durusut, Element Energy
- Brett Ryan, ERM

Emrah Durusut

Element Energy



Hy4Heat WP6:
Conversion of Industrial Heating Equipment to Hydrogen

9 March 2020

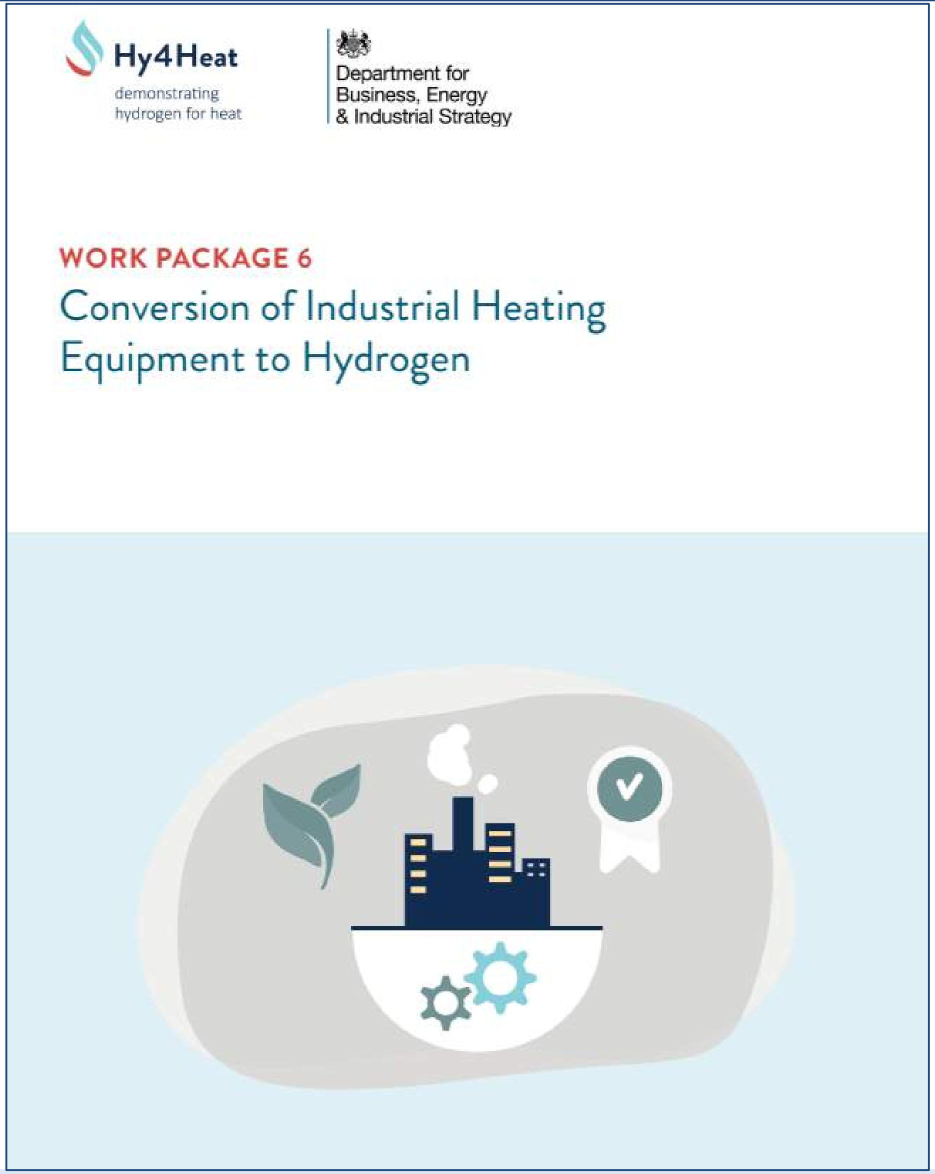
elementenergy

Advisian
Worley Group

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Emrah.Durusut@element-energy.co.uk

Report is available on the Hy4Heat website

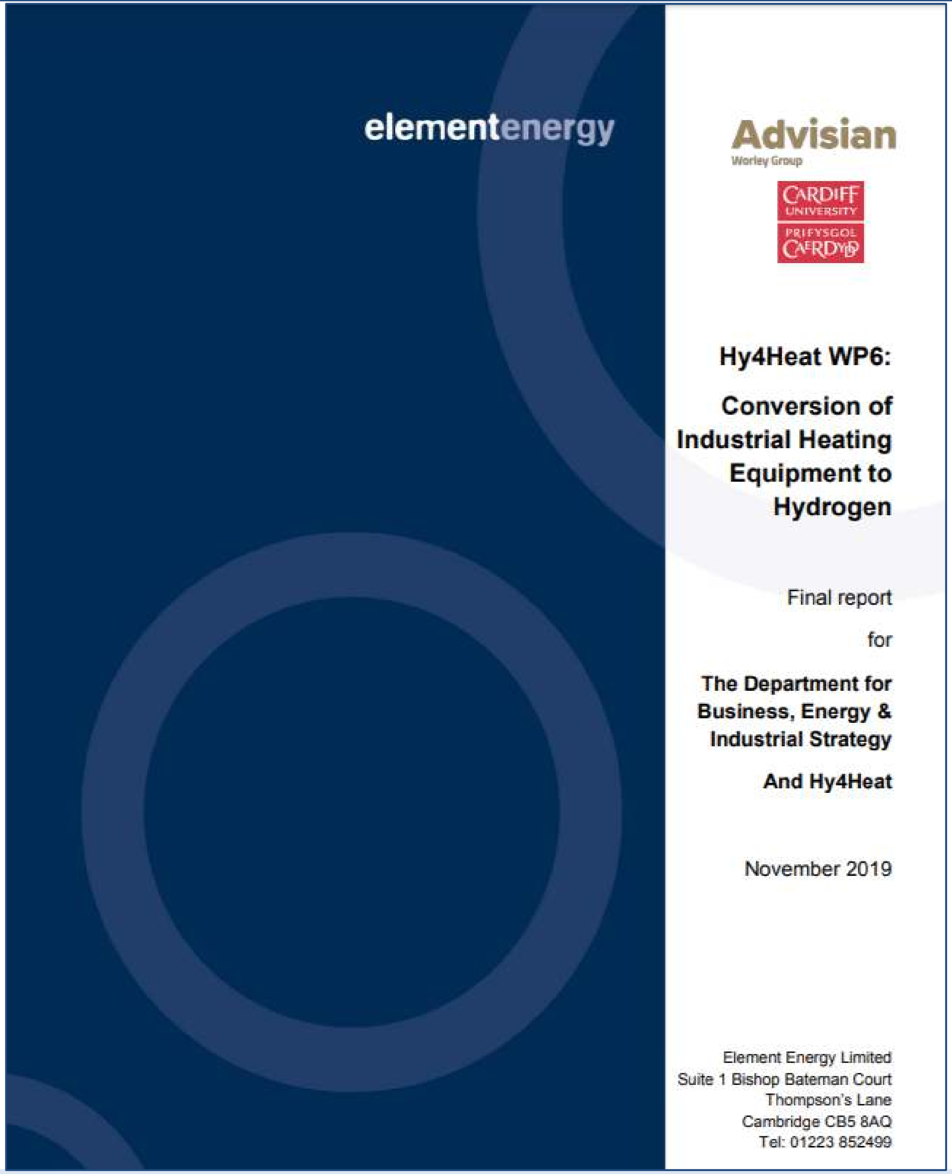


Hy4Heat
demonstrating
hydrogen for heat

Department for
Business, Energy
& Industrial Strategy

WORK PACKAGE 6

Conversion of Industrial Heating Equipment to Hydrogen



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Advisian
Worley Group

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Hy4Heat WP6:

Conversion of Industrial Heating Equipment to Hydrogen

Final report

for

The Department for Business, Energy & Industrial Strategy

And Hy4Heat

November 2019

Element Energy Limited
Suite 1 Bishop Bateman Court
Thompson's Lane
Cambridge CB5 8AQ
Tel: 01223 852499

Study objectives and approach

The key aims of the study

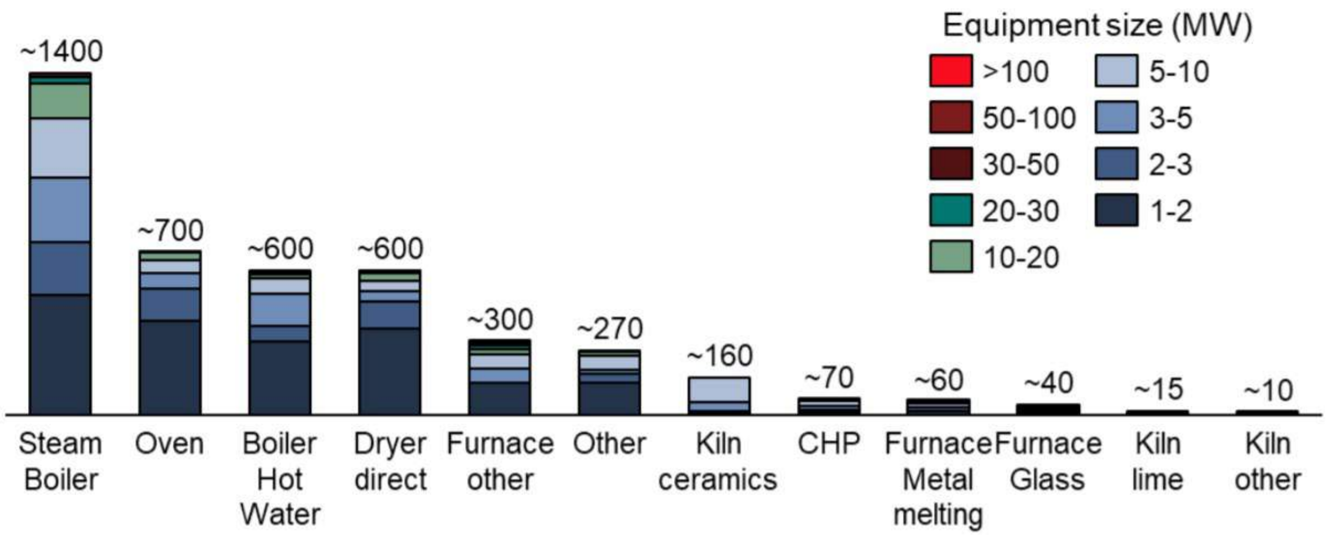
- **Characterise the industrial equipment market** in the UK
- **Assess technical challenges and constraints** of hydrogen conversion
- **Estimate the costs** associated with industrial hydrogen conversion,
- **Understand the equipment research, development and demonstration work required**
- **Highlight the remaining challenges and knowledge gaps** which require further consideration.
- Focusing on sites **connected to the <7 bar gas network**, and equipment with thermal capacity of **above 1 MW.**

Study approach

- **Stakeholder engagement**, with input from gas distribution network operators, Industry Associations, industrial sites and technology vendors. An industry survey also gathered data on around 70 industrial sites, and an industry workshop was organised, attended by 45 stakeholders.
- **A detailed literature review** was carried out to gather best-available data.
- **A detailed model of the existing stock** of natural gas consuming industrial heating equipment was built, broken down by sector, equipment type and size.
- **Technical modelling of hydrogen as a fuel** was carried out, helping to identify which equipment components require replacement and key technical challenges for future demonstration programmes to overcome.
- **Equipment conversion costs** were estimated by combining subcomponent conversion or replacement costs using information from OEMs.
- **Site visits were carried out to assess on-site aspects** such as pipework replacement costs, permitting and regulation.

Capital investment required to convert ~4,300 relevant equipment and sites (<7 bar network, >1 MWth, operating on natural gas) was estimated at £2.7 billion (£1.0 – £3.9)

of industrial natural gas heating equipment (<7 bar network)



Indicative estimated capex for hydrogen conversion

Industry sector	Typical Equipment	Equipment Conversion Cost – Variation with Size (£ '000s)*		Conversion Cost for Typical Equipment (£ 000's)*	
		1 MW	10 MW	Example Size (MW)	Typical Cost
Food and Drink	Steam Boiler	170	690	20	1,040
	Oven	150	490	2	210
Chemicals	Steam Boiler	100	490	20	780
	Furnace	110	530	25	980
Vehicle Manufacturing	Hot Water Boiler	170	690	20	1,040
	Oven	150	490	5	340
	Direct Dryer	140	430	2	200
Basic Metals	Furnace	180	730	40	1,680
Paper	Direct Dryer	150	470	3	260
	Steam Boiler	190	750	20	1,140
Glass	Glass Furnace	200	800	25	1,390
Ceramics	Kiln	160	570	5	390
Lime	Lime Kiln	150	520	15	640
Other NM Minerals	Rotary Dryer	140	430	15	520
Elec and Mech Engineering	Hot Water Boiler	170	690	5	450
	Oven	150	490	3	260
	Steam Boiler	170	690	5	450

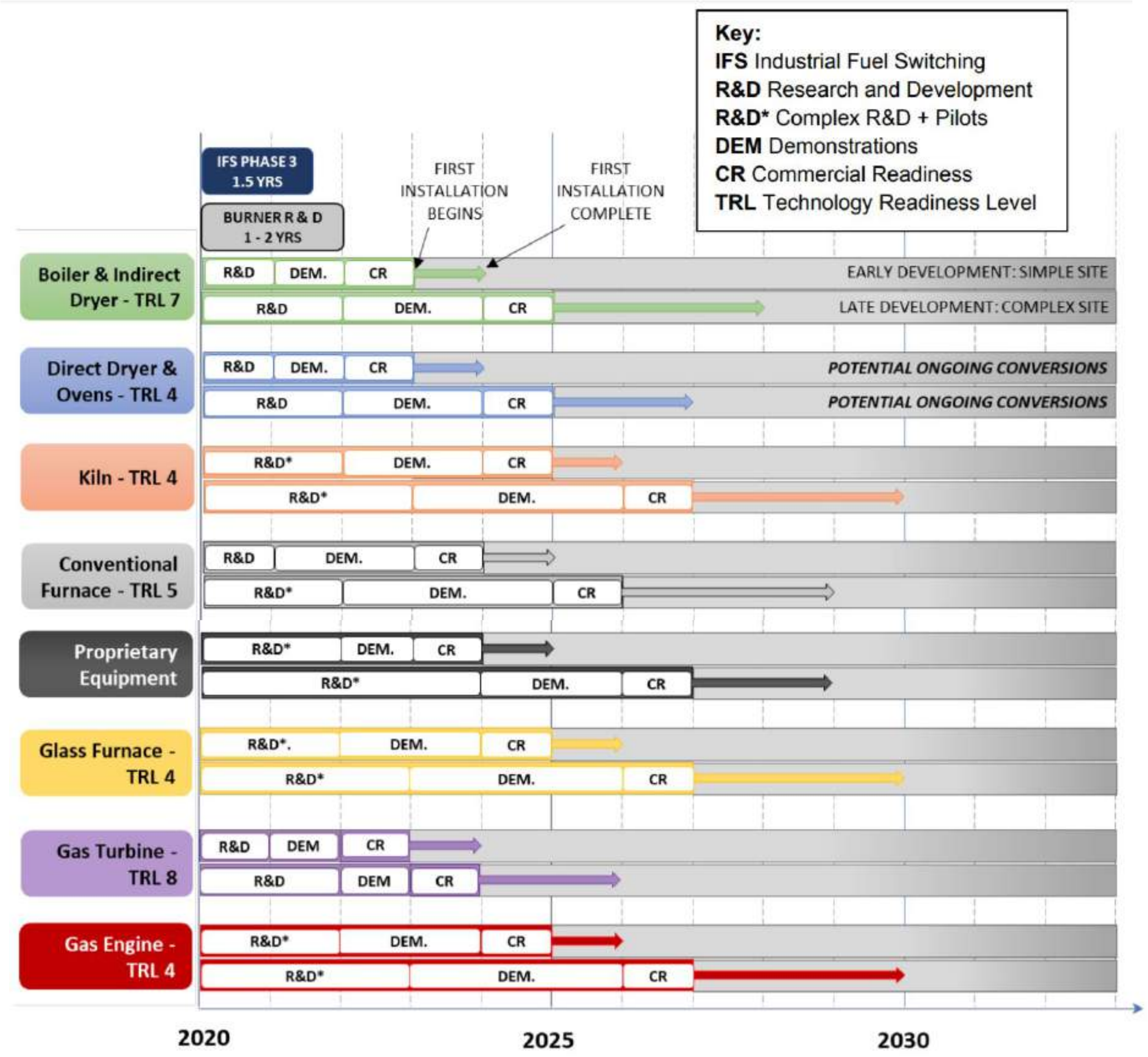
*All costs are in thousands of GBP

No showstopping barriers were identified: Although several challenges have been identified, there are multiple solutions of varying impact to these challenges

	Barriers	Enablers	Impacted equipment	Impact Rating
Technical	**Radiative Heat Transfer** – lower emissivity results in decreased radiant heat flux	Further experimental investigation on heat transfer balance, particularly in glass furnaces and kilns. Additives could be used to increase emissivity.	Furnaces, Kilns	🟠
Technical	**Convective heat transfer** – lower air requirement reduces the gas volume available to transfer heat.	Flue Gas Recirculation (FGR) increases gas volume, and is also beneficial elsewhere (e.g. NO_x emissions), equipment recalibration for indirect fired equipment.	All equipment	🟡
Technical	**NO_x emissions** – may be increased through higher flame temperature.	Technologies to mitigate this include Flue Gas Recirculation (FGR), steam addition and post-combustion treatment. Further work on low NO_x burners may also reduce emissions.	All equipment	🟠
Technical	**Flue Gas Composition** – e.g. increased moisture content with H_2 might impact product quality	Product specific tests required for some direct heating applications to evaluate impact and any possible mitigating actions (e.g. adjusting combustion parameters).	Direct fired equipment	🟠
Technical	**Gas Engine Conversion for CHP**	Period of R&D, small scale and large-scale trials. May require full replacement with potential new design, rather than retrofit.	Gas Engines	🟠
Technical	**Piping and fittings** (leakage risks and embrittlement)	Materials and standards currently exist for hydrogen piping. Site distribution systems would need to be checked for hydrogen compatibility and replaced if incompatible.	All sites	🟡
Technical	**Hydrogen burner development**, including materials	Burner materials currently exist, though further R&D by burner manufacturers is required.	All equipment	🟡

	Barriers	Enablers	Impacted equipment	Impact Rating
Environment, Health and Safety	**Explosive Atmosphere Regulations** (DSEAR) - cost and space impact	Solution on a site by site basis – assessment of impact and new zoning requirements. Affected equipment and workstations might need to be moved or replaced.	All sites	🟠
Environment, Health and Safety	**Possible Emissions Re-permitting**	Technical solutions to NO_x emissions. Standardisation and collaboration with Environment Agency over permitting requirements. Emissions monitoring required.	Some sites	🟢
Environment, Health and Safety	**Accident regulations (COMAH) risk** – H_2 on site might push sites over aggregation limits	Solution on a site by site basis. Only a small number of sites may be affected. Re-permitting or reduced storage.	Very small number of sites	🟢
Resources & Site	**Staff Training**	Training on H_2 equipment is available; requires resources and sufficient early warning of conversion to plan.	Industry Wide	🟢
Resources & Site	**Demo & implementation resource**	Clear policy will allow for equipment manufacturers and sites to plan for the significant resources and training required for demonstrations and conversion	Demo Specific	🟡
Resources & Site	**Hidden Costs** e.g. feasibility studies, site downtime etc.	Site by site basis. Further research into full implications and costs.	All sites	🟡

The level of evidence required to secure user acceptability of hydrogen equipment varies by sector and application, from OEM guarantees through to onsite application specific trials



Key messages

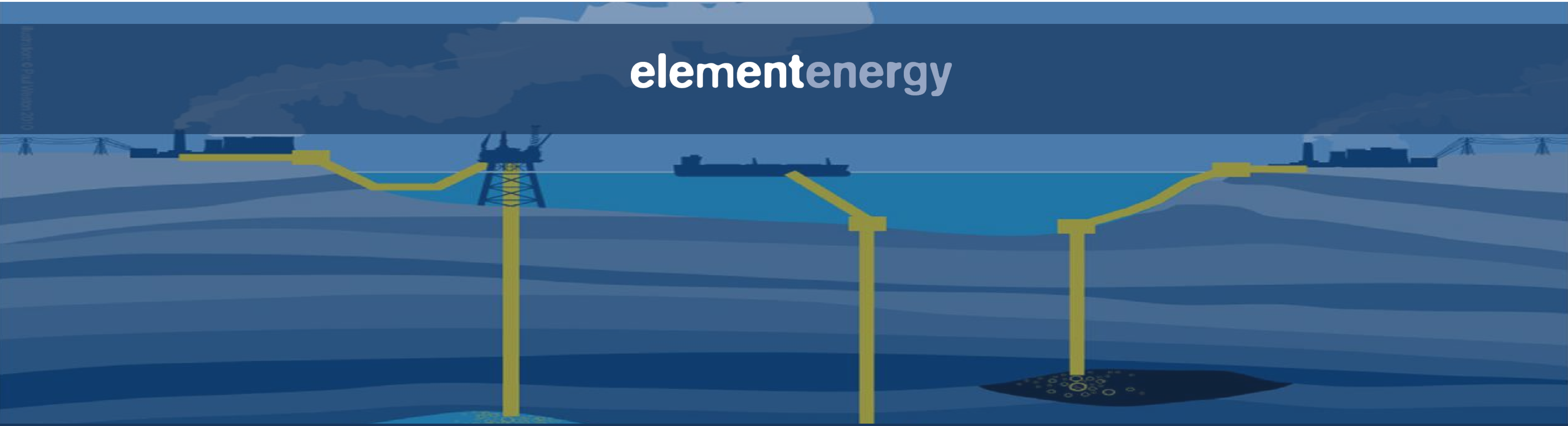
- Indirect fired equipment, such as boilers, may only require cross-sectoral trials and an OEM (Original Equipment Manufacturer) guarantee that equipment conversion would not adversely impact operations, as these equipment types are more general across sectors and applications.
- Direct fired equipment, such as kilns and furnaces, will generally require a greater level of demonstration to reach TRL 9 and secure user acceptability, due to potential impacts on product quality.
- Demonstrations and tests at a more application specific level are likely to be required for OEMs to provide guarantees.
- Beyond TRL 9 in the core equipment types, a small number of sites might require site and application specific tests, potentially due to stringent product quality requirements or particularly bespoke pieces of equipment.

Recommendations

- **Demonstration programmes** are needed in the early 2020s to provide the required evidence of industrial equipment using 100% hydrogen before a decision is made on the long-term decarbonisation pathway for heat.
- **Determine a support mechanism for hydrogen conversion/use in industry**, evaluating different business models to understand who is bearing what cost burden, what funding and support needs to be available, and to clarify risk ownership. However, any industrial incentives should ensure the best decarbonisation option is delivered from a technical, cost and system perspective.
- **Modelling and lab scale tests for technically challenging equipment types** to understand potential impacts on equipment operation and product quality (e.g. flue gas atmospheres) at a detailed level and to channel the development of 100% hydrogen equipment.
- **Further technical development work around direct fired equipment and gas engine CHP** to overcome the remaining technical uncertainties and barriers. 'Hydrogen ready' equipment should also be investigated further, assessing technical challenges and costs of this approach.
- **Investigation of emissions control strategies** for each equipment type, particularly where NOx control techniques are already in use on natural gas equipment, or if regulations become more stringent.
- **Increase awareness of hydrogen options within industry** through engagement with major manufacturers and industry bodies across the UK, e.g. dissemination via workshops with industry.
- **Investigation of different deployment strategies for hydrogen conversion**, examining the impact on costs of risks of approaches such as retrofit or 'hydrogen readiness', as well as regional vs. national mechanisms. Clarity on future hydrogen roll-out timeframes and mechanisms should be given as soon as possible to allow organisations to plan appropriately and mitigate impacts.
- **Detailed comparison of hydrogen with other decarbonisation options for each industrial sector**, determining the best option for each sector on a technical, economic and system-wide basis.
- **Further work on each industrial cluster to develop cluster specific costs and timelines** should take place, considering 100% hydrogen as well as other decarbonisation options such as electrification, biomass or CCS.

Element Energy is a leading low carbon energy consultancy working in a range of sectors including industrial decarbonisation, carbon capture utilisation and storage (CCUS), hydrogen, low carbon transport, low carbon heat, renewable power generation, energy networks, and energy storage. Element Energy works with a broad range of private and public sector clients to address challenges across the low carbon energy sector.

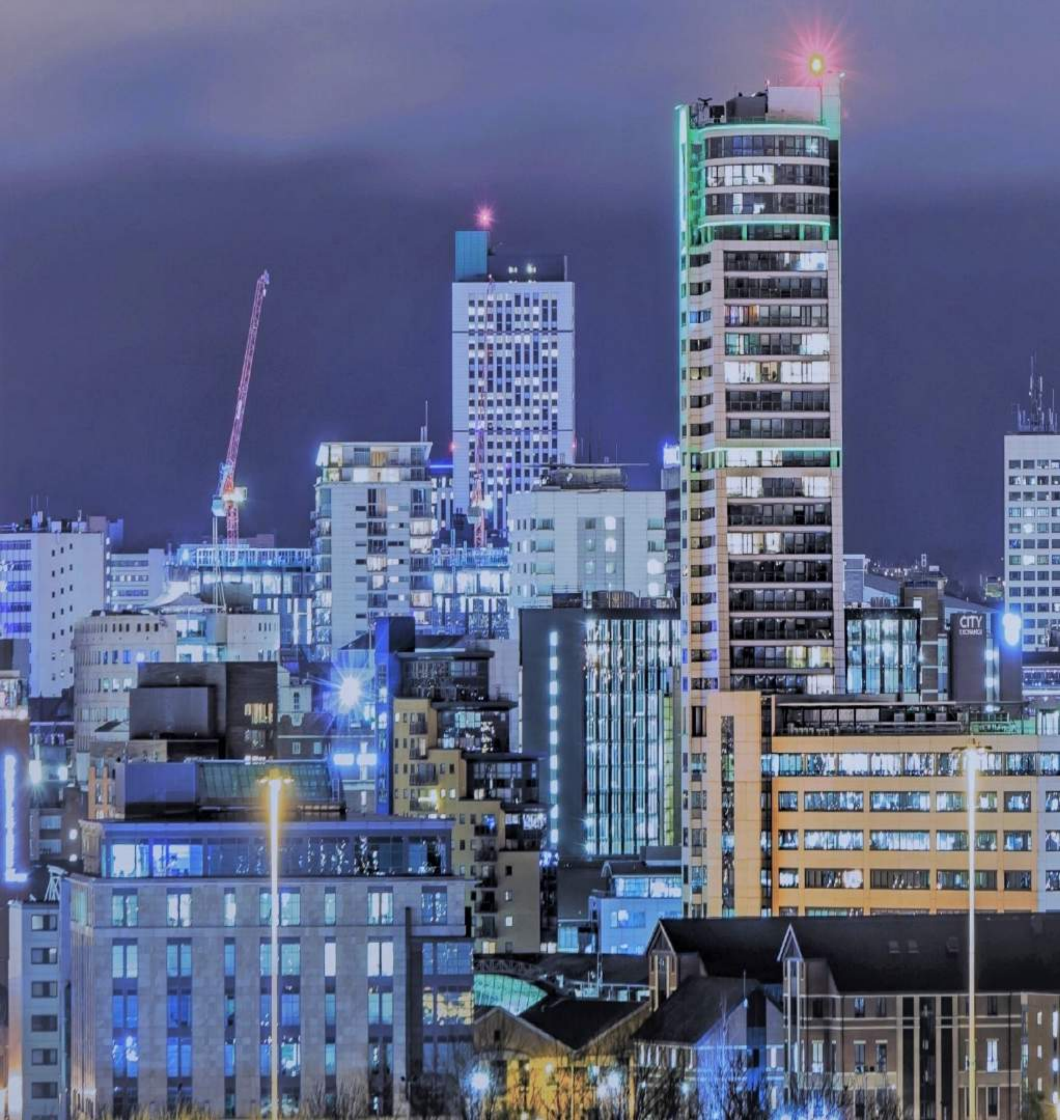
For further information please contact:
emrah.durusut@element-energy.co.uk



Hy4Heat

Brett Ryan

ERM



Hy4Heat WP5: Understanding Commercial Appliances

Stakeholder Event
9th March, 2020
Brett Ryan (ERM)

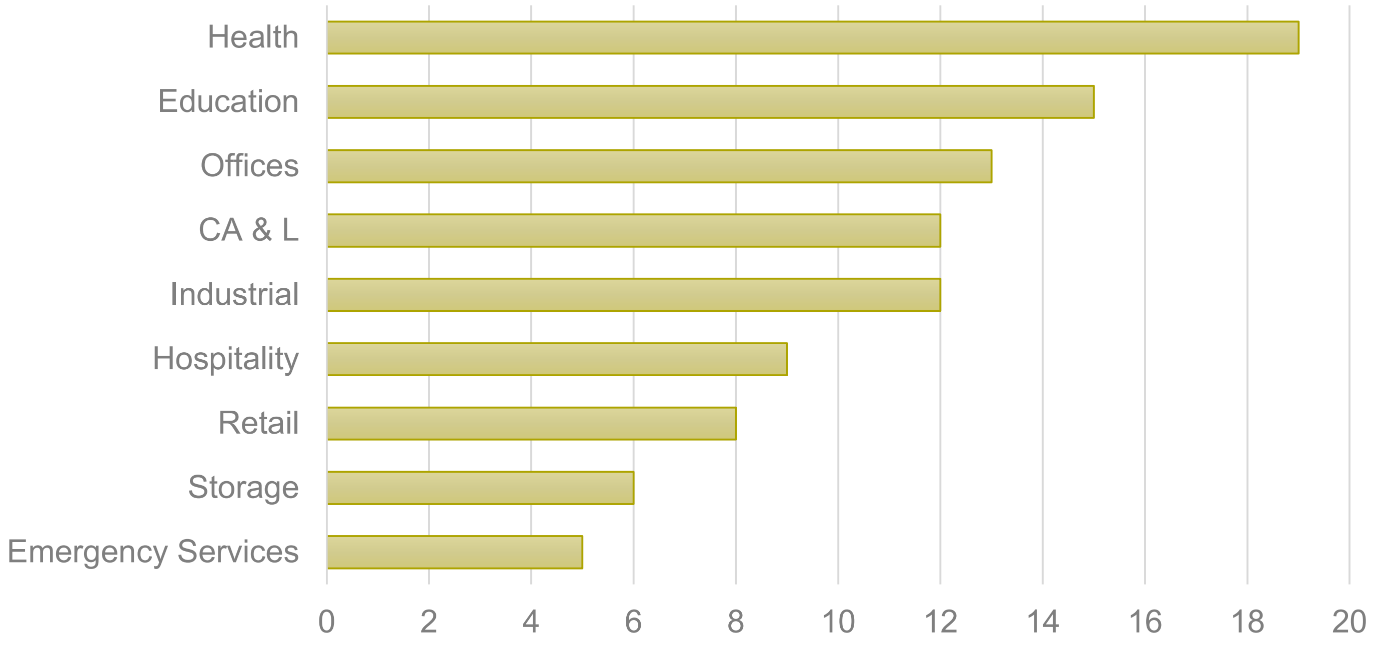
The business of sustainability

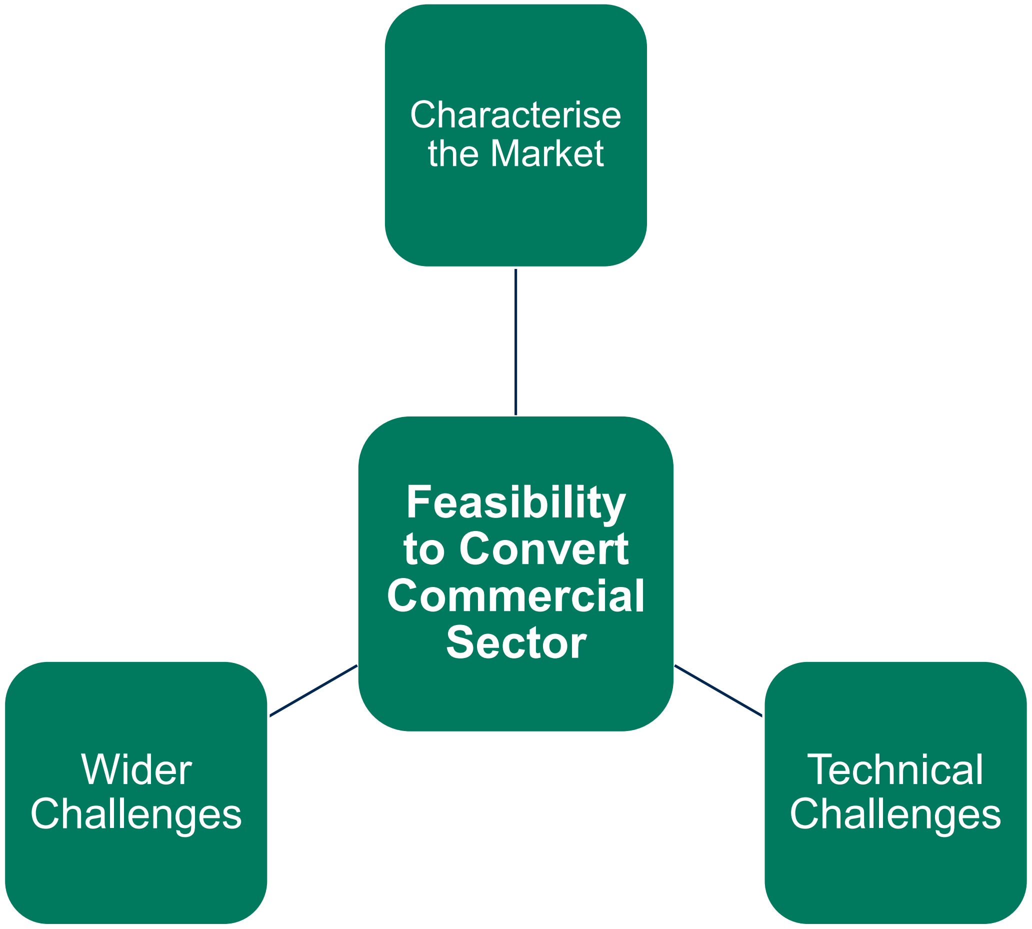
HSE IGEM Institution of Gas Engineers & Managers ERM

Work Pack 5 Overview

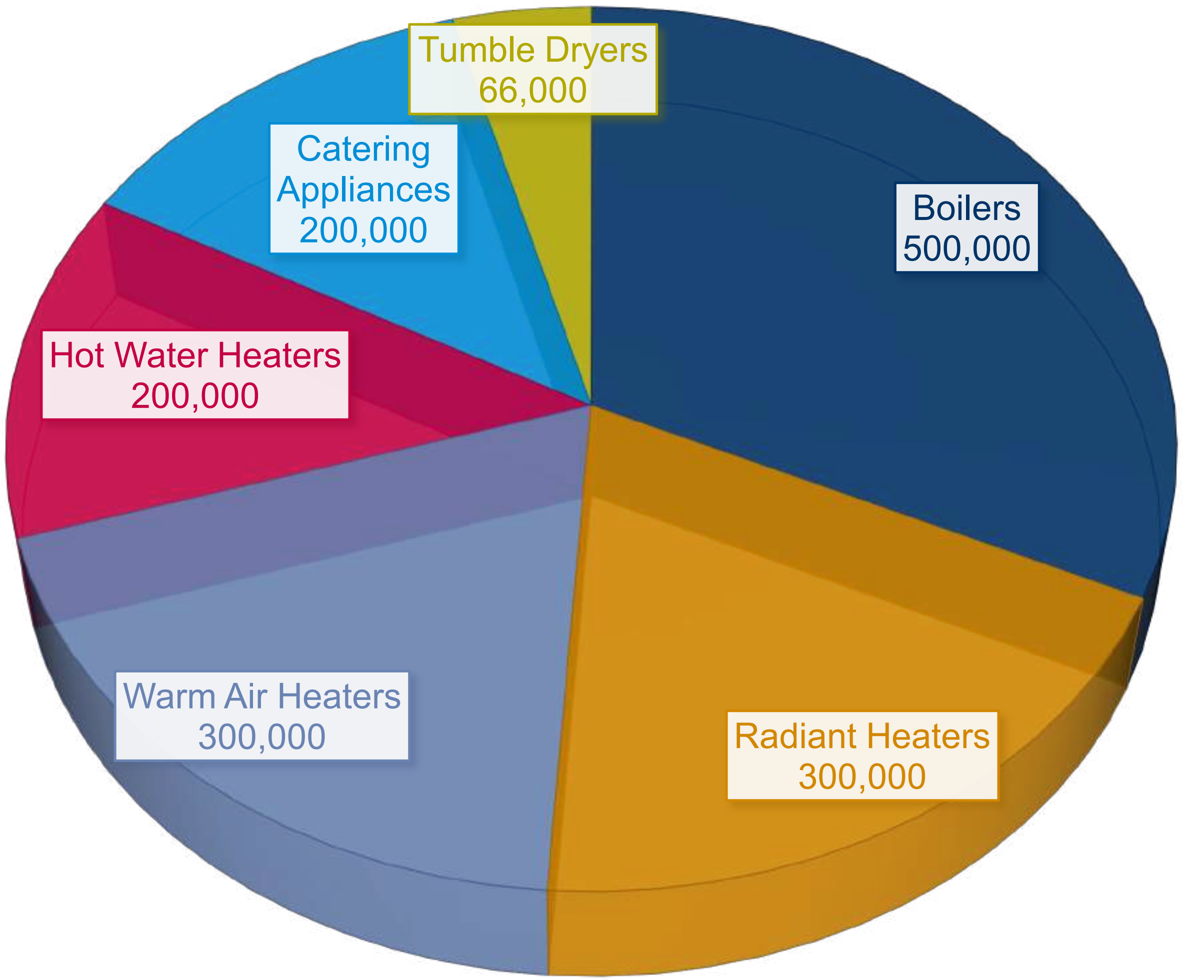
Commercial Sector Consumption: **104 TWh/yr**

- 1/3 of Domestic sector (297 TWh/yr)
- Similar to Industrial sector (96 TWh/yr)



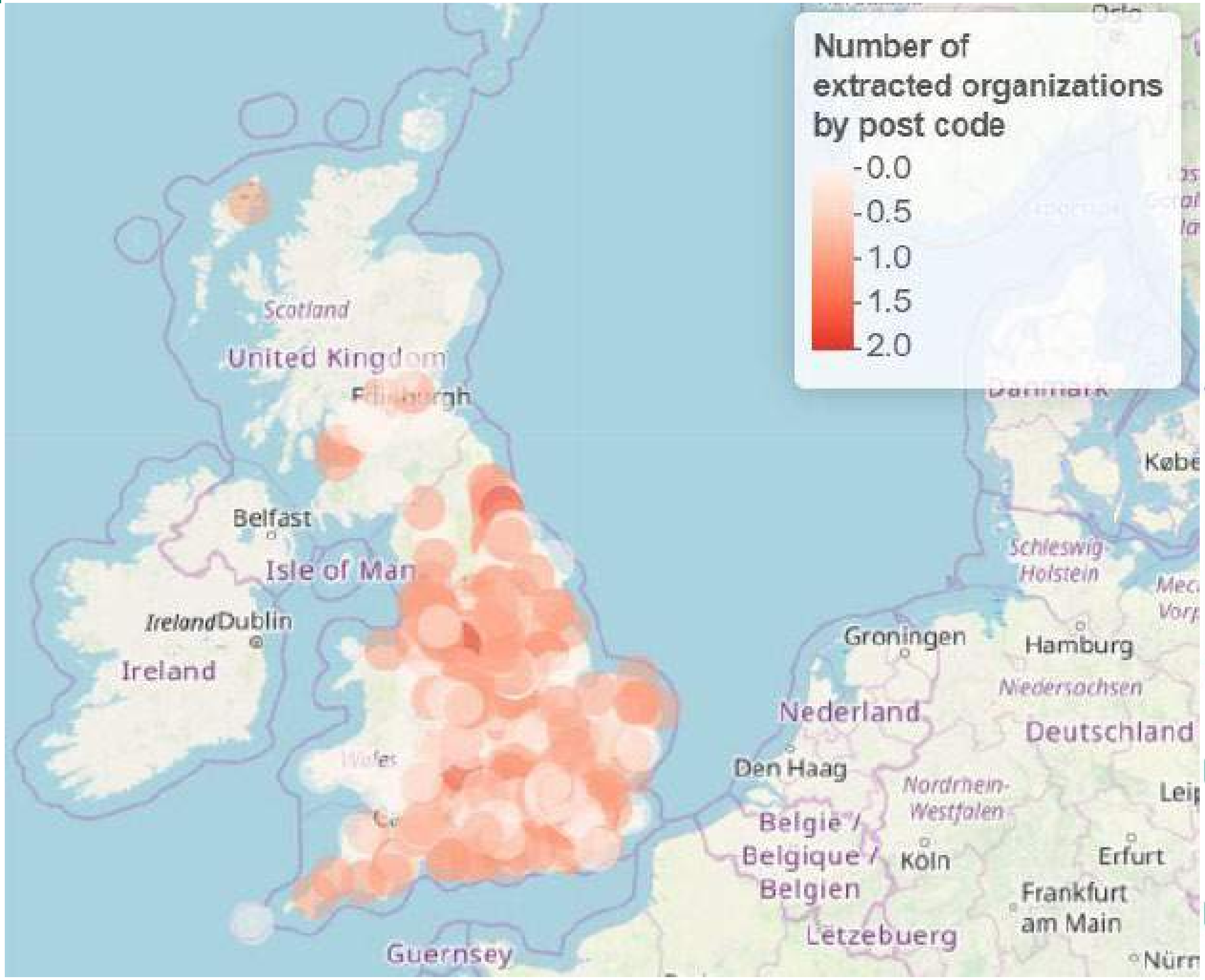


1.5 million UK commercial gas appliances

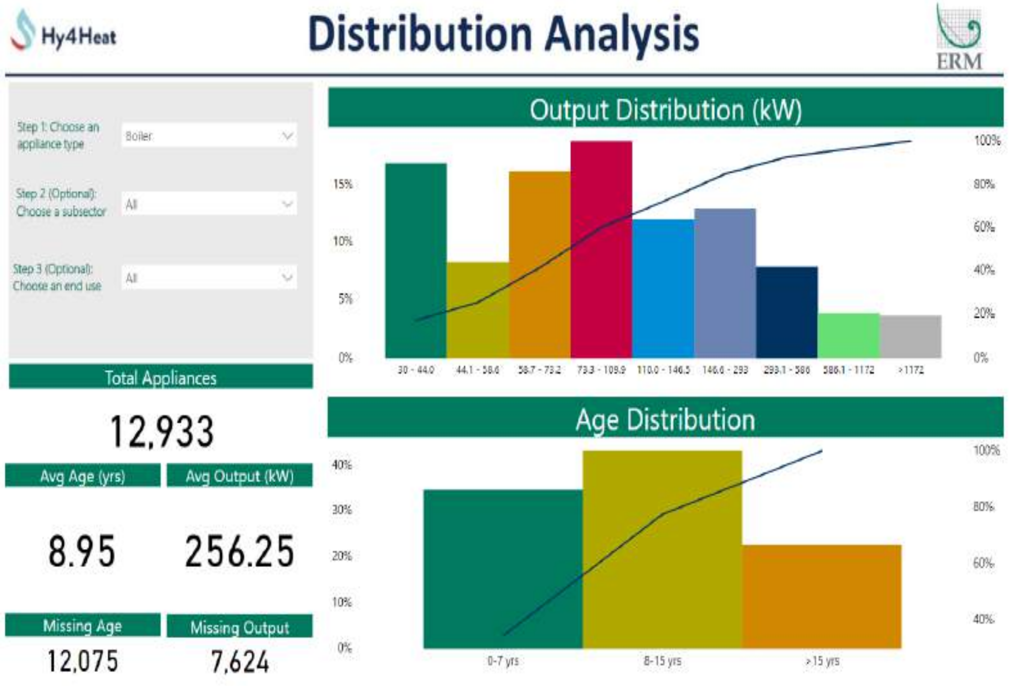


- Estimated rage: 1.0 - 2.0 million
- **Boilers**:
  - 80% less than 150 kW output
  - 73-110 kW most common unit size
  - 3% larger than 400 kW output
- **Warm Air and Radiant Heaters:**
  - Industrial, Storage and Large Retail
- **Catering Appliances**:
  - Ranges, fryers and grills most common
  - Electricity is dominant energy source
- **Tumble dryers:**
  - Universities, prisons, laundrettes, hospitals

Public Sector Data



- **141** – usable data sets from 883 relevant bodies
  - NHS Trusts, Local Authorities, Police Forces, Fire Services, Universities, Prisons
- **20,000+** – gas appliances in the extracted data sets



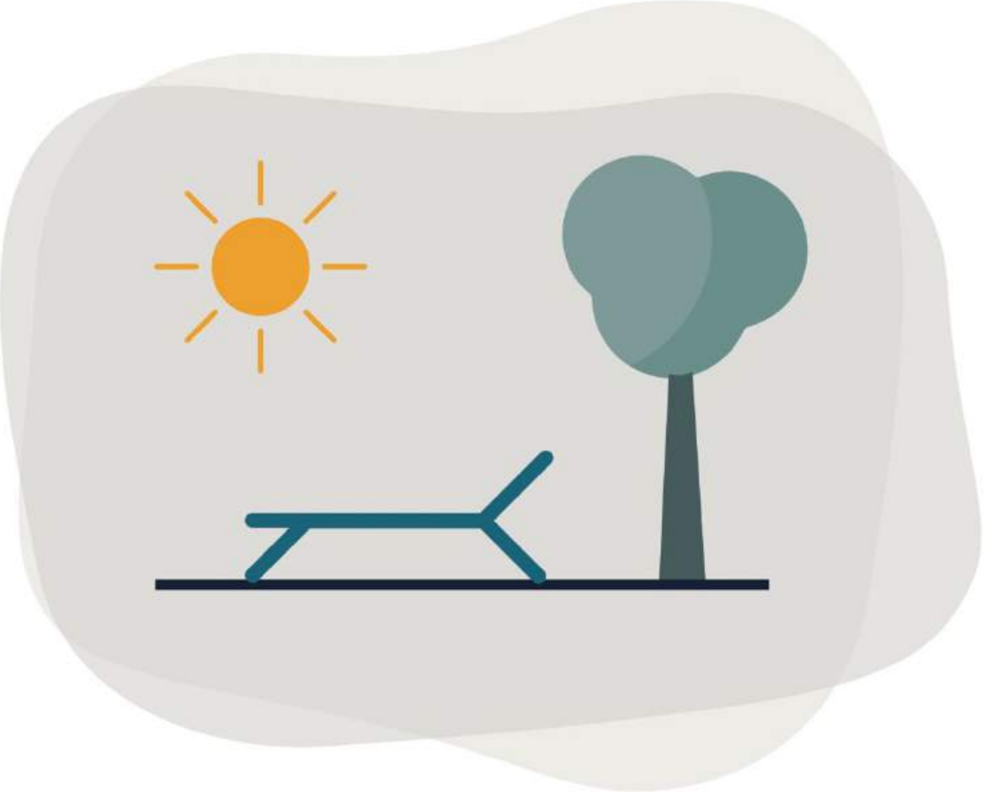
Technical and Wider Challenges

- **No technical show stoppers** identified unique to Commercial sector
- Challenges related to **emissions, efficiency and footprint**
- Commercial catering has added challenge of achieving equivalent/improved **product quality**
- **Economics** is the main barrier to appliance development
- **Hydrogen-ready appliances** expected to be the key to transition
- **Conversion pathway** requires careful consideration
- **Cost and safety** are major concerns for End Users

Thank you

Hy4Heat

A Quick Break



Standards and Certification

Standards and Certification

SPEAKERS

- Bob Walsh, BSI
- Martin Brown, DNV GL
- Ian McCluskey, IGEM

Bob Walsh

BSI

PAS 4444: Hydrogen Fired Gas Appliances - Guide

PAS (Publicly Available Specification)

Mr. Bob Walsh, CEng FIMechE
Sarem Consultancy Services

Monday, 9th March 2020

By Royal Charter

bsi.

PAS 4444:2020 key dates

Activity	Key dates
Scoping workshop	9 April 2019
Hy4Heat Stakeholder event	14 May 2019
Steering Group (SG) review (~2 weeks)	14 June – 27 June 2019
SG Meeting 1 *(resolution of SG comments on Draft 1)*	8 July 2019
SG review (~2 weeks) [Additional]	4 September – 18 September 2019
SG Meeting 2 *(resolution of SG comments on Draft 2)* [Additional]	21 October 2019
Public consultation (~4 weeks)	2 December – 10 January 2020
SG Meeting 3 *(resolution of public comments on Draft 3)*	21 January 2020
SG editorial review (~1 week)	21 February – 27 February 2020
PAS publication	**End of March 2020**

bsi.

Application

- Boilers – domestic
- Boilers – commercial
- Burners – forced draught
- Water Heaters
- Gas Fires and Radiant Convectors
- Independent flueless space heaters
- Cookers
- Commercial catering equipment
- Overhead radiant tubes
- Forced convection air heaters – domestic
- Forced convection air heaters – commercial

The PAS is not applicable to Industrial or Process Equipment

Issues

- Distributed hydrogen gas specification
- Hydrogen not covered by existing standards
- Test / limit gases not defined
- Risk management

Outcome

- Pragmatic document
- Broad application
- Scope for development
- Compliant

Thank you

Bob Walsh - CEng.FIMechE.

Sarem Consultancy Services

By Royal Charter

Hy4Heat

Martin Brown

DNV GL

OIL & GAS

Hy4Heat (WP2) – Hydrogen Purity Specification

9 March 2020

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Our Partners

- The **NPL** Gas and Particle Metrology Group supports the UK's energy industries with their existing and future measurement needs and has become a centre of expertise for standards for hydrogen as a fuel.
- **Element Energy** has worked in the hydrogen sector for over 15 years and has gained a deep understanding of the techno-economics of hydrogen technologies including generation, transport, storage and end-use appliances.
- **HSE Science Division (HSL)** is one of the UK's leading health and safety research facilities. For over 15 years, HSL has been involved in understanding and communicating the safety aspects of emerging hydrogen energy technologies
- The Low Carbon Technology group at **Loughborough University** specialises in energy conversion through combustion and fuel cell technology with a focus on Hydrogen as a fuel source, additives and their effect on appliances.

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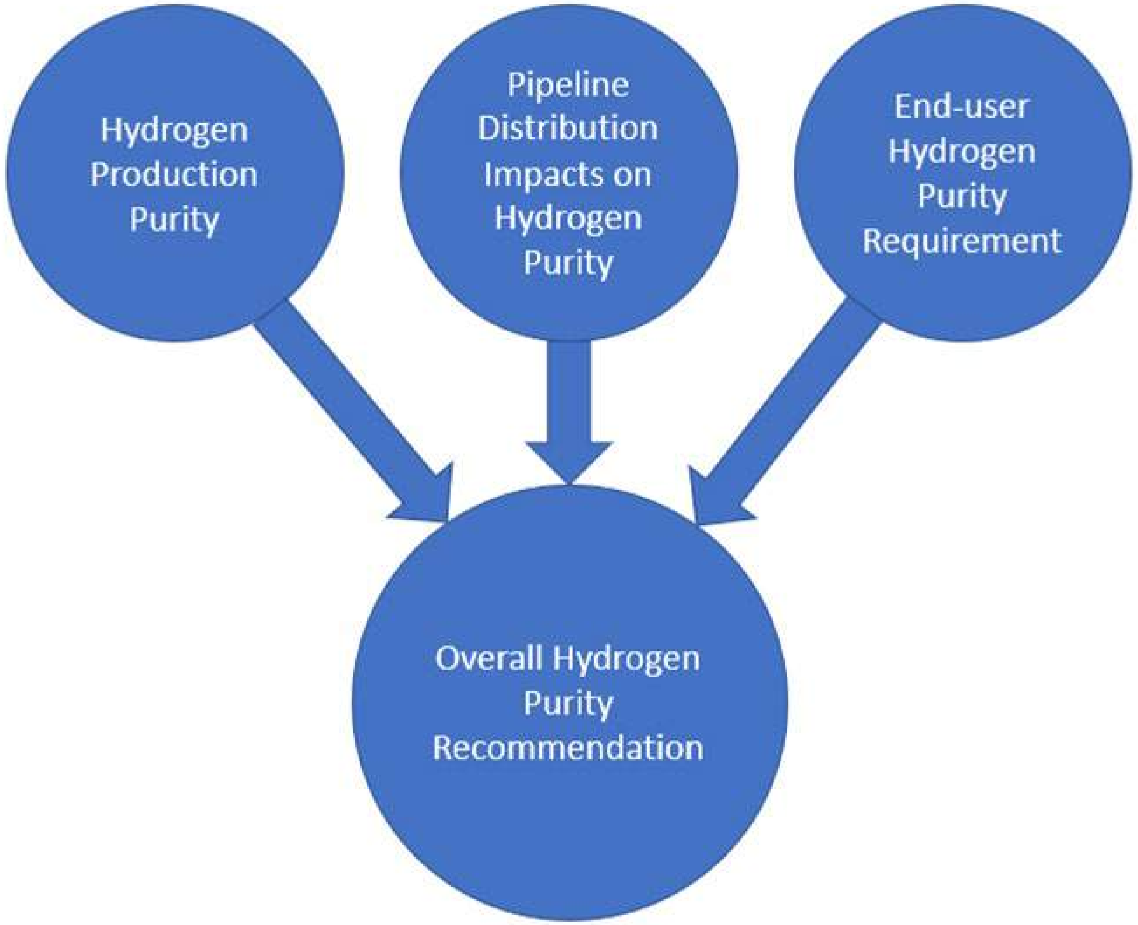
Hydrogen Purity – Scope of Work

- To evaluate the potential hydrogen sources and purity levels that might be available in the UK
- To assess the potential impacts and cost effectiveness of introducing hydrogen at these quality levels into the wider distribution network
- To recommend a purity level for use by the Hy4Heat programme.
- To consider and include key information on any potential trace contaminants that might be picked up by the hydrogen as it is distributed through the existing, repurposed pipeline network to end users.



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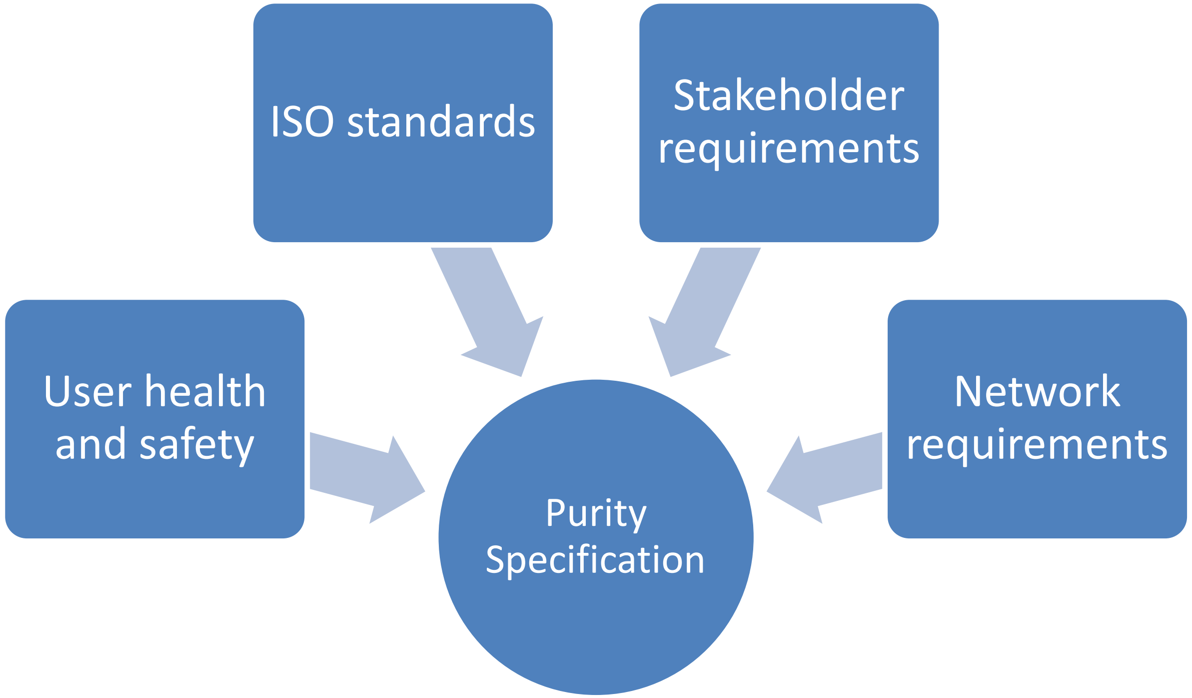
Hydrogen Purity – A multi-input study – "balancing act"

- Purity specification guided by:
  - What's achievable from a production point of view
    - Cost:benefit analysis
  - Key network operation factors
    - Pipeline integrity
    - Dusts and dewpoints
    - Network Engineer Health and Safety
  - Stakeholder views on requirements for appliances
  - Overall health and safety for all end users
- Overall the approach links the output on existing standards, with the proven track record of the Gas Safety (Management) Regulations to establish a workable specification for hydrogen



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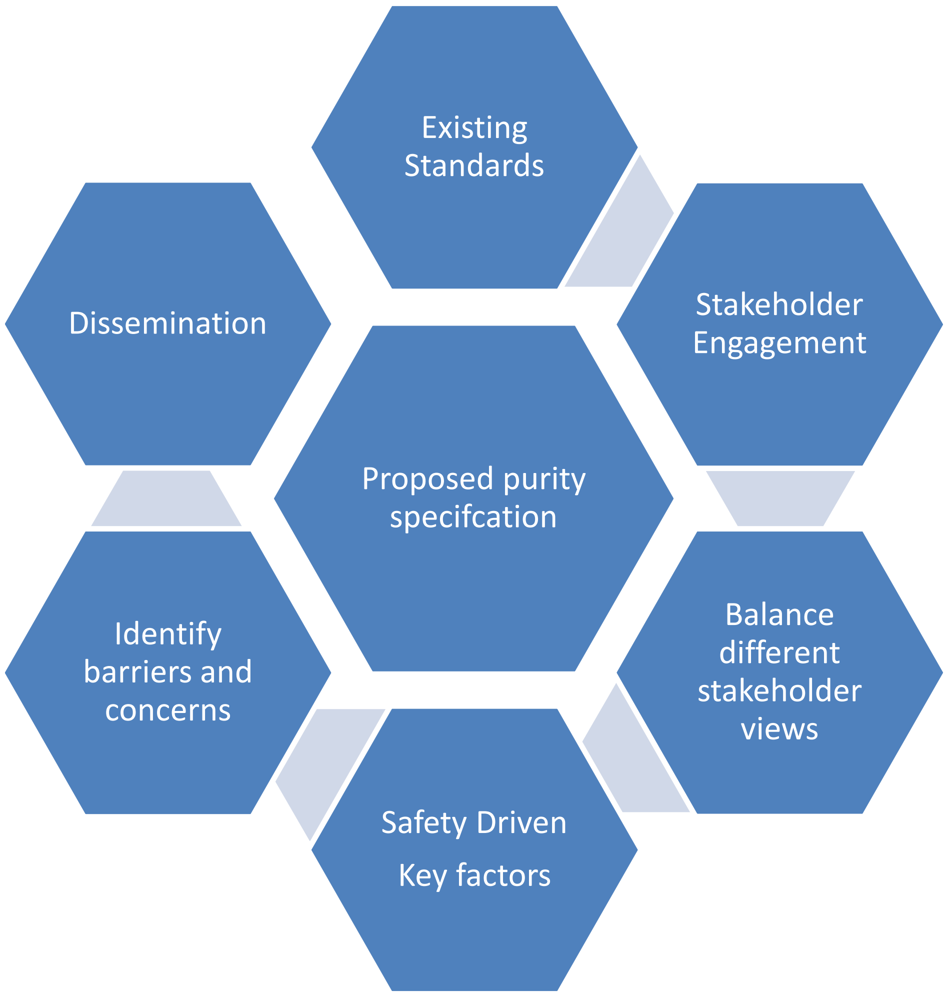
Hydrogen Purity – Approach

- A Purity specification has been drawn up, guided by;
  - Literature review undertaken on existing quality recommendations for hydrogen used for heating
  - Key stakeholder views sought to support the evaluation of the purity specification.
  - Cost:benefit analysis of hydrogen production and clean-up options undertaken using selected target scenarios to determine purity levels
  - Uncertainties identified (the specification will not meet the requirements for PEM fuel cell without further purification



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Hydrogen Purity Specification

Content or characteristic	Value	Rationale
Hydrogen content (minimum)	98 %	This minimum value is a balance between hydrogen cost, impact of distribution and appliance requirements.
Carbon monoxide	20 ppm	A practical engineering limit based on achievable production limits and to meet long term exposure limits HSE EH/40)
Hydrogen sulphide content	≤ 3.5 ppm	These values are taken from GS(M)R 1996 as any detrimental effects would be similar for hydrogen and natural gas. A small amount of oxygen may be beneficial from a pipeline integrity viewpoint.
Total sulphur content (including H_2S)	≤ 35 ppm	
Oxygen content	≤ 0.2 %	
Hydrocarbon dewpoint	-2°C at any pressure up to 85 barg	In line with GS(M)R 1996 and EASEE-gas. Need to avoid liquids in the pipeline.
Water dewpoint	-10°C at 85 barg	
Sum of methane, carbon dioxide and total hydrocarbons	≤ 1%	No detrimental effects to appliances. This limit is to ensure that carbon emissions are as close to zero as possible (and links to Wobbe Number range)
Sum of argon, nitrogen and helium	≤ 2%	To avoid transporting inert gases with no calorific value in the hydrogen gas (in agreement with ISO/FDIS 14687) and to limit the impact on Wobbe Number.
Wobbe Number range	42 – 46 MJ m^{-3}	Range and percentage variation based on natural gas range in GS(M)R 1996 Wobbe Number is calculated at UK metric standard conditions of 15°C and 101.325 kPa
Other impurities	The gas shall not contain solid, liquid or gaseous material that might interfere with the integrity or operation of pipes or any gas appliance, within the meaning of regulation 2(1) of the Gas Safety (Installation and Use) Regulations 1998, that a consumer could reasonably be expected to operate	

Wobbe Number

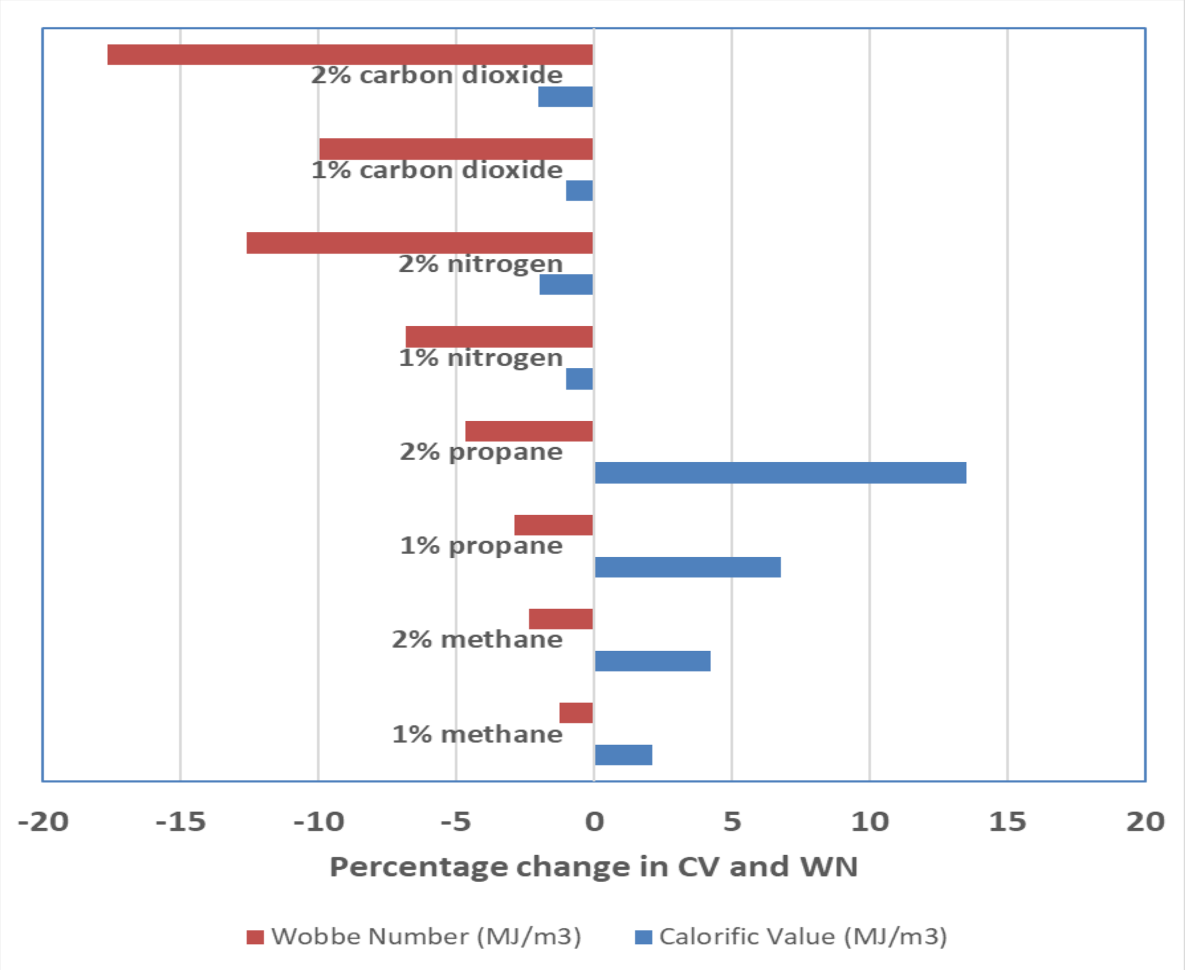
- **Wobbe Number** has been included in the Purity Specification to meet the requirements from traditional burner manufacturers

- Wobbe Number is an important aspect as the variation can be significant if heavier trace components like carbon dioxide are present

  – Addition of small quantities of hydrocarbon increases the CV but decreases the WN

  – Addition of small quantities of nitrogen or carbon dioxide decreases both CV and WN

  – A decrease of 10% in the WN is significant and viewed as a limit



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Hy4Heat

Ian McCluskey

IGEM

WORK PACKAGE 2 STANDARDS

HY4HEAT STAKEHOLDER EVENT
9th March

Ian McCluskey CEng FIMechE FIGEM
IGEM, Head of Technical and Policy

www.igem.org.uk

IGEM WORK PACKAGE 2 STANDARDS

IGEM Deliverables of HyHeat WP2

1) A REFERENCE STANDARD - Identifying Key Safety Requirement

Describes the essential functional requirements for safe hydrogen utilization and installation.

Defines the characteristics of hydrogen and outlines the key differences to Natural Gas.

Explains the common principles and suggested practices, necessary for the safety and integrity of a hydrogen installation.

2) AN ENABLING STANDARD – The Application of essential requirements

Describes the installation requirements to enable and underpin future standards for an occupied trial.

IGEM WORK PACKAGE 2 STANDARDS

Overview of HyHeat WP2

IGEM METHODOLOGY

- Set up working group of experts from across the industry
- Review existing standards and practice
- Review evidence, where available, and cite this in support of standards
- To identify where gaps in evidence exist and advise the Hy4Heat team of these
- Obtain IGEM committee approval for the new standards
- As a body, continue to communicate to the gas industry prior to commencing the trials

Hy4Heat

HSE

DNV·GL

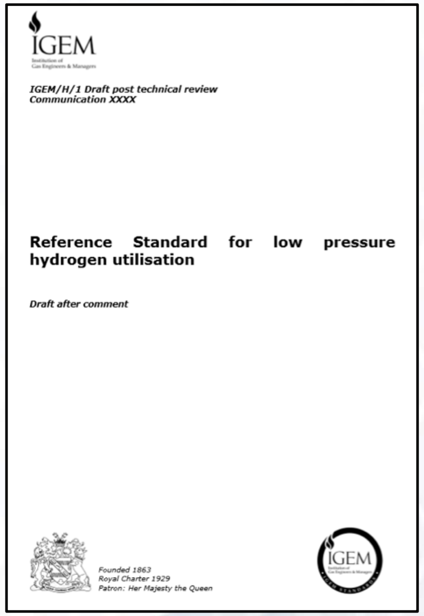
Global Energy Associates : Gas Consultancy & Training

IGEM WORK PACKAGE 2 STANDARDS

Progress to date of the IGEM HyHeat WP2

- Gap analysis drafted and presented
- First draft of Reference Standard signed off by Hydrogen Committee
- Draft shared with Arup+ for comments
- Due to go to IGEM Technical Coordination Committee for final sign off March 2020
- Currently identifying relevant work to be presented to IGEM to fill gaps and enable the development of more robust standards

Hy4Heat


IGEM

IGEM/H/1 Draft post technical review
Communication XXXX

Reference Standard for low pressure hydrogen utilisation

Draft after comment

Founded 1863
Royal Charter 1929
Patron: Her Majesty the Queen

IGEM

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IGEM WORK PACKAGE 2 STANDARDS

<u>Contents of Reference Standard</u>

Section 1 - Introduction

Section 2 - Scope

Section 3 - Legal and Allied Considerations

Section 4 – Background

Section 5 - Characteristics of Hydrogen

Section 6 - Effect on Materials

Section 7 – Effect on Application

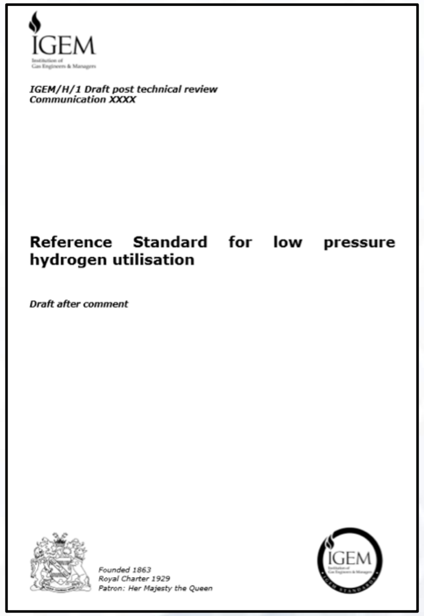
- Construction, flueing and ventilation
- Risk Assessment
- Hazardous Areas

Section 8 - Effect on Practices

- Metering
- Design and Installation of Pipework
- Appliance Installation
- Testing, Purging & Commissioning
- Detection & Response

Appendices

- Hydrogen Purity Standard
- Glossary, Acronyms & Symbols
- References
- Further detail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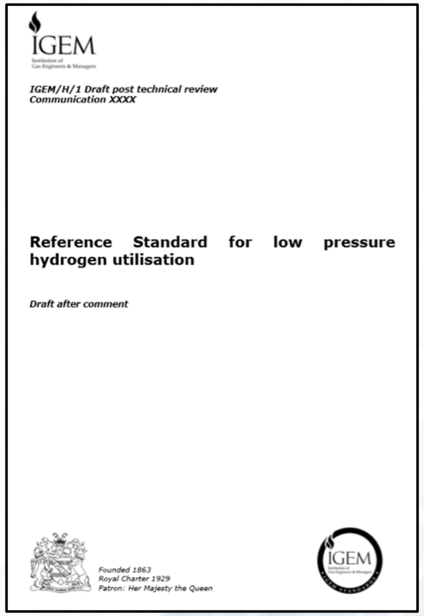
IGEM WORK PACKAGE 2 STANDARDS

Next Steps

- Production of Enabling Standard for first occupied trial
- Continued identification of relevant work to be presented to IGEM to fill gaps and enable the development of more robust standards
- Supporting delivery of training material for installers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Thank you

Hy4Heat

Safety Assessment

Sophie Brown

Arup+

Albert Law

Arup+

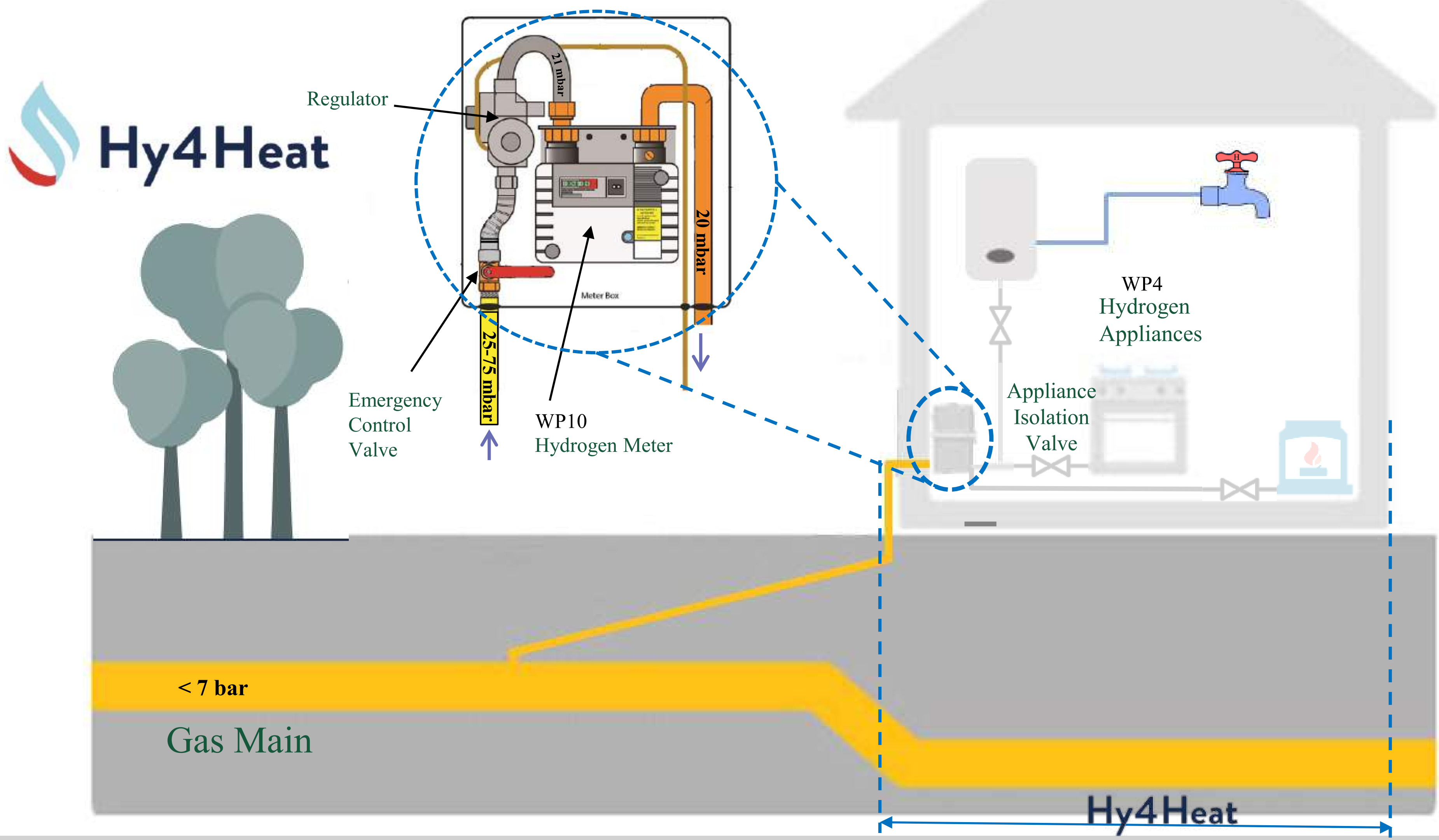
Safety Assessment - Objective

- **Comparative assessment:**
  Aim to demonstrate overall level of risk associated with hydrogen, is **no more than current level of risk** associated with methane

- Risks and incidents related to **carbon monoxide** are **excluded** as part of this assessment i.e. improvement in the overall safety by removal of carbon monoxide risk will not be used to improve the hydrogen safety case

- Assessment will consider fatalities and serious injuries

Safety Assessment - Scope



Key Assessment Assumptions

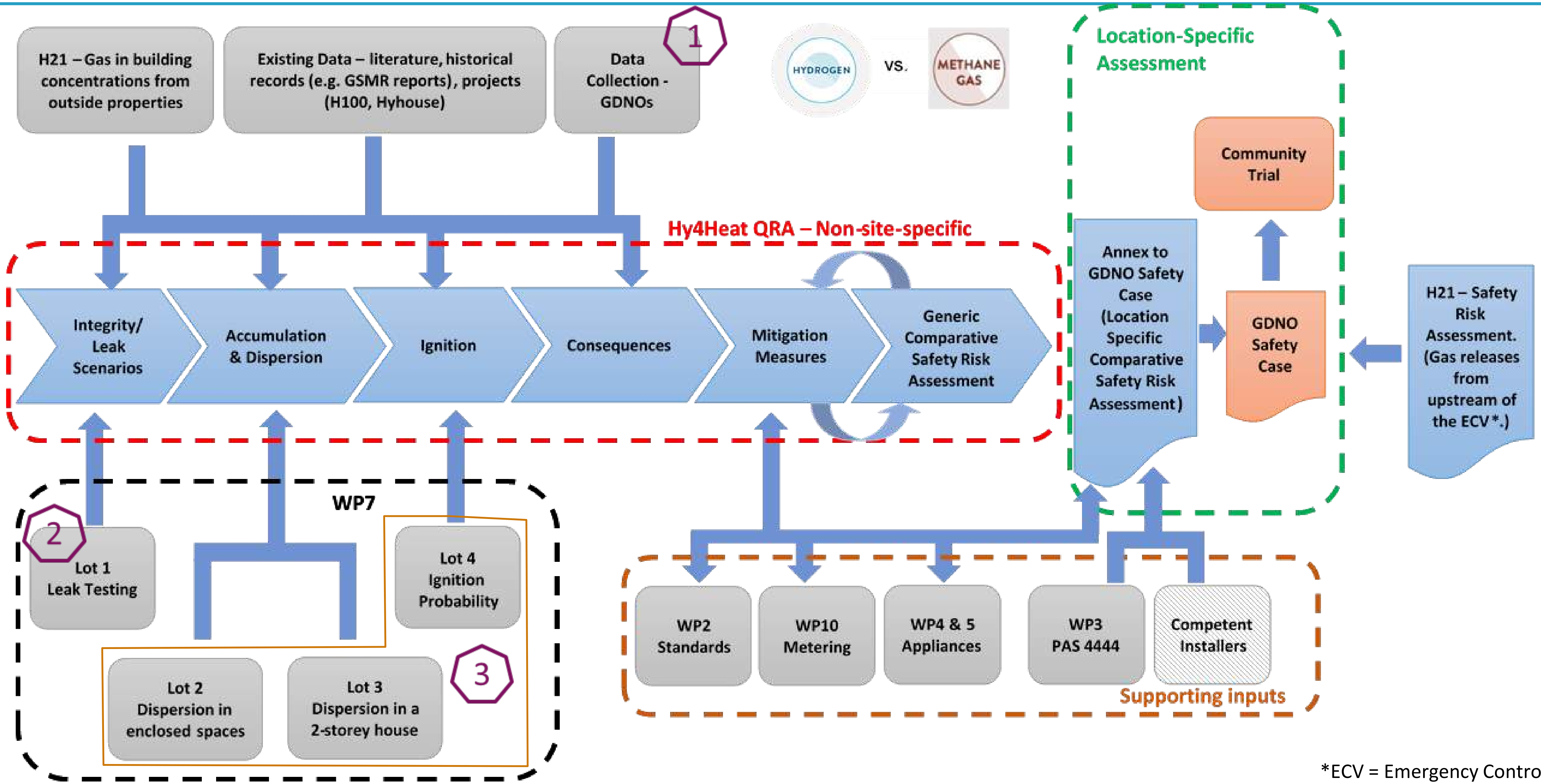
- Assumed 2-storey brick-built terraced house – multi-occupancy buildings (e.g. blocks of flats) **excluded**
- Pipework infrastructure within a property is the same for methane and hydrogen
- Property ventilation and air tightness based on current levels and building regulations
- Low pressure, downstream of the ECV, scenarios considered (up to 75mbar)
- Leaks upstream of the ECV, which track into property
- Existing odorant used in the network will also be used for hydrogen gas
- Occupancy levels based on data from Office for National Statistics
- Likelihood of malicious intent not explicitly assessed, assumed unchanged between gases

Key Assessment Assumptions

Differences in the gas properties and behaviour:

- Density
- Flammability Limits
- Stoichiometry
- Stratification
- Minimum Ignition Energy
- Combustion Properties (e.g. laminar burning velocity, effects of turbulence)

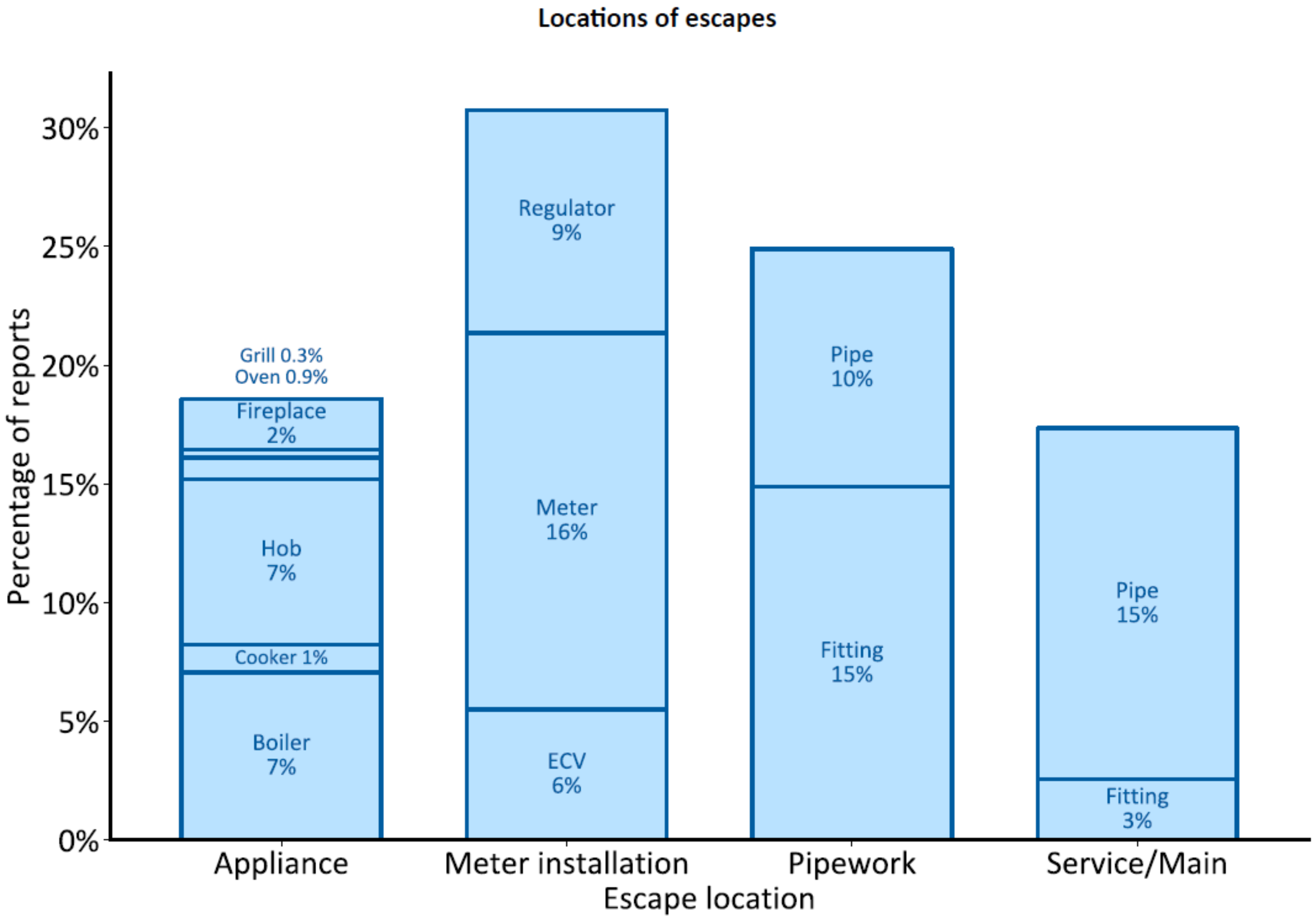
Key Assessment – Illustrative Approach



*ECV = Emergency Control Valve

Data Collection

Data collected by GDNOs for the Safety Assessment – **Leak Locations**



Hy4Heat

Nick Ryan

Steer Energy

Hy4Heat WP7 Lot1

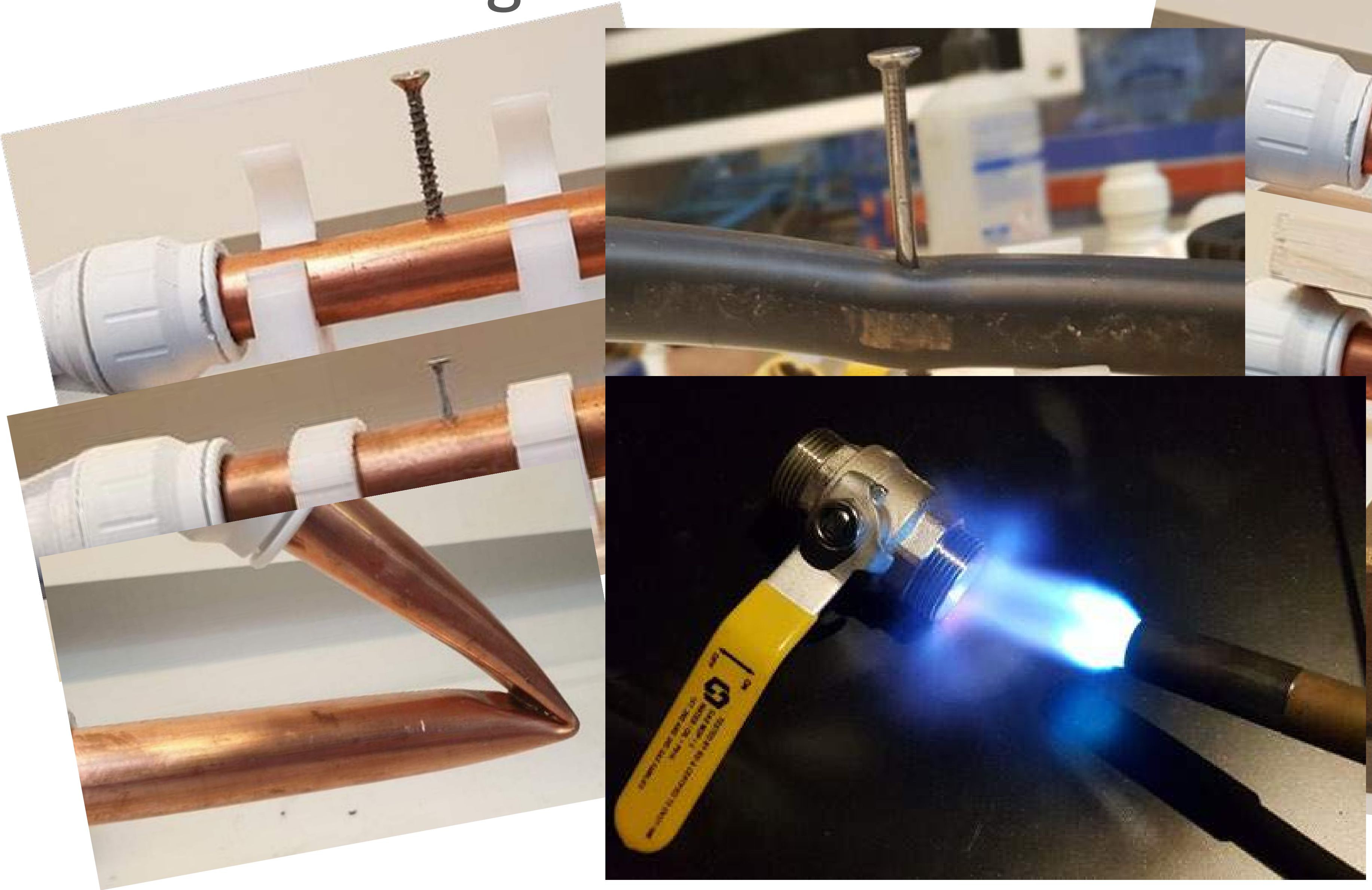
Comparison of hydrogen and methane leakage from domestic and light commercial systems

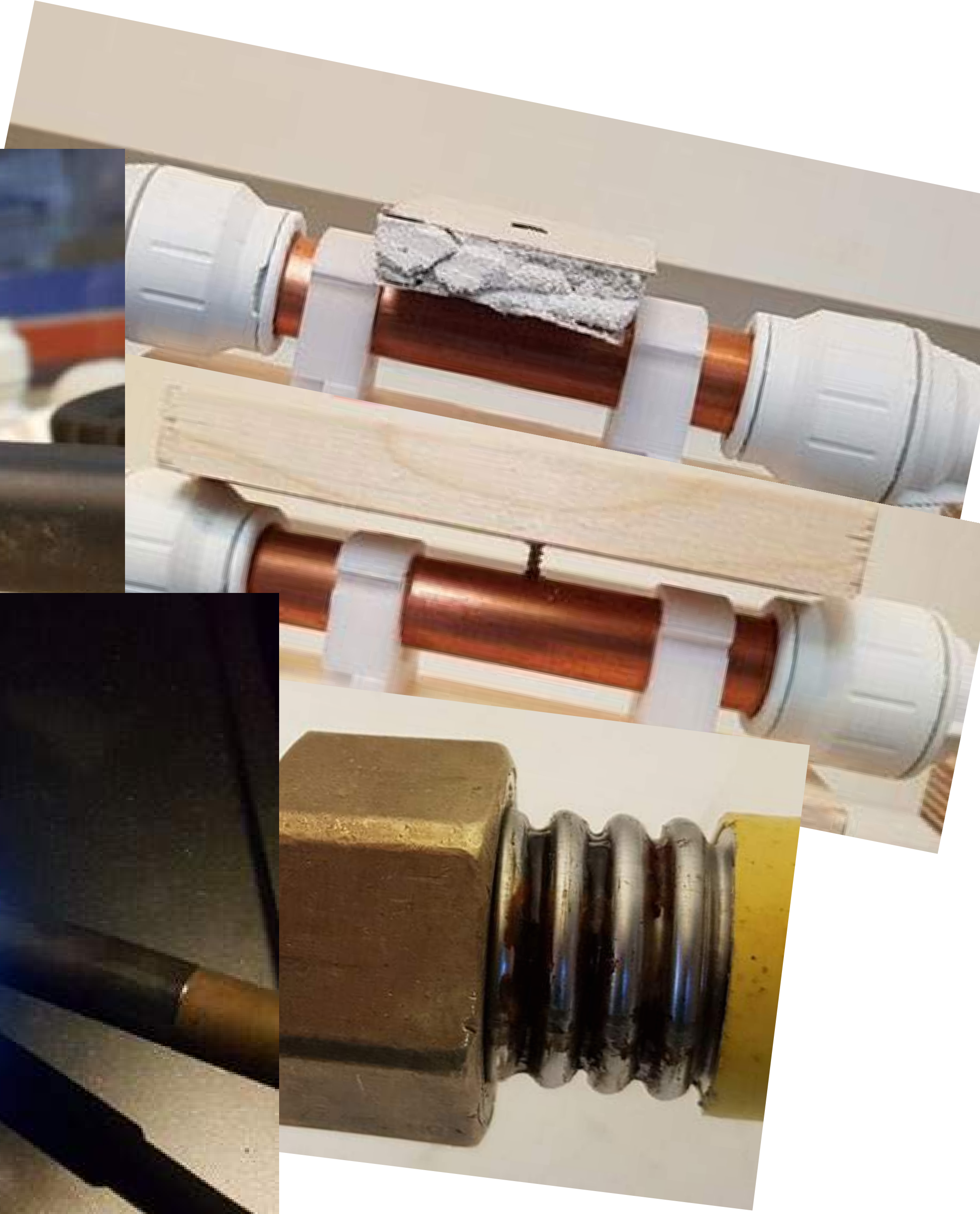
Holes and fittings

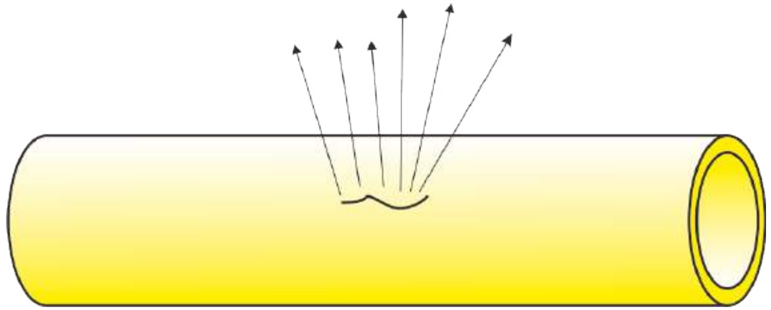
Steer Energy

Regulators and valves

Damage







Non-leaking in Methane = Non-leaking in Hydrogen

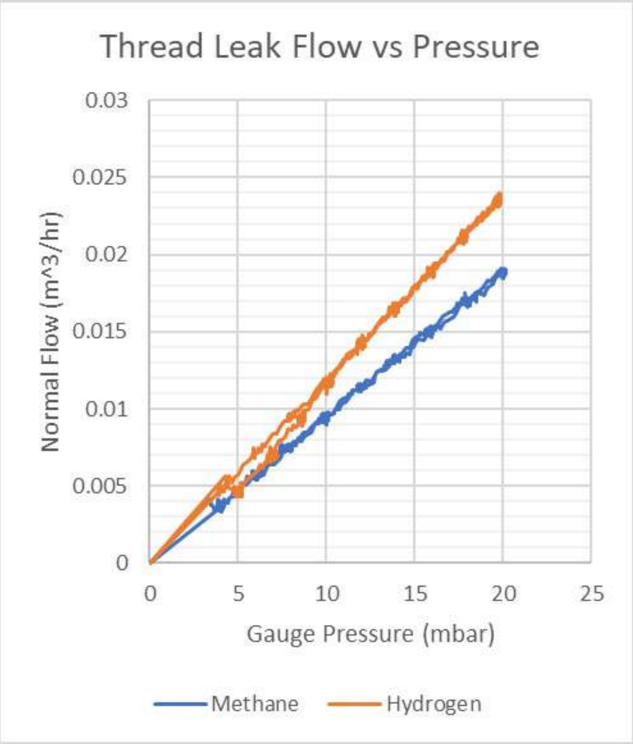
Leaking in Methane = Leaking in Hydrogen

Flow Regime	Hydrogen	Methane	Likely cause
Turbulent flow	2.8 :	1	Gross leaks: accidents, holes and cuts
Laminar flow	1.2 :	1	Small leaks: loose and damaged fittings
Transition flow	>1.2 <2.8	1	Large fitting leaks
Transition from laminar to turbulent flow occurs at a lower pressure in methane than in hydrogen			

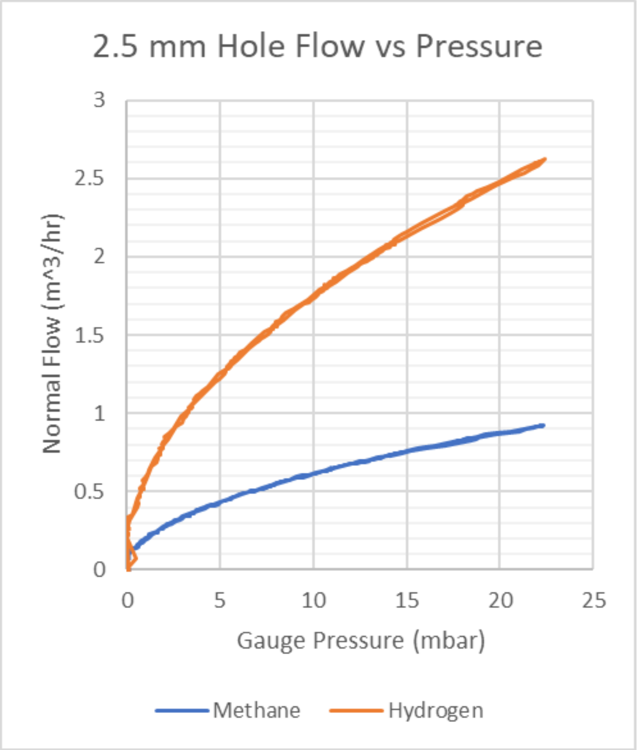
Theory and practice

Model			H_2	Ratio	CH_4
Model			μ = 0.87 x 10^{-5} Pa.s	1 : 1.24	μ = 1.08 x 10^{-5} Pa.s
			P = 0.0852 kg/m^3	1 : 7.98	*P* = 0.6681 kg/m^3
Turbulent flow (significant leaks)	High Reynolds; Momentum dominates; (High speed, unchoked)	Darcy- Weisbach	$Q \propto \sqrt{\frac{\Delta P}{\rho}}$	2.82 : 1	$Q \propto \sqrt{\frac{\Delta P}{\rho}}$
Laminar flow (small leaks)	Low Reynold; Friction Dominates; (Low Speed)	Hagen-Poiseuille	$Q \propto \frac{\Delta P}{\mu}$	1.24 : 1	$Q \propto \frac{\Delta P}{\mu}$

Laminar leak

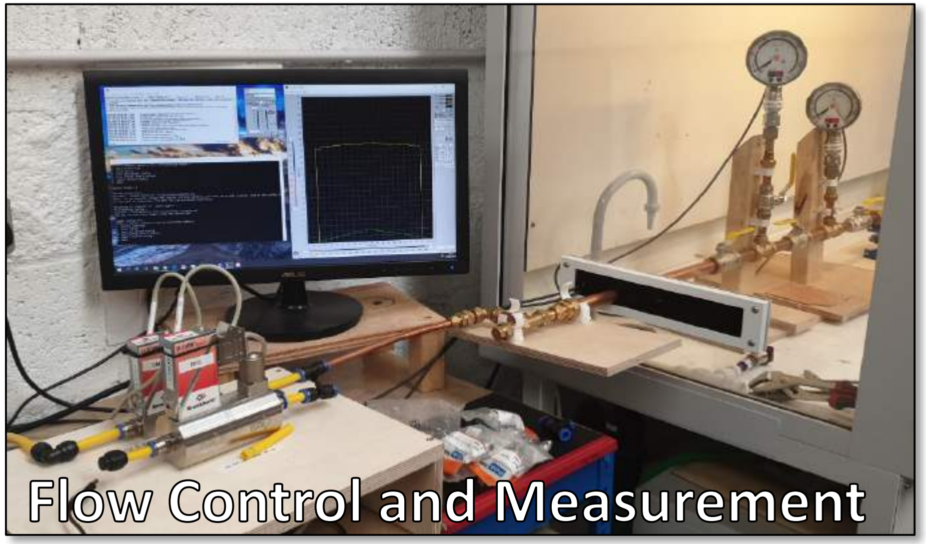


Turbulent leak

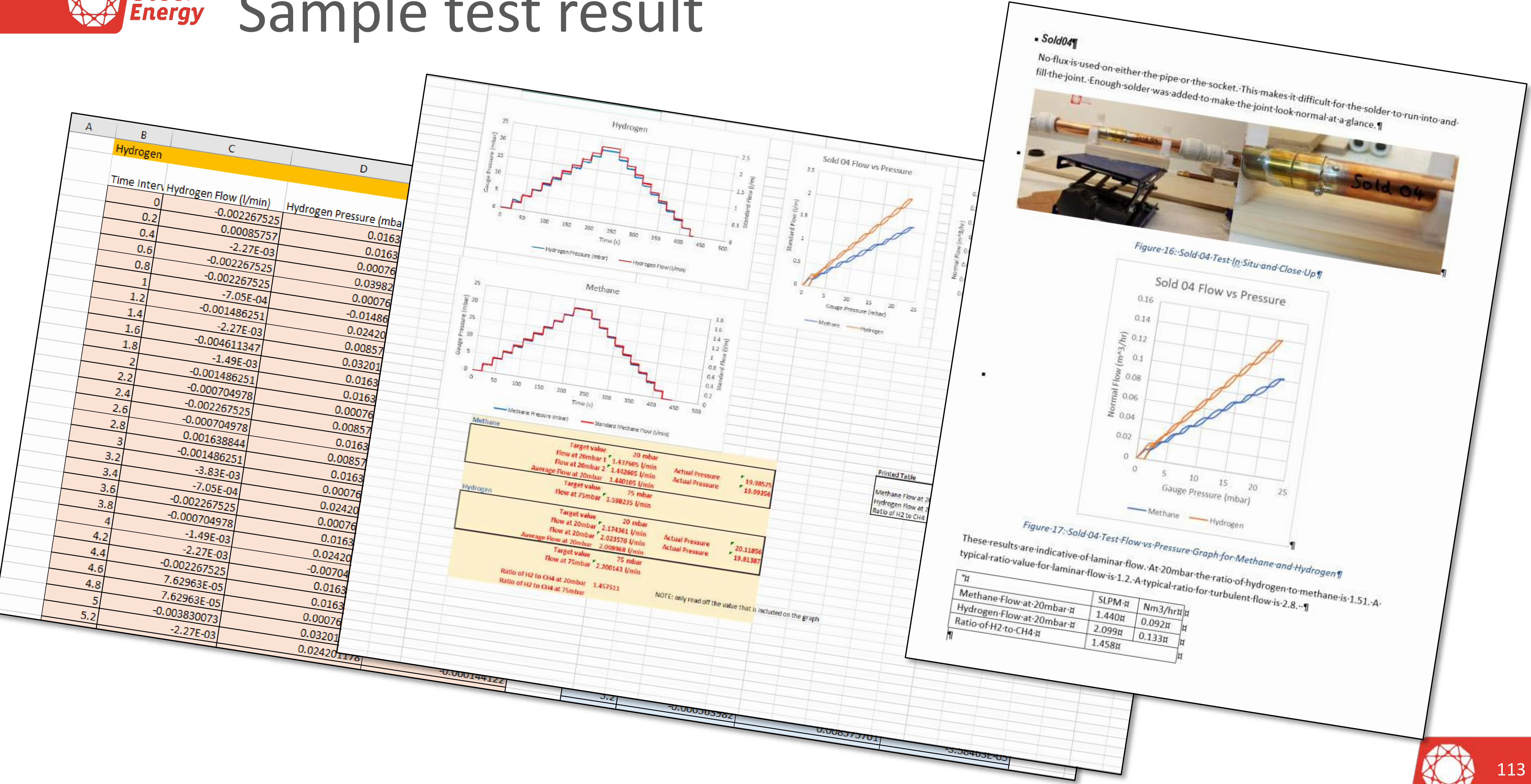


Steer Energy

Gas → Data

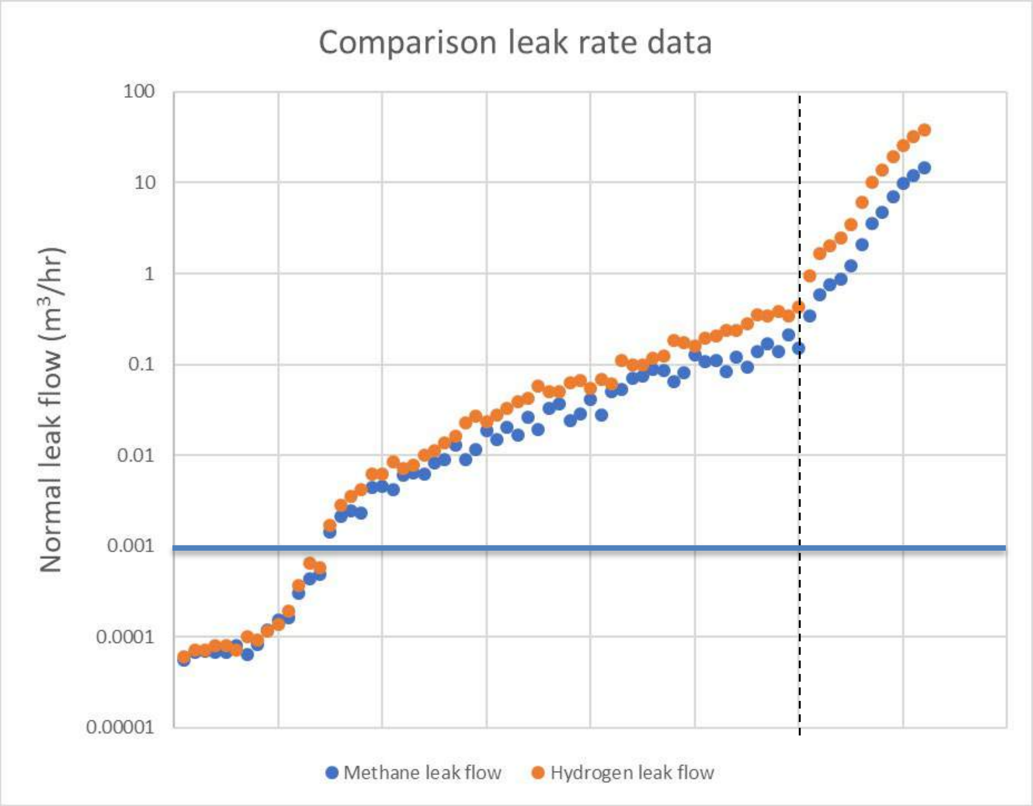


Sample test result



Summary of results

- Leaks measured over six orders of magnitude
- Leaks below 1 l/hr unlikely to be seen with current tightness tests
- Large leaks are turbulent (2.8 : 1)
- Small leaks are laminar (1.2 : 1)



A good system in methane is a good system in hydrogen

Hy4Heat

Daniel Allason

DNV GL

Hy4Heat WP7 Lot2, Lot3 and Lot4

Dan Allason CPhys

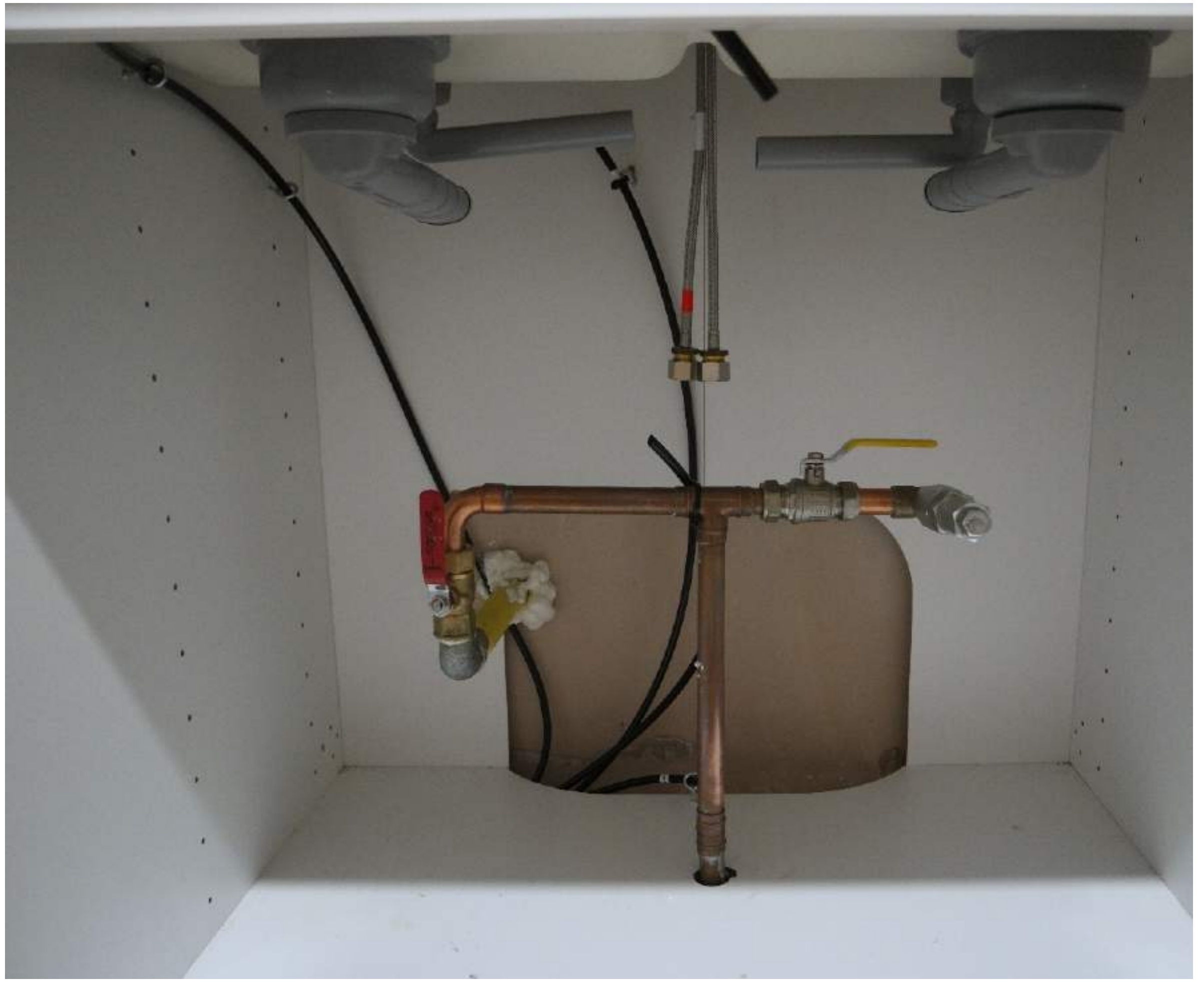
09 March 2020

Research Houses Facility

HyStreet


Hy Street
DNV GL Spadeadam Testing and Research Centre
R5BC Control Building
881 m
© 2019 Infoterra Ltd & Bluesky
Image © 2019 Getmapping plc
© 2018 Google

Internal Arrangement



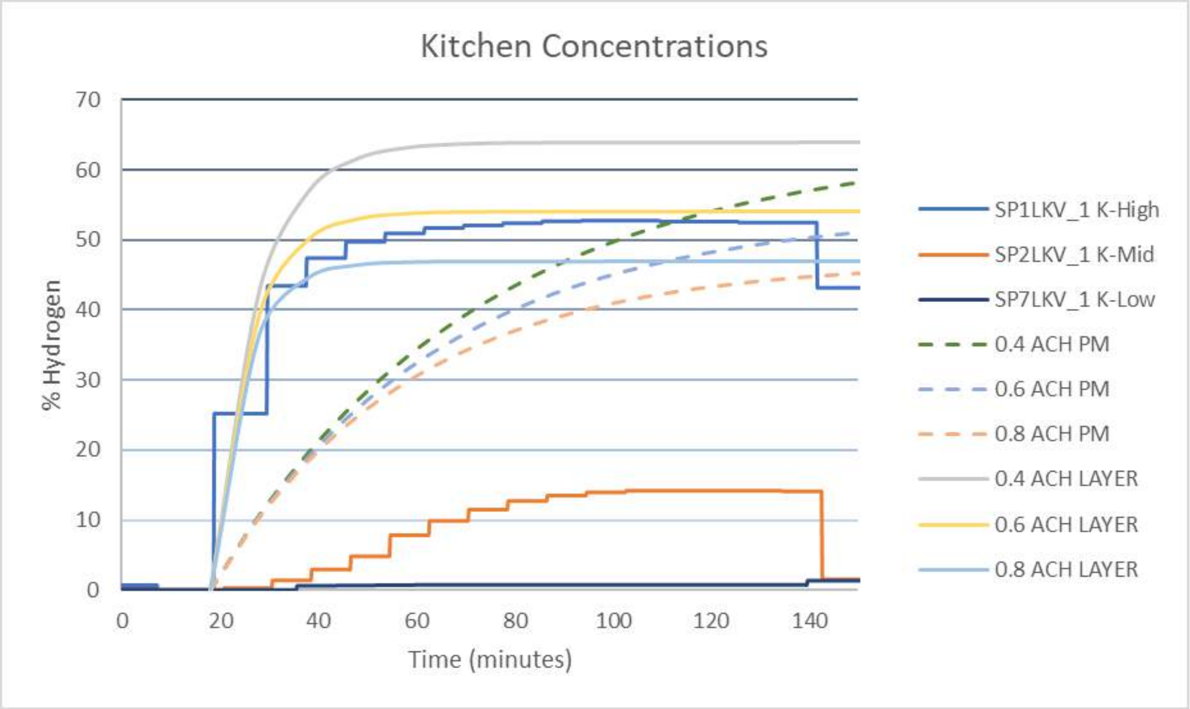
Lot2 and Lot3: Control and Metering

- Controlled Variables:
  - Fuel
  - Hole Size
  - Flow Rate
  - Release location
  - Orientation
  - Doors open / closed
- Others
  - Wind speed / direction
  - Ambient temperature

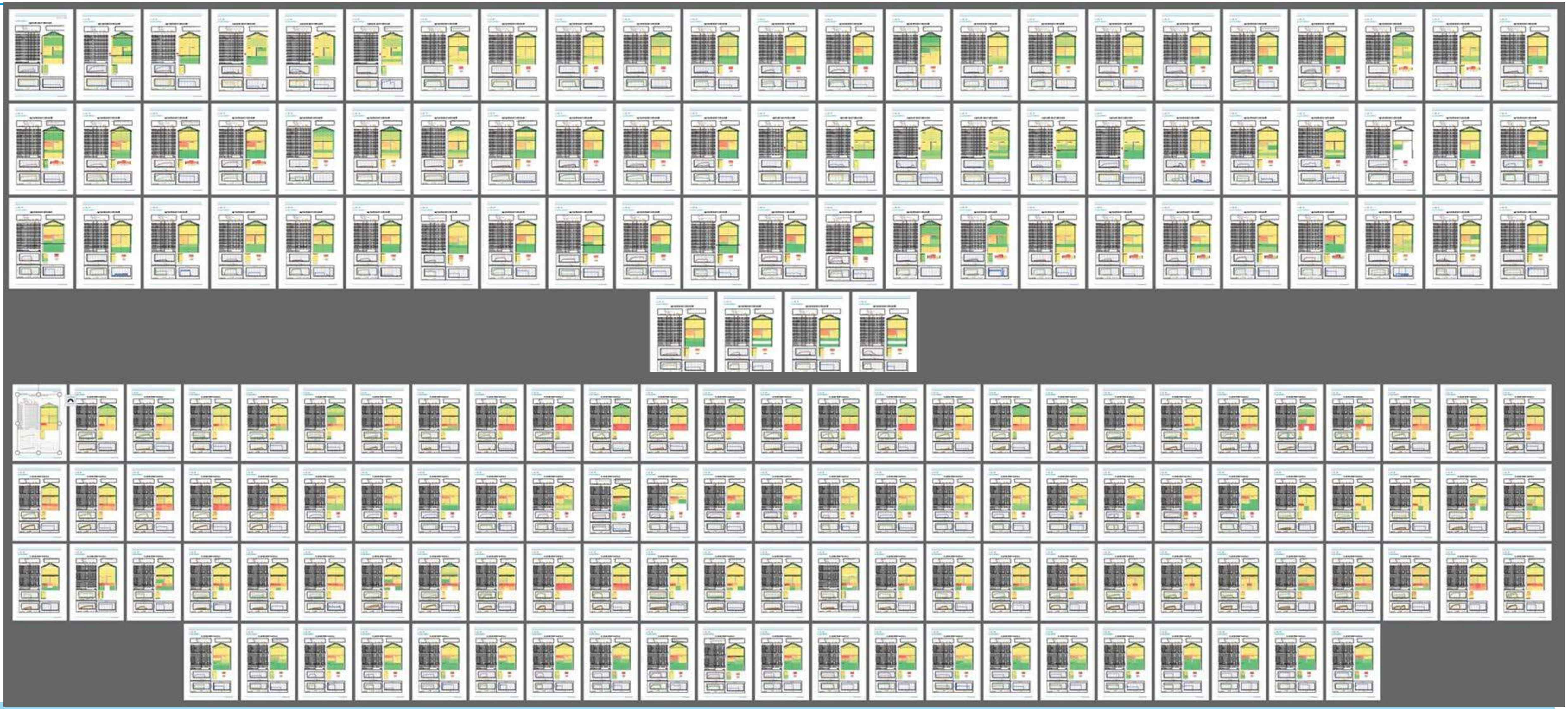
Lot2 and Lot3: Example Test Result

$$C = \left(\frac{100Q_g}{Q_a + Q_g} \right) \left\{ 1 - \exp\left[-\left(Q_a + Q_g \right) t / V \right] \right\}$$

Room Length	5	**m**
Room Width	3	**m**
Room Height	2.4	**m**
Leak Height	2.0	**m**



Lot2 and Lot3: All Tests



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Lot4: Ignition Potential

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Next Steps

- Analysis of data collected from experiments and GDNOs
- Update quantitative risk assessment and conclude the comparative risk
- Identify mitigation measures as appropriate
- Align with outcomes from other Hy4Heat work packages (including standards, appliances, meters)
- Conclude Generic Comparative Safety Risk Assessment – using both quantitative and qualitative assessment

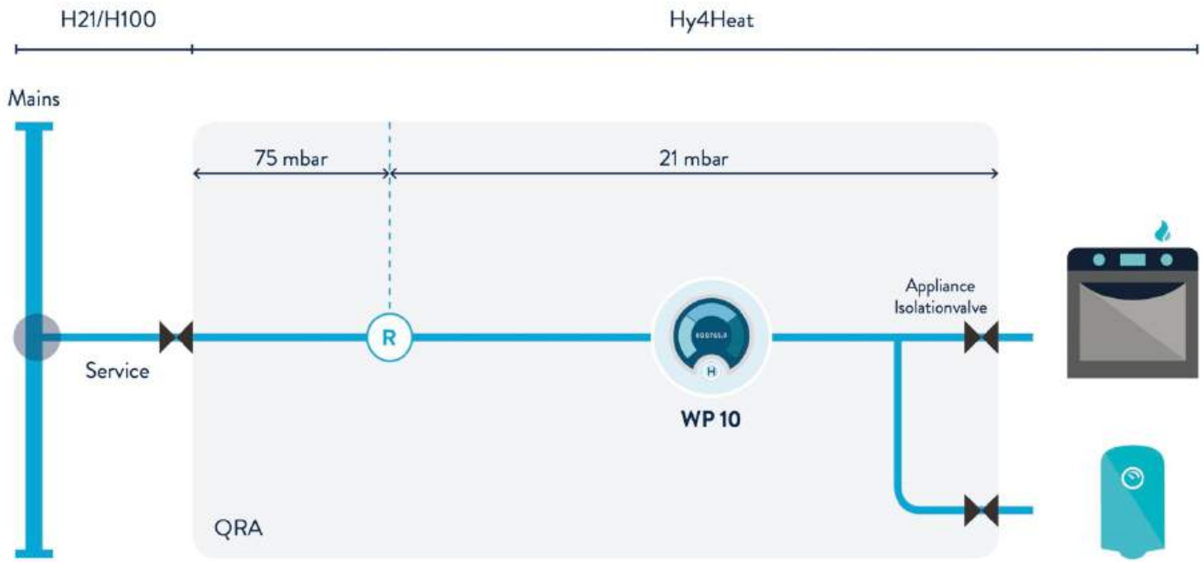
Hy4Heat

Appliance Development

Phil Brain

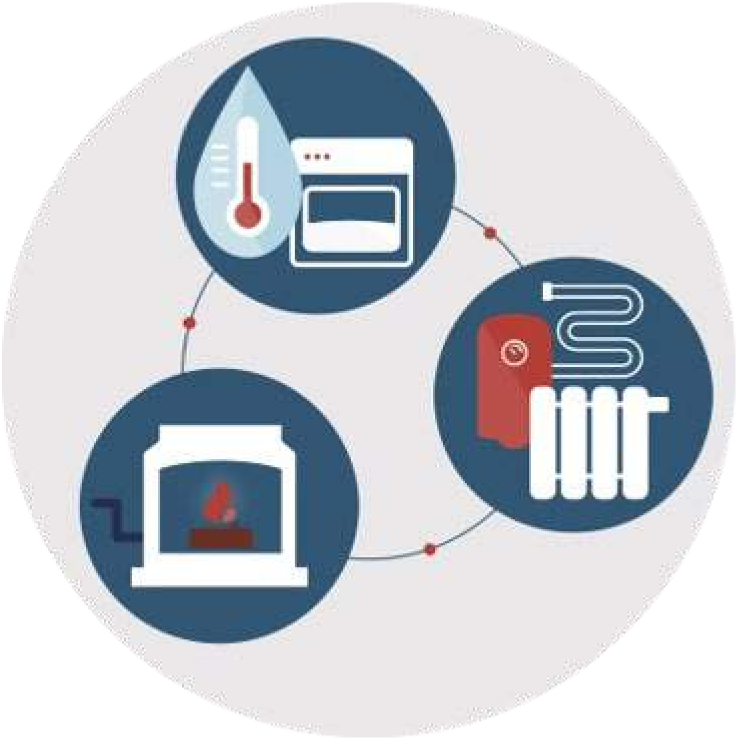
Kiwa

Appliance Development: Area of Focus



Domestic Hydrogen Appliances (WP4)

BAXI HEATING
Birmingham Burner (Walsall) Limited
Charlton & Jenrick – Best of British fires, fireplaces & stoves
Clean Burner Systems
Enertek International
FOCALPOINT
GAZCO – Fire Your Imagination
Glen Dimplex HEATING & VENTILATION
UNIVERSITY OF LEEDS
Legendfires
Teddington Bemasan – part of the Teddington Group
Valor
WORCESTER BOSCH
WORGAS – A Beckett Company

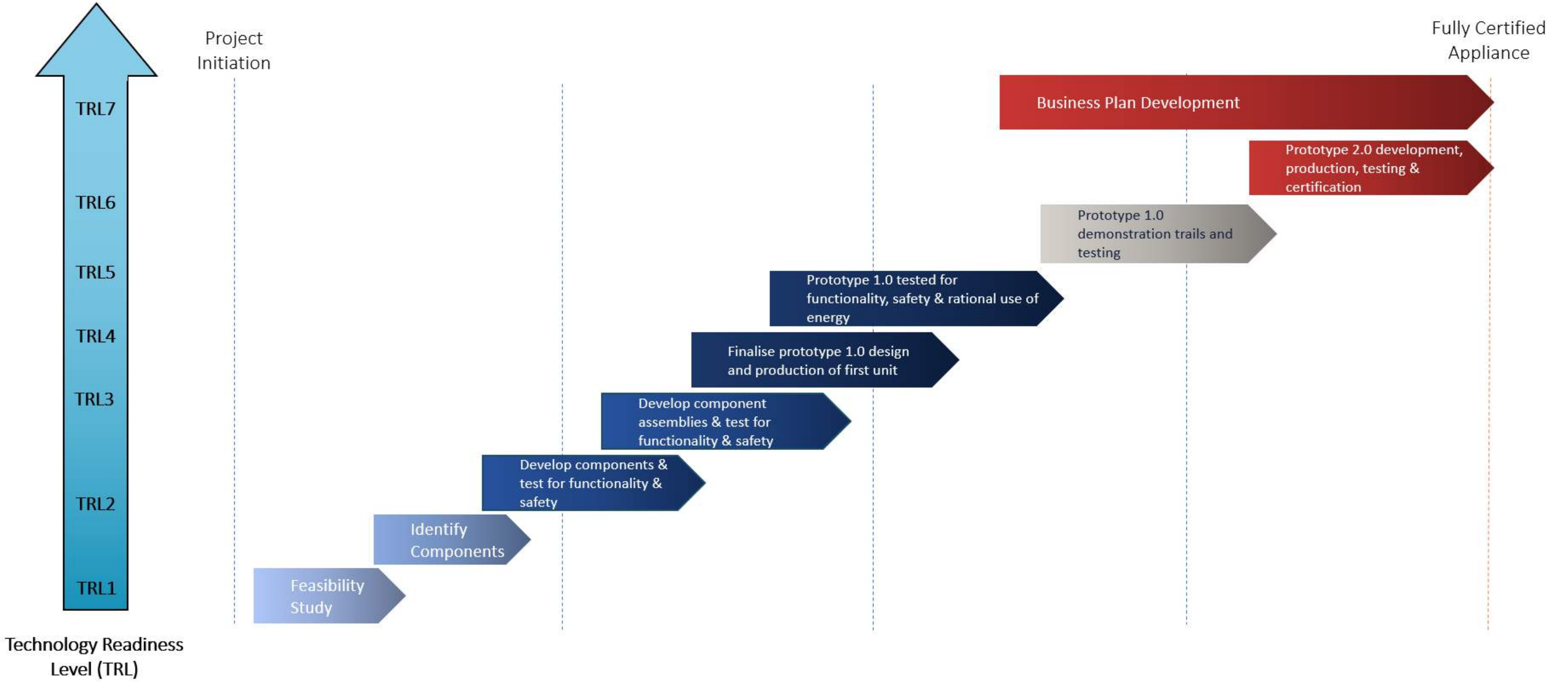


Hydrogen Meters (WP10)

Pietro Fiorentini

MeteRSit

Verification Process



Appliance Development

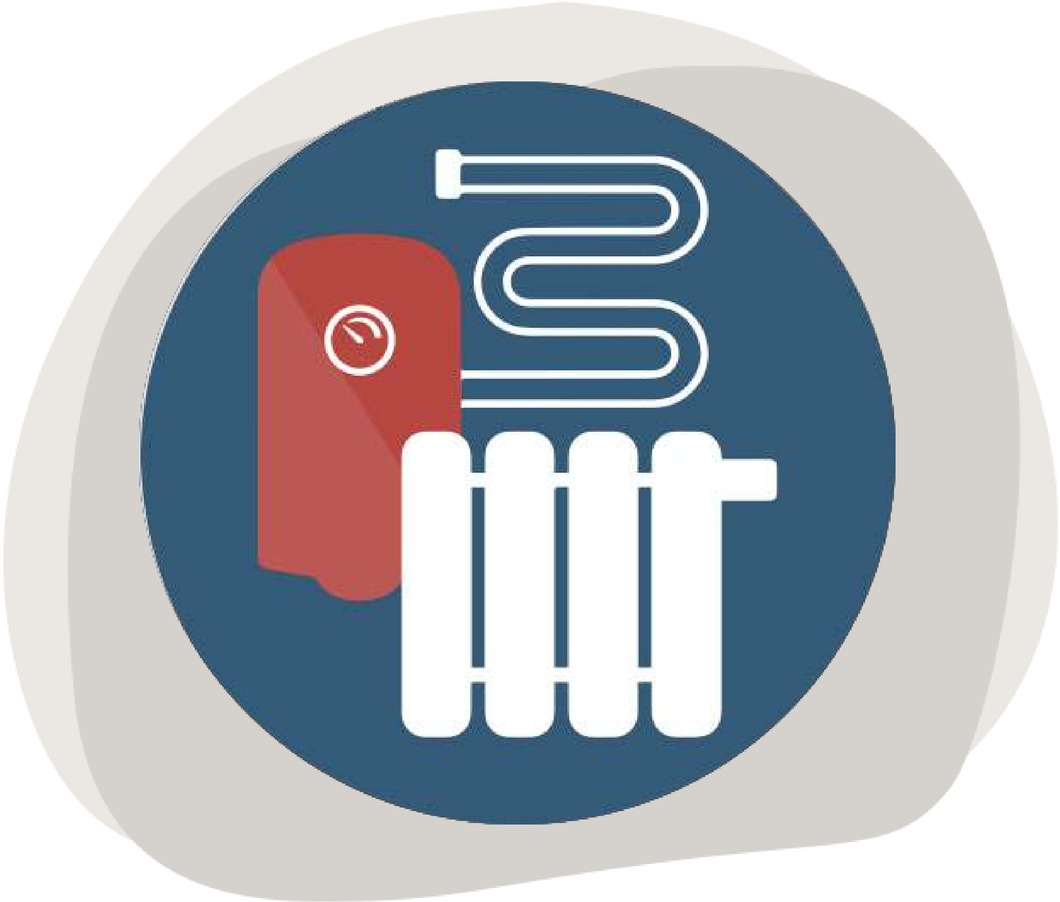
SPEAKERS

- Jeff House, Baxi
- Tom Collins, Bosch
- James Maxfield, Clean Burner Systems
- Paul Needley, Enertek
- Hossein Madani, Samad-Power
- Tony Goose, Peitro Fiorentini
- Darren McNeil, MeteRSit

PANEL

Jeff House, Tom Collins, James Maxfield, Paul Needley, Hossein Madani

Boilers



Jeff House

Baxi

Baxi Heating is a **hydrogen ready** company

Hy4Heat WP4 Boiler Development
9th March 2020

BAXI HEATING

Design Considerations

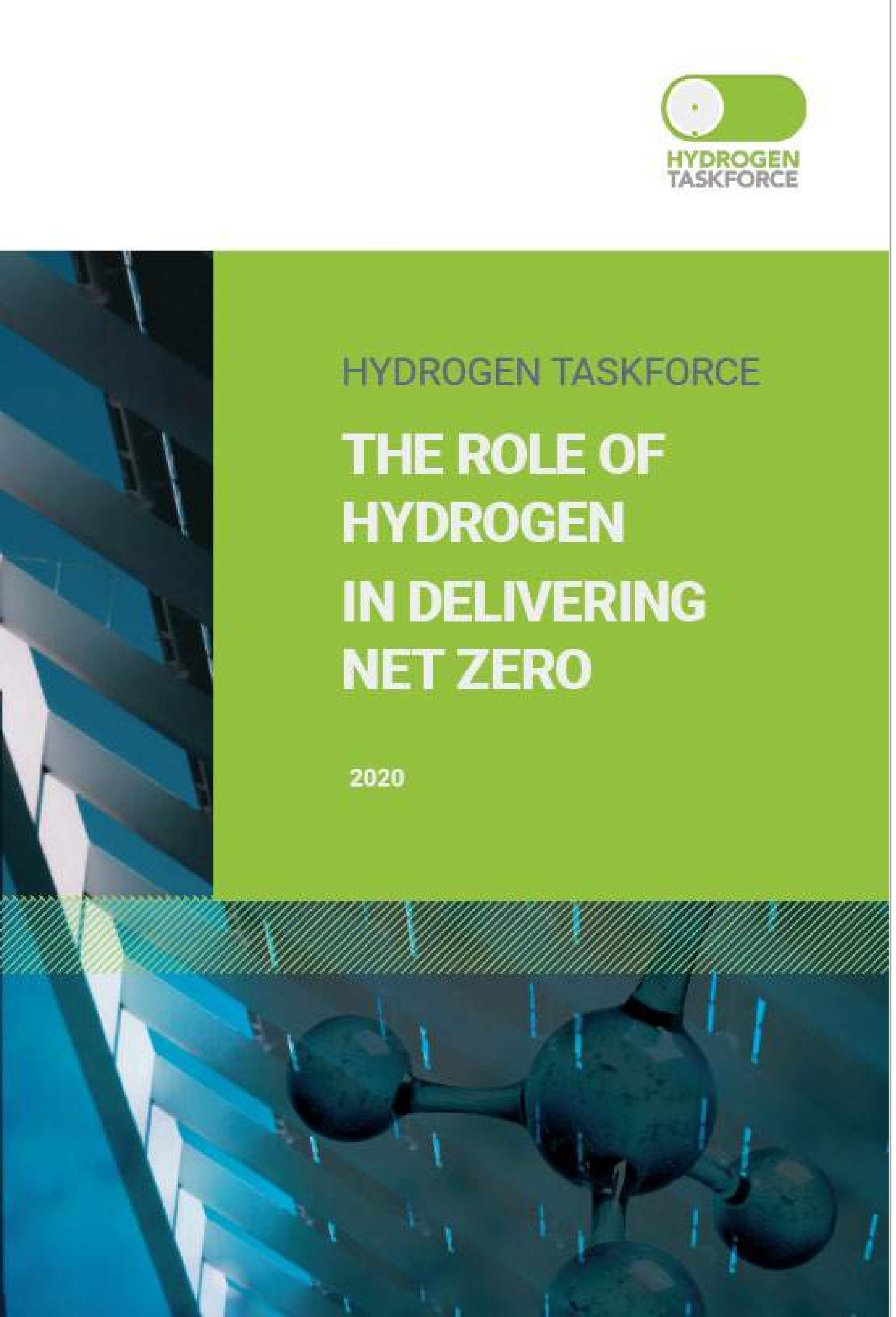
- Based upon current donor platform (as picture) with modifications to suit hydrogen combustion
- Target for comparable size, lift weight, efficiency and performance as current
- Hydrogen flame speed, control and detection key
- Flashback prevention and mitigation
- Material compatibility of gas carrying parts
- Higher volume of condensate to handle

BAXI HEATING

Progress and Findings

- Field trial certified appliances
- Able to meet design intent (size, weight, performance)
- NOx exceptionally low
- No CO production potential; positive safety benefit
- “Hydrogen Ready” concept understood by specifiers
- Ready for scale up to fulfil pilot project demand

BAXI HEATING



Next Steps and Ambition

- Development of a cross-departmental hydrogen strategy within UK Government
- Amend GSMR to enable large scale blending as a step towards a hydrogen economy
- Proceed with large scale demonstrator projects
- Strong presence and message at COP26
- Maintain UK's leading position in hydrogen

BAXI HEATING

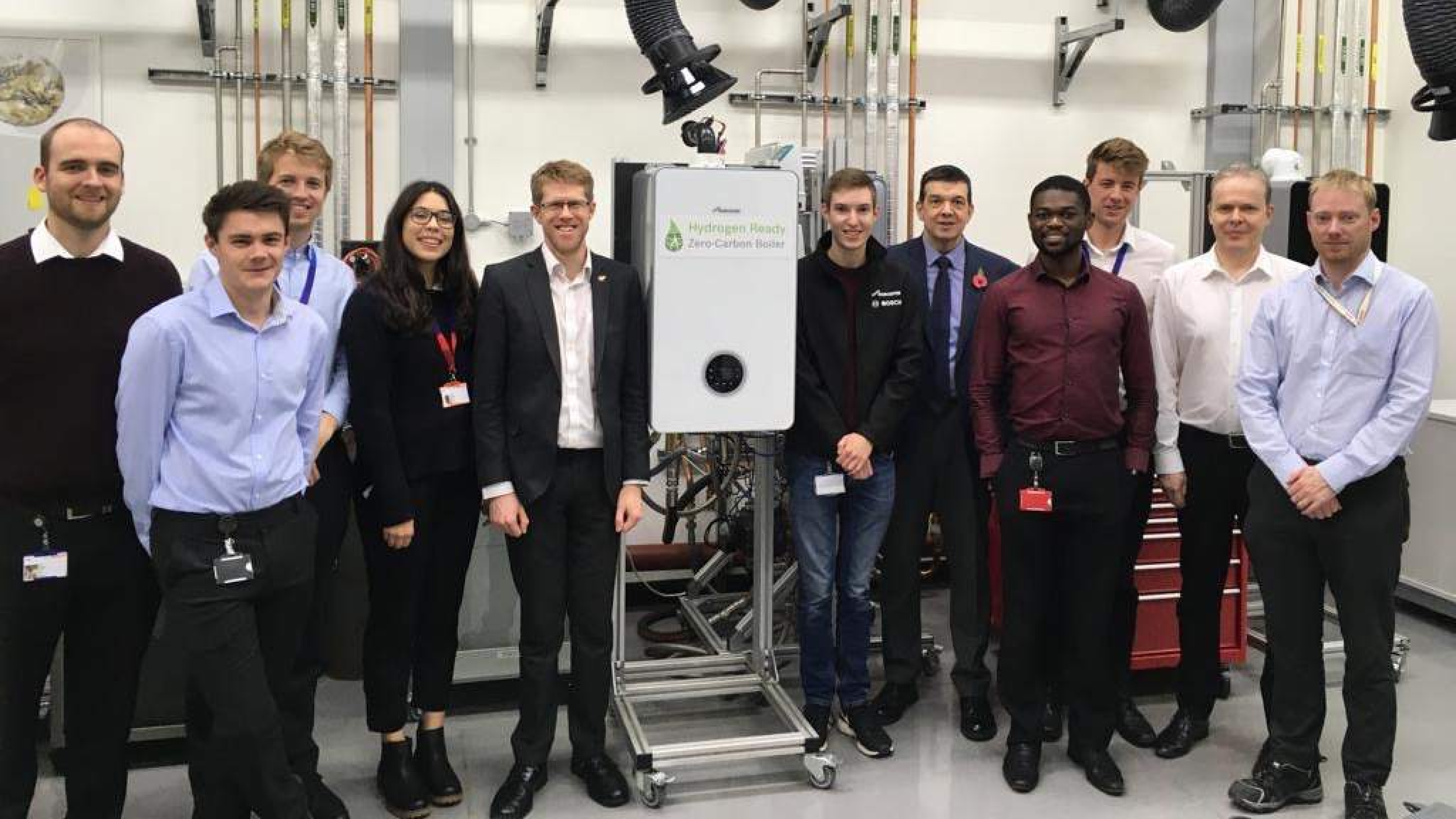
Hy4Heat

Tom Collins

Bosch

HyLife

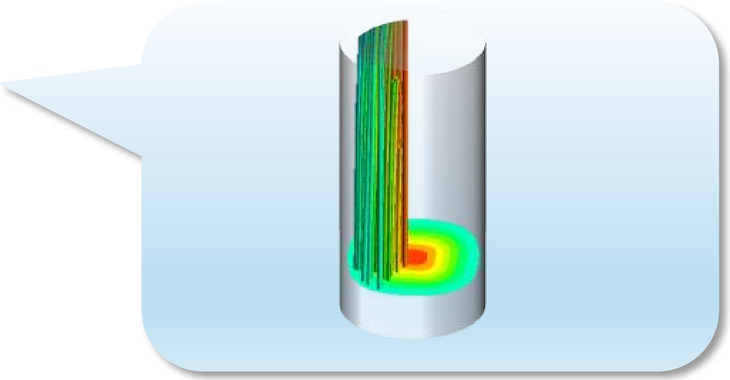
WORCESTER BOSCH


Hydrogen Ready
Zero-Carbon Boiler


WORCESTER
55°C


T4


H2
ready



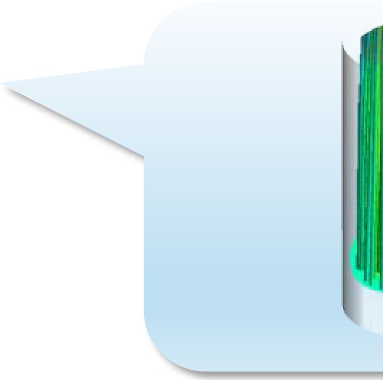
Hydrogen Ready

- **Category II** (Cat $\mathrm{II}_{2H4(x)}$)
- **Conversion kit availability** assured for product lifetime
- **Conversion kit cost** capped with reference to product cost
- Conversion **duration $\lesssim$ 1 hr**
- Conversion requires **standard skillset**


Low
emission
ZONE

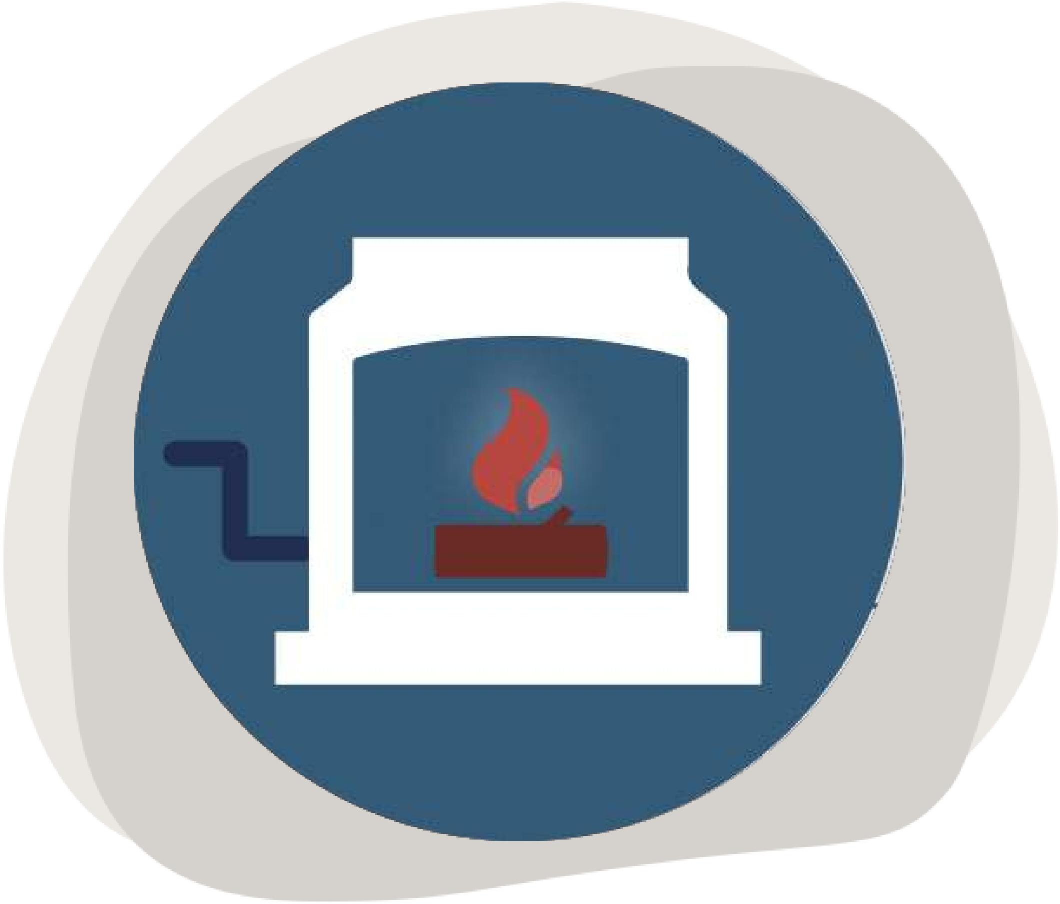

H2
ready


WORCESTER
Carbon-Free
Ready
55°C



Hy4Heat

Fires



James Maxfield

Clean Burner Systems

The Hy4Heat CBS led consortia has 3 Hy4Heat WP4 contracts.

1. **DHOFAF: Domestic Hydrogen Open Fire: Adapted (dual fuel option)**
   Reference Fire: Focal Point Blenheim Slimline

2. **2HyBaFF: Dual Fuel Glass Fronted Balanced Flue**
   Reference Fire: Legend Evora

3. **IDHA: Innovative domestic hydrogen appliance – Dual Fuel**

The CBS led team is:

1. **Clean Burner Systems (CBS) [part of the Nuphalt Grou] – Consortia Leader: James Maxfield (CBS)**
2. **University of Leeds (UoL) – Technical Lead Prof. Gordon E. Andrews**
3. **Birmingham Burners (BB) – Chris McGlone**
4. **Focal Point Fires – Andrew Lester**
5. **Legend Fires – Ray Massey**

This team is working well together and is a good example of industrial/university co-operation and its good to see University Professors on their knees in burner tests! Capitalists meeting Guardian readers makes meetings interesting!

Hy4Heat

Dual fuel hydrogen/NG fires are advantageous as they can be sold immediately and are then ready for hydrogen when it is available. There is no appliance conversion necessary in each house. Estimated conversion costs with a qualified engineer visiting 23M dwellings is £24bn, so dual fuel potentially drastically reduces the cost of the transition to hydrogen. Also, there are insufficient trained gas fitters to do this conversion work.

Dual fuel is possible because the Wobbe number for NG and hydrogen are similar.
However, dual fuel is technical much more challenging than hydrogen only, but has been successfully demonstrated on all three fire types.

Principles of Design of Dual Fuel Fires Used in this Work.

1. The same burner and fuel control system is used for both fuels with no change in the burner or fuel control system.
2. Premixed or aerated burners cannot be used as they will flash back on hydrogen. Thus all the burner designs are non-aerating.
3. A new dual fuel pilot and flame supervision systems is required as the existing pilot burner is premixed.
4. Non-aerated flames potentially have higher NO_x than lean premixed flames and our design aim was lower NO_x on both fuels than on the reference fire, which we have demonstrated.
5. Non-aerated fuels need to have fast mixing of the fuel and air and this is achieved using the available fuel pressure loss at the fuel jet outlet and by interacting the fuel jets with the ceramic 'coals' to both mix the air and fuel, coupled with heat extraction from the flame by the 'coals'.
6. No colourant is used, the natural colour of non-aerated hydrogen flames is orange as this slide.

   Well mixed hydrogen/air flames are blue.

DHOFAF: Domestic Hydrogen Open Fire: Adapted (dual fuel option) Reference Fire: Focal Point Blenheim Slimline

Reference fire NG

New burner design on Hydrogen and NG

Best Emissions Results — NO_x mg/kWh at 0% oxygen

Fire	Reference NG	New Hydrogen	New NG
NO_x mg/kWh	128	35	94
CO ppm	<200	0	35

The new impingement mixing non-aerated design has lower NO_x than the Reference Fire on NG and H_2

2HyBaFF: Duel Fuel Glass Fronted Balanced Flue : Legend Evora

Reference fire NG

New burner hydrogen

New NG

Best emissions results **NO_x mg/kWh at 0% oxygen**

Fire	Reference NG	New Hydrogen	New NG
NO_x mg/kWh	83	31	48
CO ppm	<200	0	400

The design goal of lower emissions than the reference fire on NG and hydrogen has been achieved on the new burner design.

We have work to do, to reduce the CO emissions on NG for the lowest NO_x designs.

IDHA: Innovative domestic hydrogen appliance – Dual Fuel

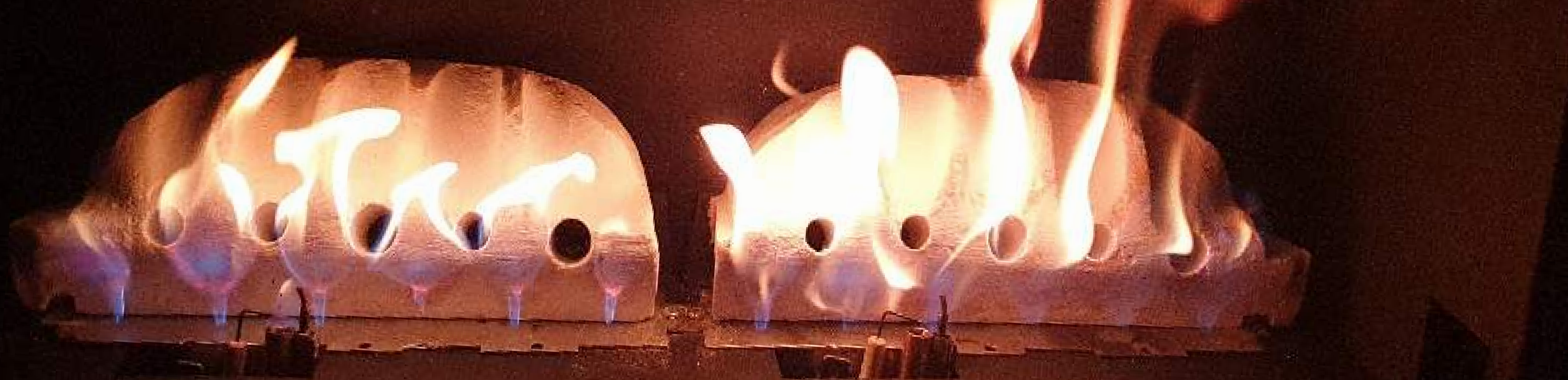
One of our innovative fire designs

The flame shape can be tailored

to a customers preference

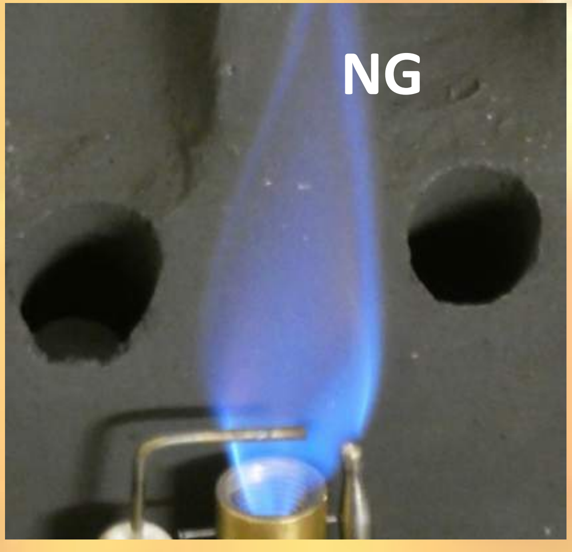
Hydrogen 4 kW NO_x 107 mg/kWh

NG 4 kW NO_x 67 mg/kWh CO 92ppm



Dual Fuel Ignitor and Flame Detector

This has been the most difficult area to develop, particularly the flame shut off time. The hydrogen flame heats the ceramics hotter lower in the bed and these radiate to the thermocouple flame detector, which slows the thermocouple cool down period. The same ignitor works fine for the Innovative and Open fires, but the Glass Fronted fire has been more difficult to achieve the shut off.



Non-aerated pilot with flame stabiliser.
Light up is good for all fires.
Remote fire control is being developed.

Conclusions

1. Dual fuel hydrogen and natural gas fires are practical using the same burner and pilot ignitor.
2. Hydrogen flames are very colourful in the innovative fire, but less so with ‘coals’ due to the good fuel and air mixing that they produce.
3. Low NO_x emissions on hydrogen can be achieved and with NG NO_x emissions lower that for the reference fires has been achieved. CO emissions regulations can be met with NG.
4. Hydrogen is a viable fuel for fires
5. Dual fuel fires will enable early (2022) placement in the market place of the new fires, which will operate initially on NG and transition to hydrogen when it is available.
6. Hydrogen in the gas grid should be the policy for the decarbonisation of heat.
7. Regulations should be introduce to make dual fuel heating equipment a statutory requirement.

Paul Needley

Enertek International

Hy4Heat Stakeholder Engagement Event

9 March 2020

Paul Needley
Enertek International Ltd

The HyFires Consortium

Enertek International

GAZCO

Valor

Charlton & Jenrick LTD
Best of British fires, fireplaces & stoves

Teddington Bemasan
part of the Teddington Group

Beckett™
THERMAL SOLUTIONS

The HyFires Consortium

Three Major Gas Fire Manufacturers

- Gazco
- Charlton & Jenrick
- Valor (Glen Dimplex)

Two Major Component Suppliers

- Beckett Thermal Solutions (Worgas)
- Teddington-Bemason

One Development Company / Project Manager

- Enertek International Ltd

Three Projects

Conventional Open Fire

- Valor (Glen Dimplex)

Glass Fronted Conventionally Flued Fire

- Charlton & Jenrick

Glass Fronted Balanced Flued Fire

- Gazco

One Objective

To Produce EC Certified Hydrogen Versions of Each Fire:

- Valor Dream 940 – Open fronted, Conventional flue fire
- Charlton and Jenrick Focus HE – Glass fronted, Conventional flue fire
- Gazco Logic HE – Balanced flue fire

Consortium Co-operation – Our Method

- All Consortium Partners worked together to develop a concept solution firebed for all derivatives – a common base

- Each Fire Manufacturer took responsibility for incorporating the hydrogen firebed in their appliance

- Teddington and Worgas, now Beckett Thermal Solutions provided specialist expertise and equipment

- Enertek facilitated the project and consortium cooperation

Specific Challenges – Hydrogen Fire Development

- Producing Realistic and Visible Flames
- Flame Detection and Monitoring
- Control Temperatures
- NOx Emissions

Solutions – Changes to Natural Gas Models

Producing Realistic and Visible Flames

- Achieved by a new burner design and firebed
- No added colourant

Flame Detection and Monitoring

- Fast acting thermocouples electronically monitored function reliably

Control Temperatures

- A specifically designed control housing prevents overheating

NOx Emissions

- A unique burner flamestrip design keeps Nox within Standard limits

Evidence of Progress

Evidence of Progress

Valor Dream 945 H

Evidence of Progress

Charlton & Jenrick FOCUS HE H_2

Evidence of Progress

GAZCO LOGIC HE H_2

Next Steps

Work is continuing within the Hy4Heat programme to:

- Work towards a hydrogen ready design
- Produce Safety Certified samples for WP 8 trials
- Enhance efficiency and NOx performance
- Produce a fully Certified design of each variant

Beyond Hy4Heat

HyFires Consortium would like to see:

- A clear government policy to support the move to hydrogen
- Clear guidelines regarding ‘Hydrogen Ready’ status
- A commitment to the future of gas fires after the WP8 trials
- Sales opportunities in widespread trials
- A sustainable future for the gas fires industry

Cookers and Hobs

Hy4Heat Stakeholder Engagement Event
9 March 2020

Paul Needley
Enertek International Ltd

The HyCookers Consortium

The HyCookers Consortium

Glen Dimplex Home Appliances

- Leading UK manufacturer of domestic cooking appliances
- Product and Project Owner

Enertek International Ltd

- Research and Development Consultants
- Project Facilitator, Project Manager and provider of Hydrogen test facilities

Three Projects

Hydrogen Hob

- Stoves ST SGH600C Stainless

Hydrogen Oven and Grill (Built-in)

- Belling BEL BI70LPG

Hydrogen Freestanding Cooker

- New World NW NH 600TSIDLm Silver

Consortium Co-operation – Our Method

- Enertek are conducting project work in conjunction with guidance from GDHA
- The consortium has been supported by several suppliers to obtain the necessary samples, and where appropriate external expertise
- The University of Hull carried out specific work relating to flame visibility and potential colourants

Specific Challenges – Hydrogen Cooker Development

- Flame visualisation
- Burner design
- Light-back on ignition
- Changes in cooking performance - H_2 v Natural Gas

Solutions – Changes to Natural Gas Models

Flame Visualisation:

- Improved by new burner design.
- No added colourant – Food contact
- LEDs added for additional indication

Burner Gas Leaks:

- Welded seams

Light-back on Ignition:

- Burner port-size and volume

Cooking performance:

- Confirmed by test work

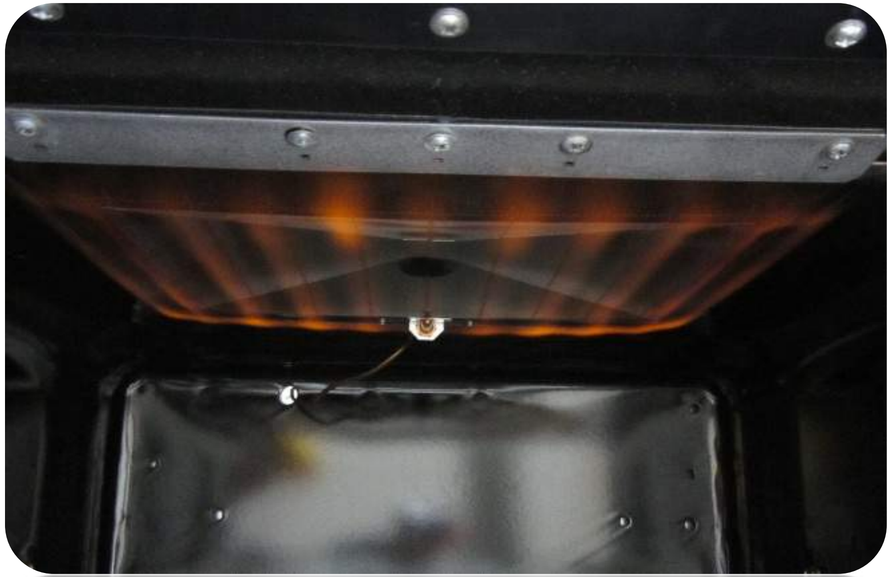
Evidence of Progress - Hob

- Gas Hob with LED Flame Indication System

Evidence of Progress - Grill

Hydrogen Cooking - Toast Test:

- 7 min
- low grill position
- grill burner @ max.



Evidence of Progress

Evidence of Progress - Oven

Hydrogen Cooking - Croissant Test:

- 19 min
- Middle shelf
- Gas Mark 6

Next Steps

Work is continuing within the Hy4Heat programme to:

- Work towards a hydrogen ready design
- Produce Safety Certified samples for WP 8 trials
- Enhance flame picture and efficiency
- Produce a fully Certified design of each variant

Beyond Hy4Heat

HyCookers Consortium would like to see:

- A clear government policy to support the move to hydrogen
- Clear guidelines regarding ‘Hydrogen Ready’ status
- A commitment to the future of gas cookers after the WP8 trials
- Sales opportunities in widespread trials
- A sustainable future for the gas cooker industry

Thank you for Listening

Hy4Heat

Innovative appliance

Ali Norouzi

Samad Power

Samad Power Ltd

Turbo Green Boiler – Hy4Heat

March 2020

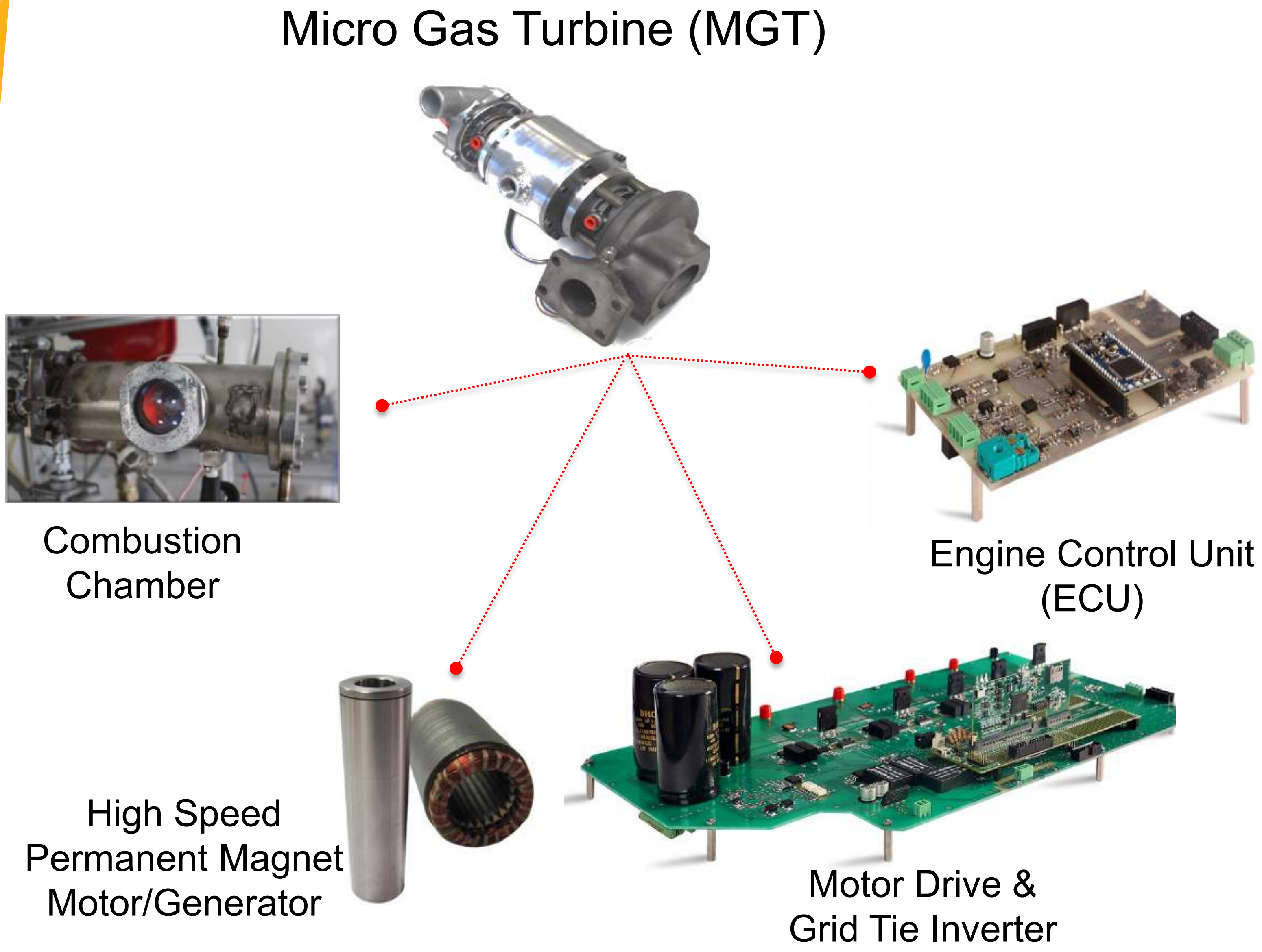
Overview

1) Introduction
2) CHP Products
3) Turbo Green Boiler (TGB)
4) Hy4Heat
5) Differences between Natural Gas TGB and Hydrogen TGB
6) Interesting outcomes
7) Project Challenges

Introduction

Samad Power Ltd

Developer of small to medium size Turbogenerators and their related enabling technologies that are used for local generation of heat and power.

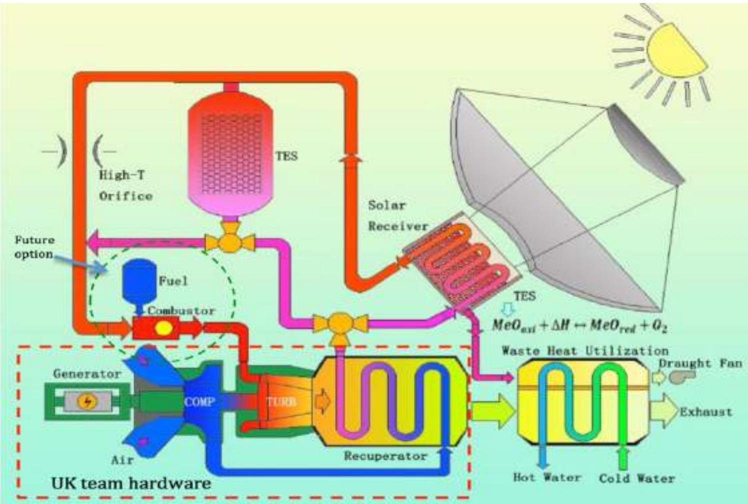


CHP Products

Turbo Green Boiler

Electric Power: 2 kW
Thermal Power: 30 kW

Renewable Solar Powered CHP

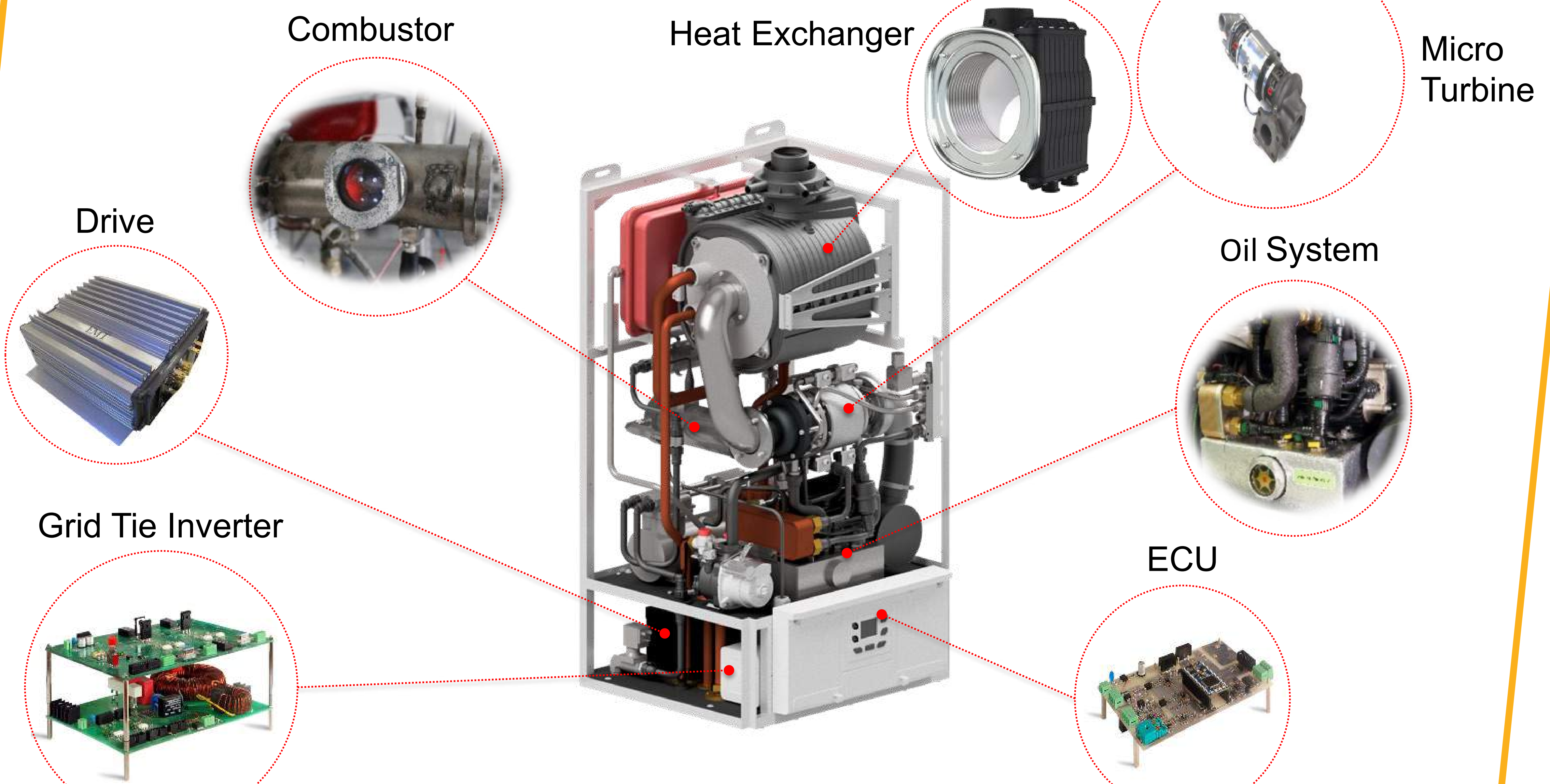


Electric Power: 10 kW
Thermal Power: Up to 100 kW

Bakery Burner

Electric Power: 2 kW
Thermal Power: 30 kW

Turbo Green Boiler (TGB)

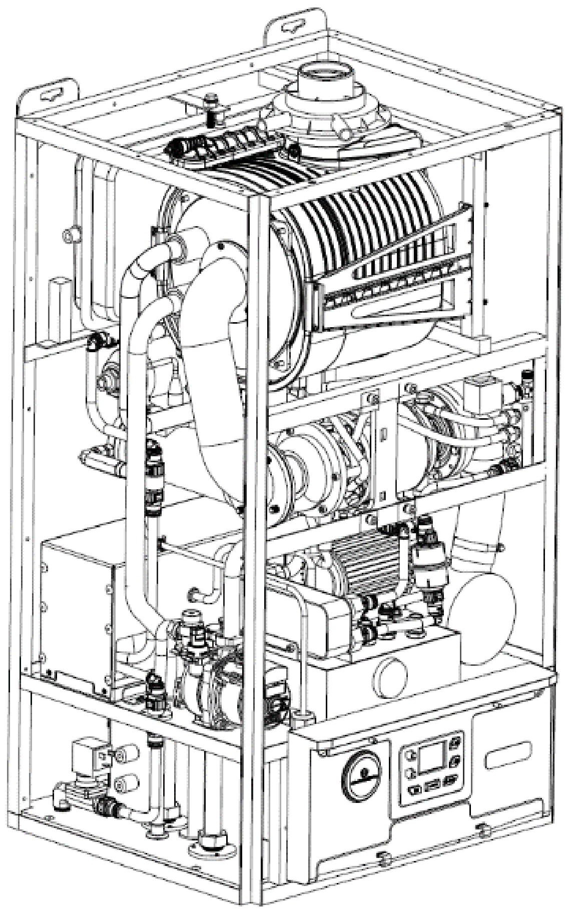


Hy4Heat
(ZERO EMISSION TURBO GREEN

Hy4Heat

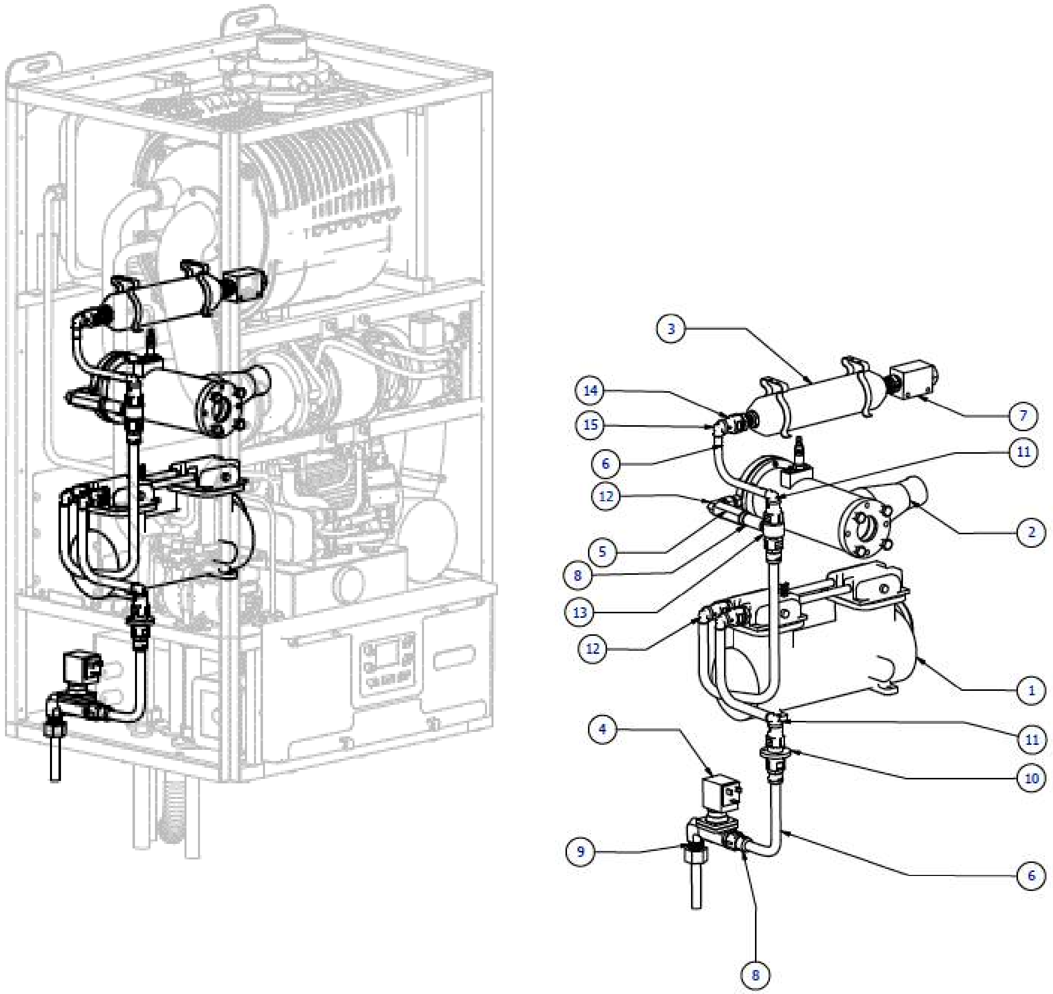
KEY FEATURES

- Application: Domestic/Commercial Boiler
- Engine: Micro Gas Turbine
- Configuration: Single Shaft
- Bearing Type: Oil Bearing
- Electric Power: 2 kW
- Thermal Power: 30 kW
- Fuel: Hydrogen
- **TRL: 4 - Technology Validated in Lab**

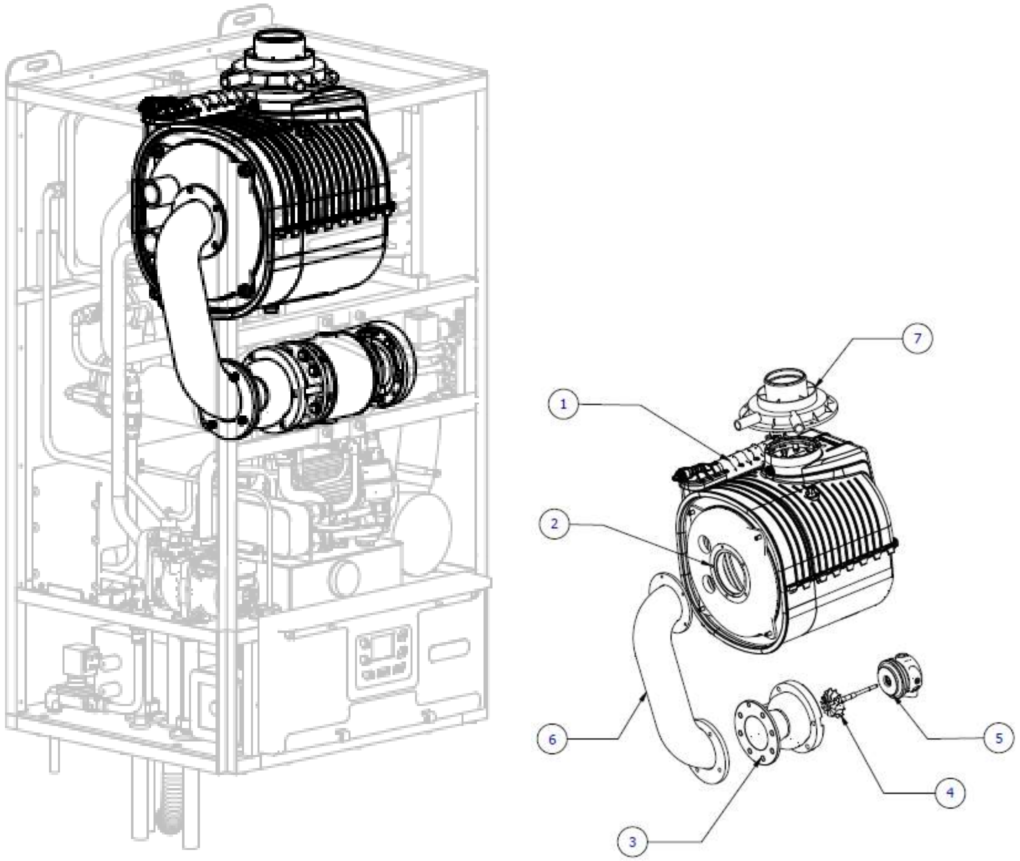


Enabling Hydrogen Burning Turbo Green Boiler

Differences
(HYDROGEN BURNING & NATURAL GAS

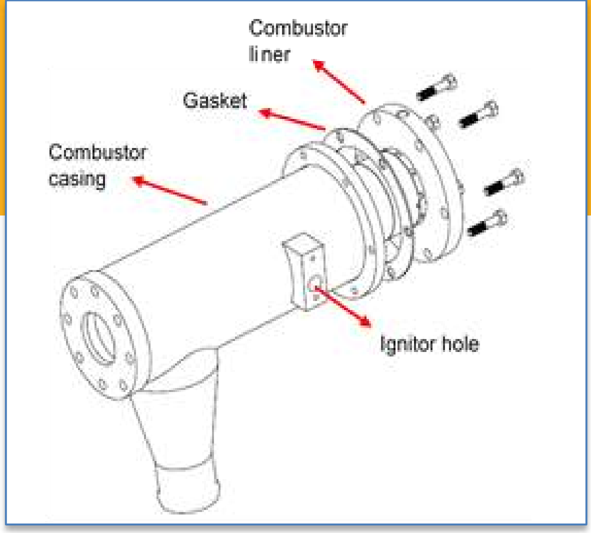


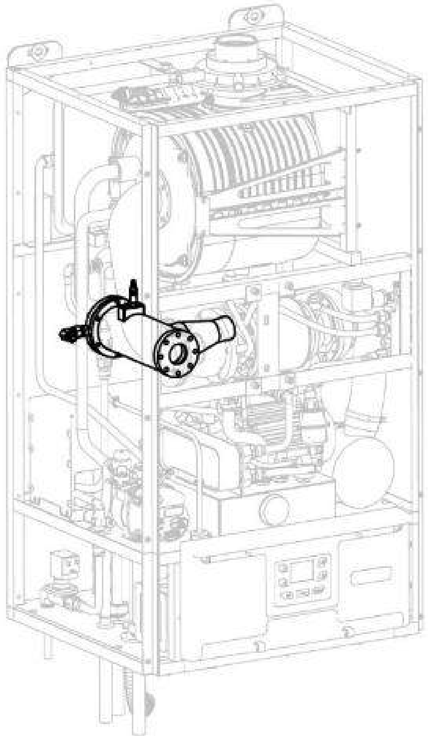
Components: Direct Contact with Hydrogen



Components: Indirect Contact with Hydrogen

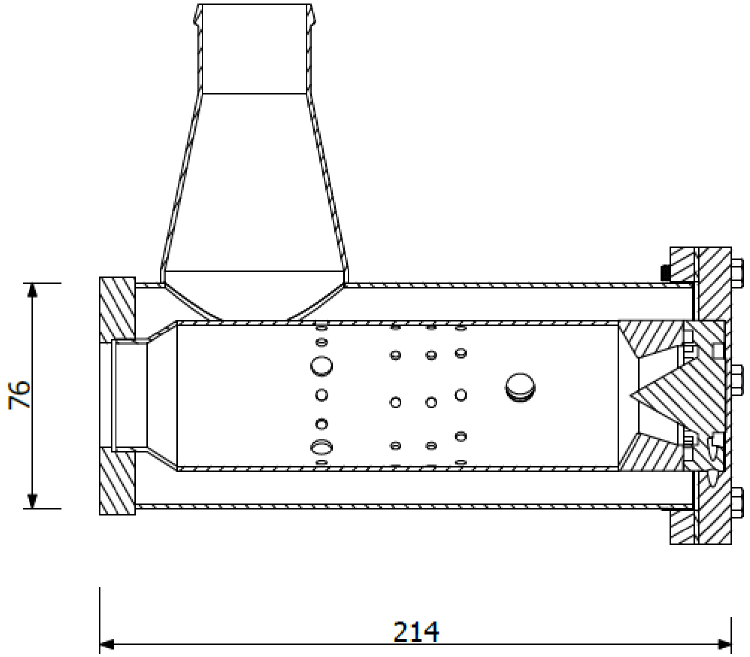
Differences
(HYDROGEN BURNING & NATURAL GAS BURNING)



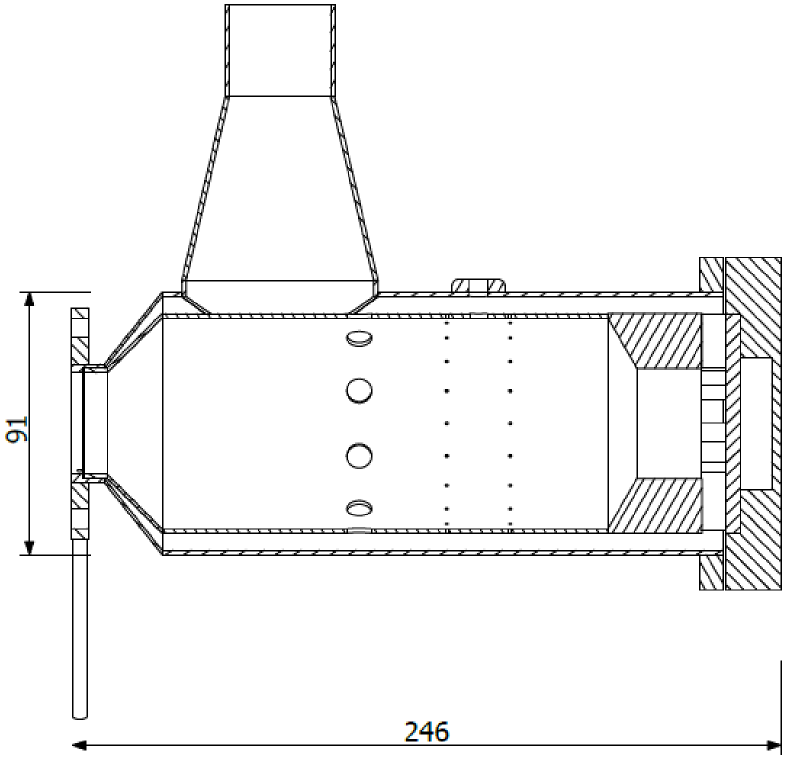


Combustion Chamber

Natural Gas Combustor

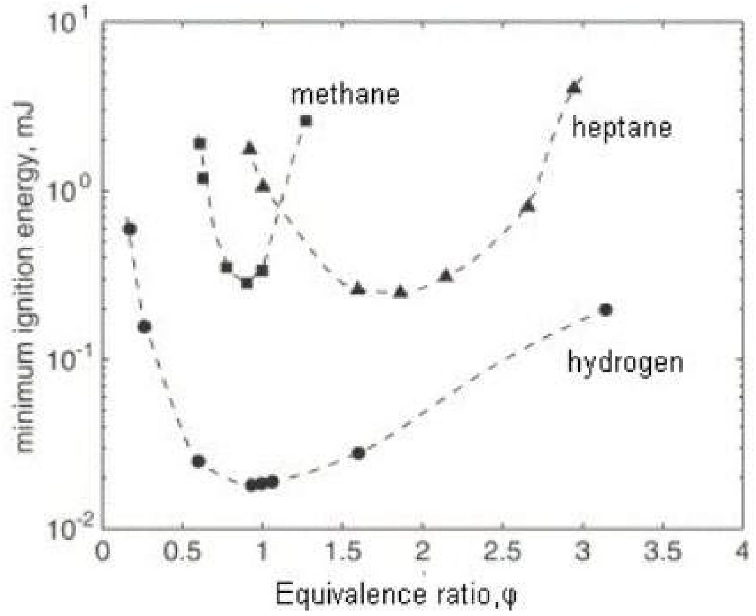


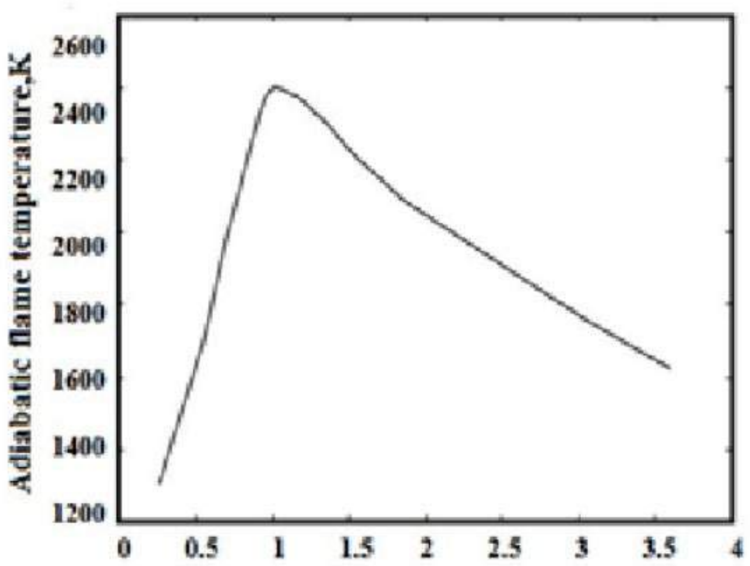
Hydrogen Combustor



Interesting Outcomes

- ❑ Moving towards Hydrogen ready product
  - Hydrogen and Natural gas on the same unit
- ❑ Appliance ignites better with Hydrogen
  - lower ignition energy
  - wider flammability limits
- ❑ Potentially safer
  - Hydrogen is not premixed
- ❑ Potentially less NOx
  - Burning at lower temperature





Project Challenges

- ❑ Integration of Flame Failure Detection with Boiler Control Unit
- ❑ Higher flow rate requirement → More powerful pump
  - ∴ Less net generation
- ❑ Unclear regulation - especially for MGT-CHP
  - First Hydrogen MGT-CHP in the UK (even in Europe)
  - Inter-regulations apply – extra activities – complication
- ❑ Different Point of Views on Technical Requirements of Appliance
  - Innovative Category
  - Project requirements
  - Non-comparable with other applications

The End

THANK YOU

Hy4Heat

Meters

Tony Goose

Pietro Fiorentini

A NEW METER FOR ALL NEEDS

Pietro Fiorentini

OUTLINE

- WHY HYDROGEN?
- ARE NATURAL GAS METERS ALSO SUITABLE FOR HYDROGEN?
- OUR APPROACH TO DEVELOPING THE HYDROGEN GAS METERS
- SOME INSIGHTS ON OUR DEVELOPMENT PROCESS

Pietro Fiorentini

OPPORTUNITY STATEMENT

OPPORTUNITY STATEMENT

PARIS AGREEMENT

- Hold the increase in the global average temperature below 1.5- 2 °C above pre-industrial levels
- Reduce CO_2 emissions

NET ZERO SOLUTION: USE OF HYDROGEN AS FUEL GAS

HOW IS HYDROGEN DIFFERENT FROM NATURAL GAS?

Pietro Fiorentini

OPPORTUNITY STATEMENT

HOW IS HYDROGEN DIFFERENT FROM NATURAL GAS?

Respect to Natural gas

- *1/8 Density*
- *1/3 Higher calorific value*
- *0.9 Wobbe index*

Pietro Fiorentini

OPPORTUNITY STATEMENT

HOW IS HYDROGEN DIFFERENT FROM NATURAL GAS?

Respect to Natural gas

- *1/8 Density*
- *1/3 Higher calorific value*
- *0.9 Wobbe index*

↓

CUSTOMERS NEED THREE TIMES FLOW RATE TO HAVE SAME ENERGY WITH HYDROGEN

Pietro Fiorentini

OPPORTUNITY STATEMENT

Pietro Fiorentini’s
Diaphgram Smart Meter "RSE"

Pietro Fiorentini’s
Ultrasonic Smart Meter "SSM-U4"

↔

NATURAL GAS

(EN 437, 2° Family)

Pietro Fiorentini

OPPORTUNITY STATEMENT

Pietro Fiorentini's
Diaphgram Smart Meter "RSE"

Pietro Fiorentini's
Ultrasonic Smart Meter "SSM-U4"

?

100% HYDROGEN

(EN 14687, Type I)

Can current gas meters work well with flow rates of Hydrogen?

No, something new should be made

Pietro Fiorentini

PIETRO FIORENTINI'S SOLUTION

PIETRO FIORENTINI'S PROPOSAL

ONE ULTRASONIC METER FOR BOTH GASES

NATURAL GAS

(EN 437, 2° Family)

100% HYDROGEN

(EN 14687, Type I)

Pietro Fiorentini

POSSIBLE EFFECTS OF PIETRO FIORENTINI'S SOLUTION

Based on our preliminary analysis and design,
we will realise a meter with this principle:

One meter & one installation

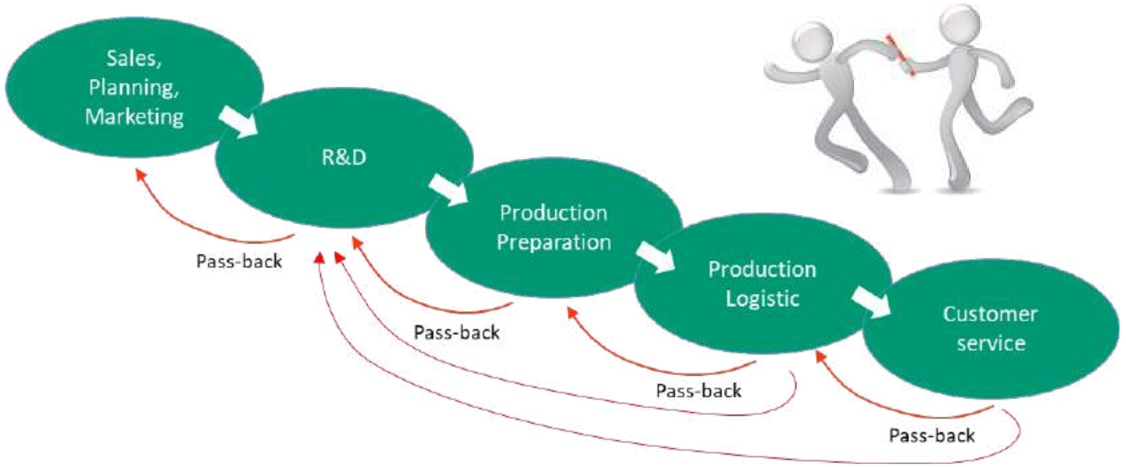
- ❑ You can switch between natural gas and 100% hydrogen (and backwards) if you want
- ❑ No additional intervention is required
- ❑ No firmware modifications after switching of gas

Pietro Fiorentini

PIETRO FIORENTINI'S DEVELOPMENT PROCESS

PIETRO FIORENTINI'S DEVELOPMENT PROCESS

~~Classic approach: PUSH to the customer with 'passing the baton'~~



PF's approach:

- Lean communication
- Continuous improving interactions on design and prototypes
- One point information (project manager, Visible planning)

- Faster development
- More attention on potential critical points
- More adaptability to market and customers' needs
- Exchange of knowledge within team

Pietro Fiorentini

Pietro Fiorentini

THANK YOU

Hy4Heat

Darren McNeil

MeteRSit

Hy4Heat stakeholder event
WP10 update and findings

March 9th, 2020

Abstract

Static gas meters and the transition to hydrogen

MeteRSit's approach: thermal-mass measurement

Differences with MeteRSit's natural gas meters

Next challenge: MID in absence of standards

Transition to H_2: opportunity for a static gas meter

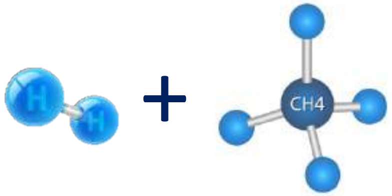
Hydrogen opportunity

Small sizes

- Approximately 3 times hydrogen flow is needed to convey the same energy of natural gas

- Inertia has little impact, no need to change meter size to measure hydrogen

Dual fuel gas meters possible



- No moving parts affected by different density / flow

- Dual gas:- for pure H_2 or blended with natural gas, easier to be realized

Future-proof

- Q_{start} can be set to very low values
- Native digital technologies

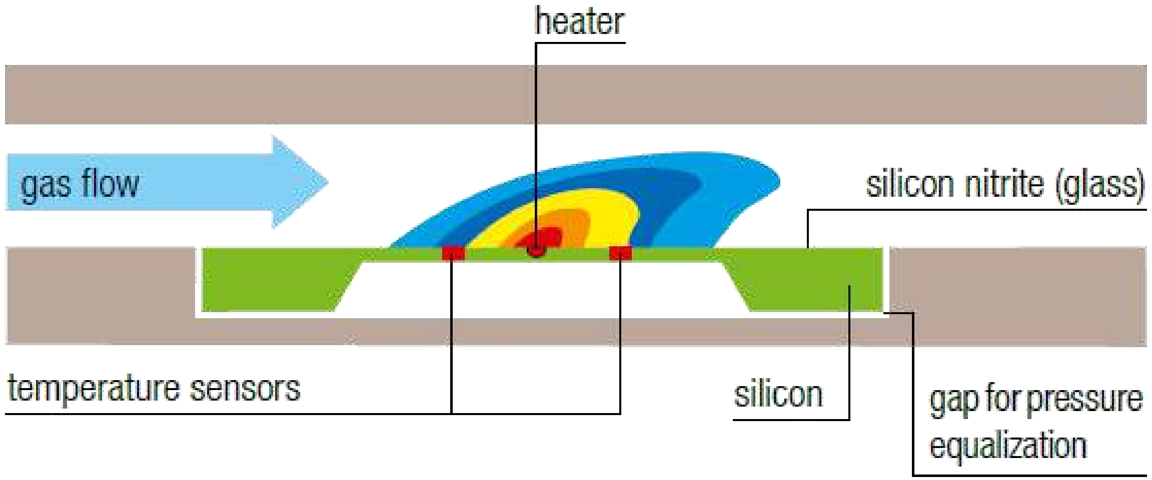
- Safety mechanisms based on leak detection can be implemented later on

MeteRSit's approach for natural gas and H_2: thermal-mass

Standard cubic metres

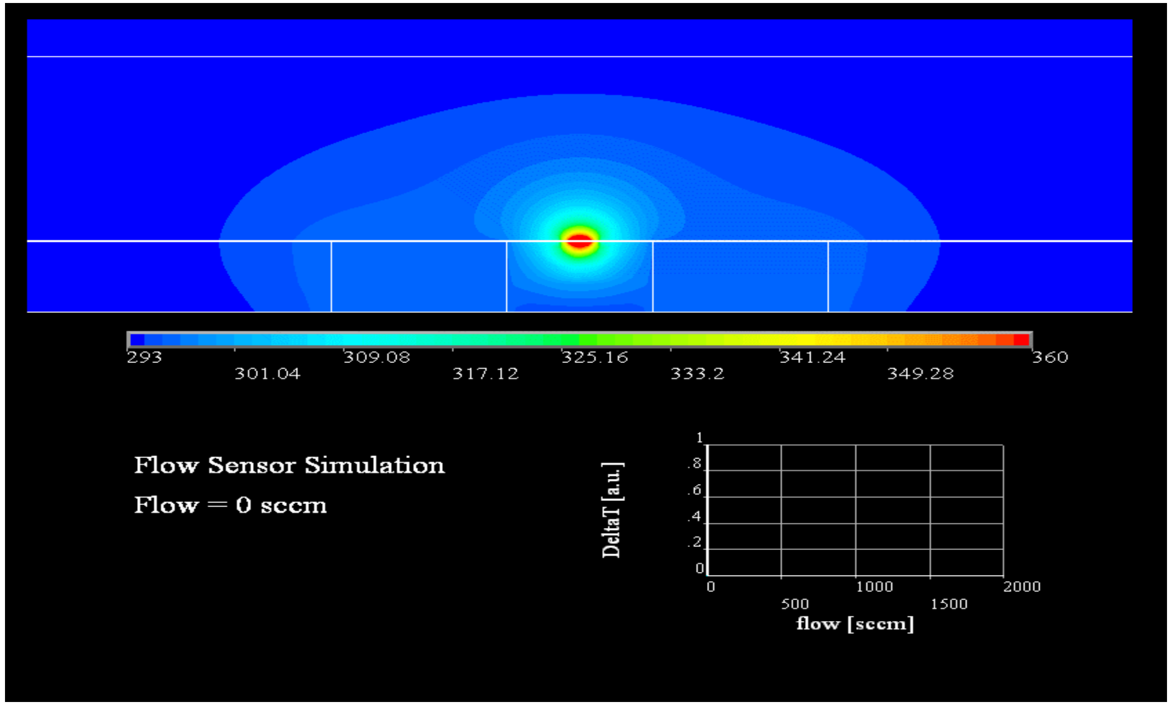
*The measurement principle is based on a **MEMS** "Micro Thermal Flow Sensing" technology:*

- *intrinsically **compensated in temperature***
- ***independent from pressure***
- *directly in **standard cubic metres***



Fluid mechanics helps

The differing fluid mechanical properties allow much higher hydrogen flow than natural gas flow to be measured with the same gas meter module size



Natural gas versus hydrogen meters

Dimensions and characteristics

- *MeteRSit’s Residential and I&C meters for hydrogen have:*
  - ✓ *The same dimensions as natural gas meters*
  - ✓ *Same sensor, different calibration*
  - ✓ *Very limited changes on materials*

Safety and SMETS2

- *Use of current MeteRSit SMETS2 electronics:*
  - – *RED and ZigBee certified*
  - – *CPA under finalization*
- *Ready for future safety mechanisms on SMETS2 specifications*

Next challenge: MID certification

No MID standards available

MeteRSit participates to the NEWGASMET EMPIR project on:*

Flow metering of renewable gases (biogas, biomethane, hydrogen, syngas and mixtures with natural gas)

Until 2021 <u>no outputs</u> are expected on:

- *Standards to be applied on renewable gases*
- *odorization for hydrogen*
- *colourants for hydrogen*

Different capacities for gas and air

For the first time it will be necessary to have, ***on the same meter, different capacities****:*

- *Residential meters*
  - ✓ *up to 6 m^3/h for natural gas / air*
  - ✓ *up to 20 m^3/h for hydrogen*
- *I&C meters*
  - ✓ *up to 40 m^3/h for natural gas / air*
  - ✓ *up to 120 m^3/h for hydrogen*

**EMPIR is the main programme for <u>European research on metrology</u>*

Thank you for your attention

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Panel Discussion

To ask a question use 'slido' or put your hand up

Join at: **slido.com**
Event Code: #Hy4Heat

wifi: CHW-guest

pass: Westminster1

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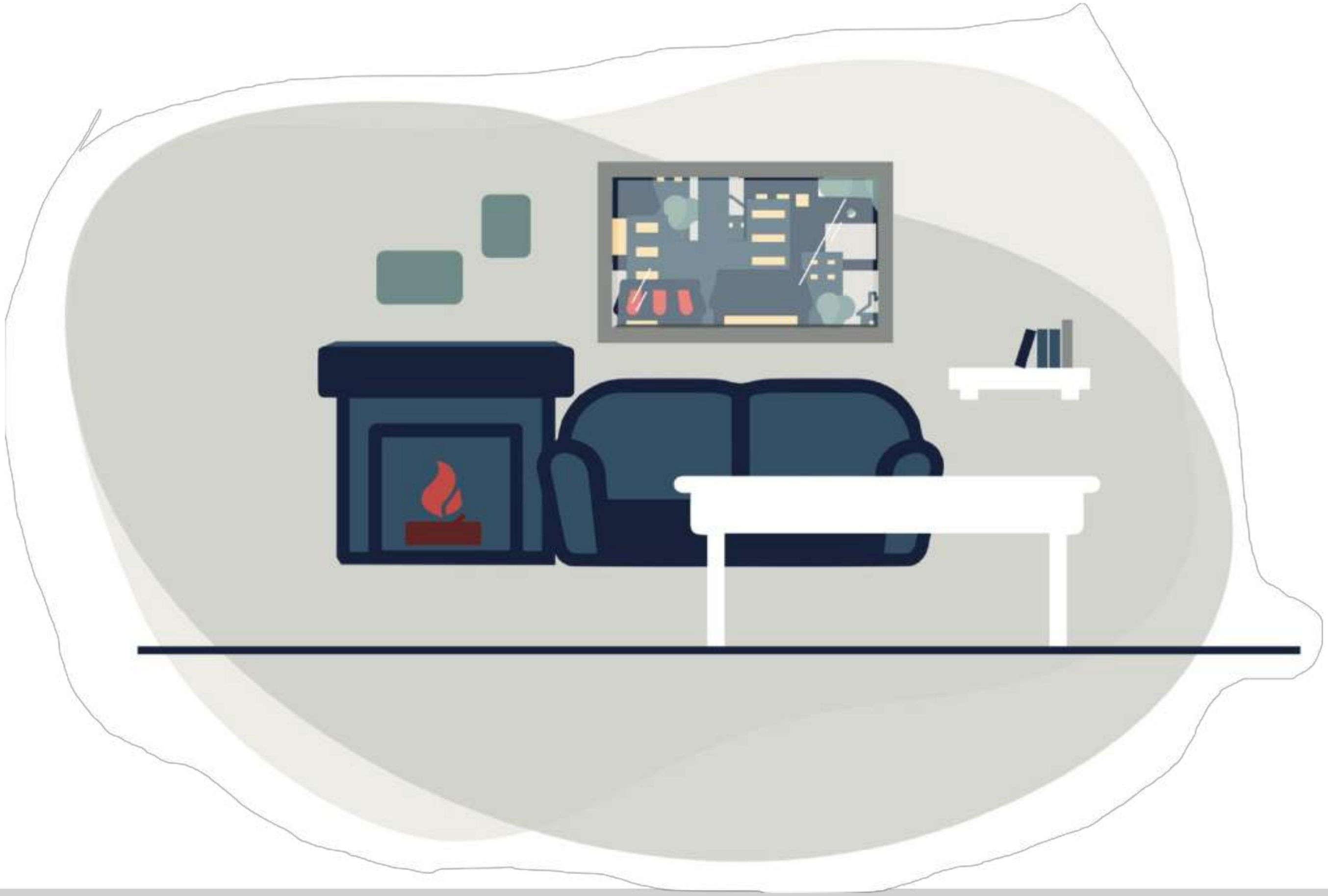
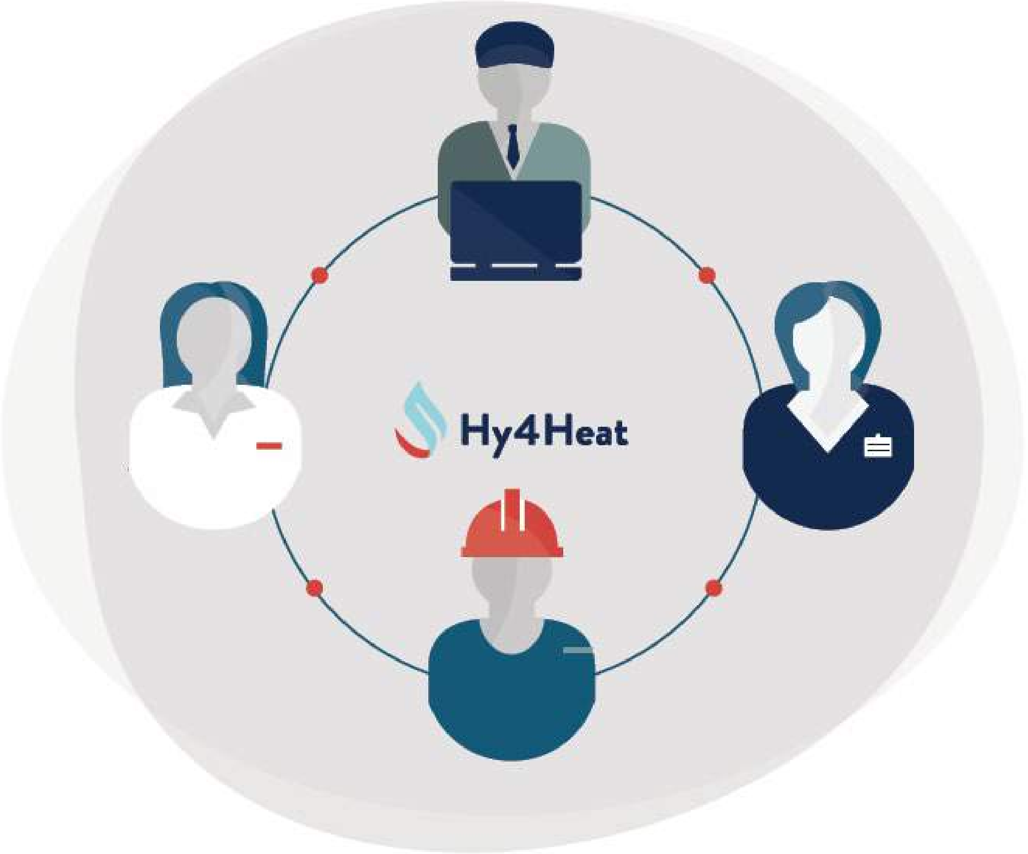
Continue Engagement: Display Facilities



Networking lunch



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