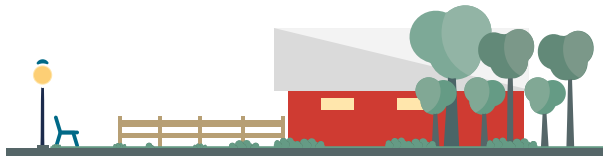


Hy4Heat Progress Report

DECEMBER 2019



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Foreword from Mark Taylor

The Hy4Heat innovation programme continues to go from strength to strength throughout its second year. I'm delighted to see the range of prototype hydrogen devices currently under development, such as boilers, cookers and fires and I'm very much looking forward to seeing them demonstrated and displayed next year.

The programme has engaged and stimulated the wider industry to play its part in supporting this decarbonisation study. It's encouraging to see collaborative work taking place across our community to deliver gas and appliance standards alongside developing and assessing the evidence on issues such as odorant and colourant. I've also been encouraged by co-operation across the industry with safety work to develop a qualitative risk assessment being supported by gas distribution network operators' collecting and providing frontline field data. As you'd expect, we are heavily engaged with the Health and Safety Executive on the programme and look forward to demonstrating what the programme has achieved in Work Package 8.

It's fair to say there is no one solution to the UK's biggest energy challenge of decarbonising heat. Many innovative solutions will likely have a role to play as transformation happens to products, systems and processes across the various pathway options: energy efficiency and storage solutions, carbon capture and use, fuel pumps, heat networks, nuclear technology, and hydrogen gas as a replacement for methane. The £25m Hy4Heat programme is an important part of the £505m BEIS Energy Innovation Programme which aims to accelerate the commercialisation of innovative cheap, clean, and reliable energy technologies by the mid-2020s and 2030s.

Other projects that the Energy Innovation Programme has helped support this year consist of over £35m investment in carbon capture utilisation and storage (CCUS) including the UK's largest carbon capture unit of 40,000 tonnes in Tata Chemicals and a further 13 projects in our Hydrogen Supply competition. If we are to become a net zero emissions economy and end our contribution towards global warming, then innovative schemes like Tata Chemicals will

be essential. The recent announcement of the £100m Low Carbon Hydrogen Fund further signifies the UK government's commitment to developing the hydrogen economy and facilitating the option of deploying hydrogen to decarbonise domestic heat.

Achieving net-zero is necessary to tackle the climate emergency that faces us. The Hy4Heat feasibility study into whether it's possible to de-risk the use of hydrogen in buildings will provide evidence to assist policy makers taking decisions about what pathways are best adopted to decarbonise heating to deliver on our net-zero commitments.



Mark Taylor
Deputy Director for Energy Innovation
Science and Innovation for Climate and Energy
BEIS

There is no one solution to the UK's biggest energy challenge of decarbonising heat. Many innovative solutions will likely have a role to play



Letter from Mark Neller

The second year for Hy4Heat has continued apace and I'm grateful for the hard work of the programme team and board, as well as the advisory panel, hydrogen co-ordination group and wider supplier team colleagues for ensuring that momentum has been maintained. There are now around 40 contracts in place, and this is a reflection of the positive response from the industry to play a part in this innovation programme.

The delivery phase of the programme is well underway with standards for using hydrogen being established by industry bodies and insight reports into commercial and industrial applications nearing completion. I'm particularly pleased that hydrogen domestic appliances are in development and nearing prototype stage. And also that a number of contracts for commercial appliance development have recently been awarded.

The safety assessment is a key part of the Hy4Heat programme and contracts have

been issued to suppliers to conduct a range of comparative experimental tests, using both natural gas and hydrogen, simulating scenarios found in domestic environments to quantify the relative risk of using hydrogen versus natural gas. The results, as well as information from the gas distribution network operators, will feed into a quantitative risk assessment (QRA) that Arup + will be undertaking.

Our aim is to demonstrate that with the correct procedures, safety features and competent individuals, replacing methane with hydrogen doesn't increase the risk to the public.

We have a structured process agreed with the HSE and will be working through this next year.

I'm encouraged by how much progress we've made over the past year, but there is still a great deal to do. Next year we aim to demonstrate the prototype hydrogen appliances to a wider industry audience and will be researching people's responses. In the past year our

stakeholder numbers have doubled, to 600, but we've reached many more when speaking at industry events and conferences and through our website.

In early 2020 we will be holding a large stakeholder engagement event where we will present the programme's work so far, and discuss the possible wider implications of the study for the industry and the UK's decarbonisation requirements.

I'm encouraged by how much progress we've made over the past year, but there is still a great deal to do. Next year we aim to demonstrate the prototype hydrogen appliances to a wider industry audience.



Mark Neller,
Director Arup, Hy4Heat



The programme is structured to ensure there are single points of accountability and clear lines of responsibility as well as providing as much support and oversight as needed. The programme's success is reliant on collaboration between different parts of the energy industry, academia, the commercial sector and regulating bodies.

Our Mission

Our Mission is 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 enable the government to determine whether to proceed to a community trial.

About Us

The Department for Business, Energy & Industrial Strategy, BEIS, has appointed Arup to be the Programme Manager for the Hy4Heat programme. Arup has joined with technical and industry specialists: Kiwa Gastec, Progressive Energy, Embers and Yo Energy, and together the team oversees the programme and technical management of all the work packages.

Hy4Heat is exploring whether replacing natural gas (methane) with hydrogen for domestic heating and cooking is feasible and could be part of a potential pathway to help meet heat decarbonisation targets. To do this the programme is seeking to provide the technical, performance, usability and safety evidence to demonstrate whether hydrogen can be used for heat in buildings.

The main advantage of hydrogen is that it does not release carbon dioxide during combustion, unlike methane and other hydrocarbons.

In May this year, the government committed to reduce greenhouse gas emissions in the UK by 100% of 1990 levels by 2050, making it the first of the G7 group of industrialised nations to legislate for net zero emissions. The net-zero target meets the UK's obligations under the Paris Agreement and responds to the need for action highlighted by the United Nations' Intergovernmental Panel on Climate Change (IPCC) in last year's Special Report* on 1.5°C of global warming.

Heat decarbonisation is an important part of achieving net-zero. There are range of low carbon heating technologies with potential to support heat decarbonisation but, at present, it is not clear which will work best at scale. BEIS is working with industry and other stakeholders to build understanding of the different approaches, to prepare for decisions in the first half of the next decade about the long-term future of heat. Hydrogen gas as a replacement for methane is just one of several routes that BEIS is considering to decarbonise heat - others include, for example: electrification, electric heat pumps, heat networks, carbon capture and use, and biomass.

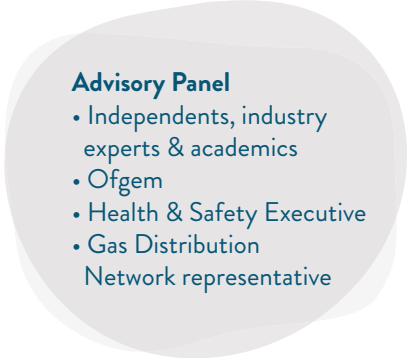
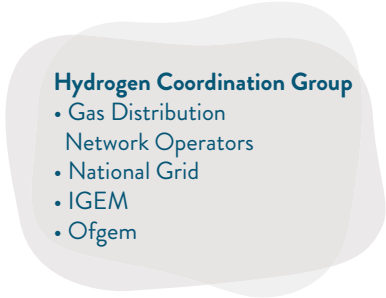
*IPCC, 2018: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

Hy4Heat Programme Governance Structure

It's essential for the Hy4Heat programme that there are clear lines of responsibility and that the organisation structure in place provides as much support and oversight as needed.

This diagram also outlines the important relationships with key industry stakeholders and emphasises the collaborative nature of the programme.

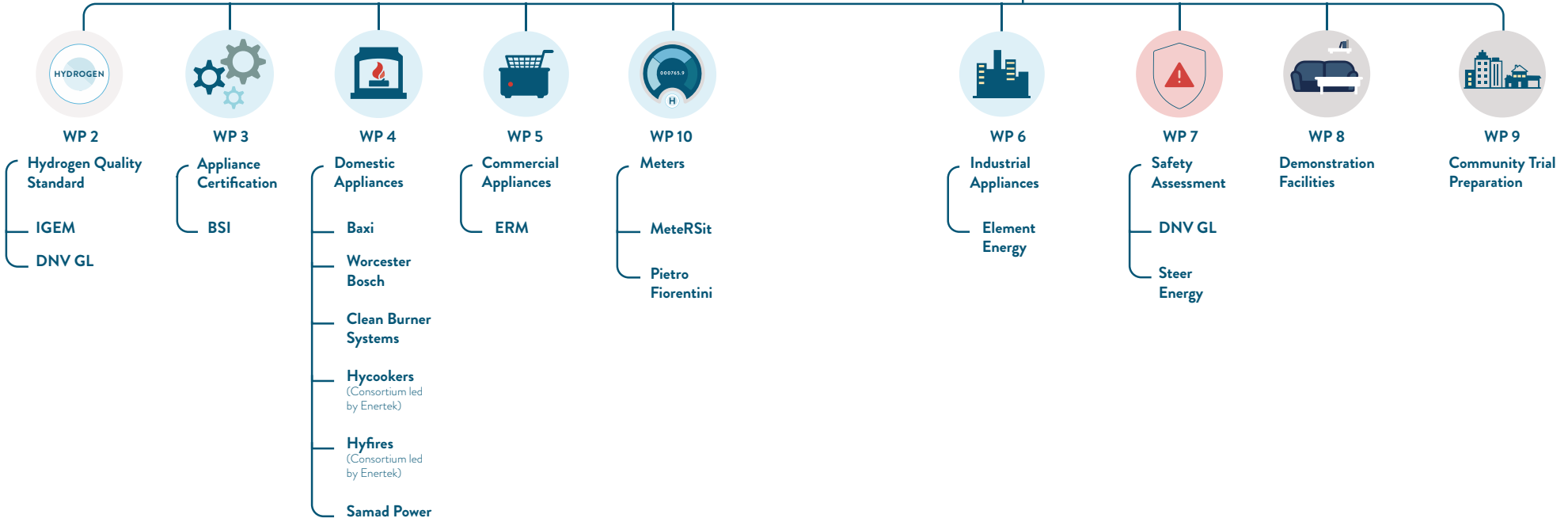
The suppliers, contractors and subcontractors who are undertaking the various work packages are the main deliverers of the programme's output.



Department for Business, Energy & Industrial Strategy

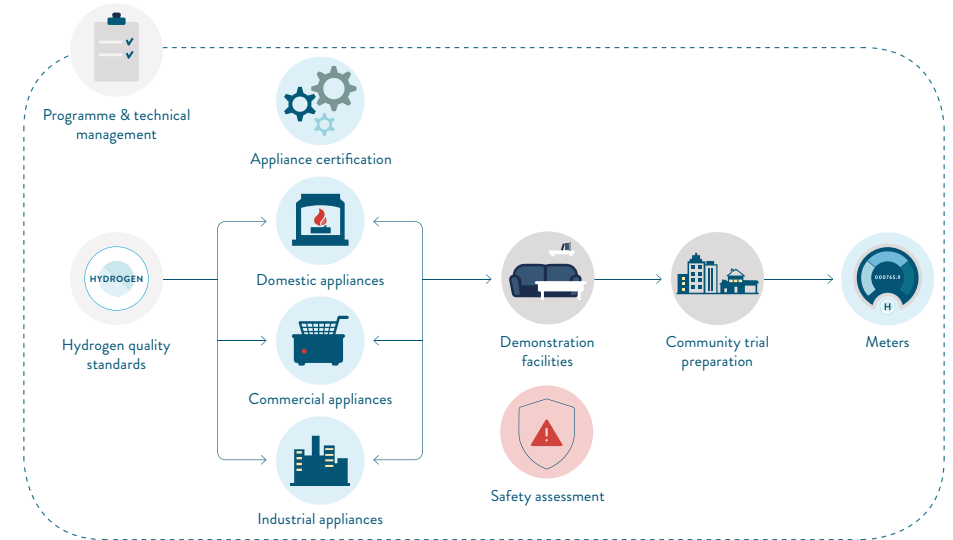
Hy4Heat
demonstrating hydrogen for heat

ARUP+



Work Package Overview

The Hy4Heat team oversees the programme and technical management of all the other various, interdependent, work packages. Work package 1 is the programme management and oversight of all the other workstreams.



WORK PACKAGE 1

WP1 is the programme management and oversight of all the other workstreams.



WORK PACKAGE 2

Hydrogen gas and IGEM standards; defining the purity of the gas and the colourant and odorant that may be required.



WORK PACKAGE 3

Hydrogen appliance certification of a new generation of appliances. A new publicly available standard PAS4444 Hydrogen Gas Appliances gives guidance on developing and testing of hydrogen appliances.



WORK PACKAGE 4

Development of domestic hydrogen appliances: including gas fires, cookers, boilers and innovative hydrogen appliances.



WORK PACKAGE 5

WP5a is research into the variety of commercial appliances and the issues to be addressed in their conversion or replacement with hydrogen appliances. WP5b is the development of a number of commercial appliances.



WORK PACKAGE 6

Research into the variety of industrial appliances and the issues to be addressed in their conversion or replacement with hydrogen appliances.



WORK PACKAGE 7

Safety experimental testing related to hydrogen in properties, such as ventilation and leakage detection. A quantitative risk assessment (QRA) and consequence assessment will support the overall safety assessment.



WORK PACKAGE 8

Establishing moveable and fixed demonstration facilities for newly developed hydrogen appliances and devices.



WORK PACKAGE 9

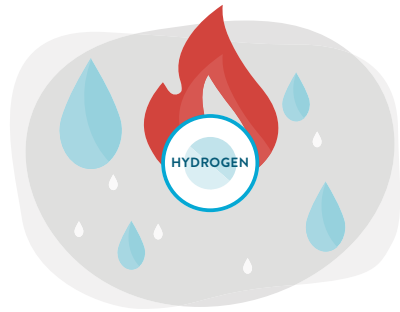
Planning and preparation for a potential community trial using hydrogen, if BEIS decides to progress to community trial stage.



WORK PACKAGE 10

Development of smart hydrogen gas meters.

Hydrogen Quality Standards



A Hydrogen Purity Standards Report has been published by DNV GL with support from NPL, HSL, Element Energy and Loughborough University. It makes a recommendation for a hydrogen purity standard to be used by manufacturers developing prototype hydrogen appliances and during their subsequent demonstration, as part of the Hy4Heat programme. The report will help to close one of the critical evidence gaps identified in work for the Hy4Heat programme, being coordinated by the Institution of Gas Engineers and Managers (IGEM), to develop a hydrogen standard.

The report makes a recommendation for a hydrogen purity level with the aim that it is reasonable and practicable and considers implications related to hydrogen production, the gas network and cost. It covers the purity of hydrogen that is made available for the end user, including the concentration of other gases and the inclusion of odorants and colourants. It recommends a minimum hydrogen purity level of 98%, as well as maximum levels for other likely trace components.

DNV GL is currently drafting a Hydrogen Colourant Report considering the flame colourant requirements for hydrogen to ensure safe burning and user acceptance.

Highlight dates

2018

- 12 March 2018 PIN published
- 15 June 2018 ITT published
- 8 October 2018 IGEM appointed to develop new hydrogen standards
- 20 October 2018 DNV GL appointed to conduct studies into purity and colourant of hydrogen gas

2019

- 21 May 2019 DNV GL present work on purity and colourant to WP4 appliance developers
- 24 July 2019 Hydrogen Purity Standard report presented at IGEM
- December 2019 Hydrogen Purity Standard report published

Hydrogen Appliance Certification



Early industry engagement concluded that hydrogen appliances are to be certified under GAR (Gas Appliance Regulation). These regulations will be aimed at providing guidance on the testing and certification of hydrogen gas appliances for notified bodies and appliance manufacturers. A survey of UK and EU notified bodies and test houses established that a dedicated Hy4Heat programme test house was not required and appliance developers would use their usual facilities.

BSI is developing a new publicly available standard, PAS 4444 in collaboration with industry stakeholders. PAS4444 is to be used primarily on the Hy4Heat programme but the aim is that it can form the basis for widescale standardisation of hydrogen-fuelled appliances. It will be a guide to be followed by appliance manufacturers and others regarding functionality, safety, installation, operating and servicing requirements for their hydrogen-fuelled and hydrogen/natural gas dual-fuelled or converted appliances.

Highlight dates

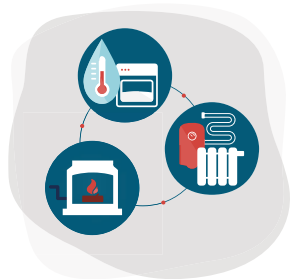
2018

- 30 April 2018, Notified Bodies and Test Labs in UK and EU surveyed
- 7 August 2018, Domestic appliance certification engagement event
- 30 November 2018 BSI awarded contract

2019

- 14 May 2019 PAS4444 draft presentation given to WP4 appliance developers
- 2 December 2019 PAS4444 published for consultation

Domestic Hydrogen Gas Appliances



This work package is the development of domestic hydrogen appliances to demonstrate the safe use of hydrogen as a fuel in providing domestic heating, hot water and cooking requirements. It aims to provide critical evidence of end use application, safety, emissions, efficiency and functionality.

Some of the appliances have been developed to be 'hydrogen-ready'. This is to assist the potential switchover of appliances from using natural gas to hydrogen.

The objectives of this work package are to:

- Deliver prototype appliances which can demonstrate safe use of hydrogen as a fuel in providing domestic heating, hot water and cooking requirements
- Contribute to positive stakeholder engagement through use of the prototype appliances in the unoccupied demonstrations (WP8)
- Understand, and where feasible address, the challenges and risks associated with progressing the appliances to a volume manufacturing stage
- Understand the challenges and potential solutions for a transition to hydrogen including products that simplify the switch-over process, for example dual-fuel, hydrogen-ready, or adaptable

Highlight dates

2018

- 15 June, hydrogen appliance stakeholder engagement event
- 31 August, ITT for SBRI competition published
- 31 August, online webinar to support applications
- 9 November, successful applicants notified
- 26 November, guidance document for phase 1 issued

2019

- 8 February, clarification questions answered and published ahead of phase 1 report submissions
- 15 February, phase 1 submissions completed
- 29 April, phase 2a guidance note issued
- 14 May, phase 2a Kick-off stakeholder event held

Phase 1 reported on technical detail of the proposed appliances, market demand and timescales to delivering.

Phase 2a is underway now and is the development of prototype appliances for use in demonstrations from spring 2020. A number of organisations are currently in the process of developing prototype appliances for demonstrations in 2020.

The appliance types include:

- Boilers (combi and regular/system)
- Cookers (stand-alone hob, integrated freestanding cooker)
- Fires (standard, mid-range, executive)
- Innovative gas appliance.

The appliances under development should aim to be comparable or better than the natural gas products being replaced in terms of NO_x and efficiency. As with all products using flammable gas, manufacturers are required to provide details of risks associated with the use of hydrogen as a fuel and describe how the design of the product mitigates these.

Phase 2b, in 2020, will be the further development of the prototype appliances to be consumer ready and fully certified to be used in an occupied home and provide plans for the potential upscaling of construction and manufacture.

WORK PACKAGE 10

Hydrogen Smart Meters



Pietro Fiorentini and MeteRSit are the organisations, appointed by BEIS, to develop hydrogen smart meters (SMETS2) for the Hy4Heat programme. The aim of work package 10 is to provide critical evidence on the feasibility of producing fiscal hydrogen smart meters within the space constraints of current meters. They will also include an excess flow valve (EFV) to automatically restrict the gas if needed.

The plan is for these meters to be demonstrated in work package 8.

Highlight dates

2018

- 14 December, Engagement event for potential manufacturers

2019

- 28 March, ITT published
- 31 July, Two companies appointed to develop meters

WORK PACKAGE 5

Commercial Appliances



Work package 5 is in two parts.

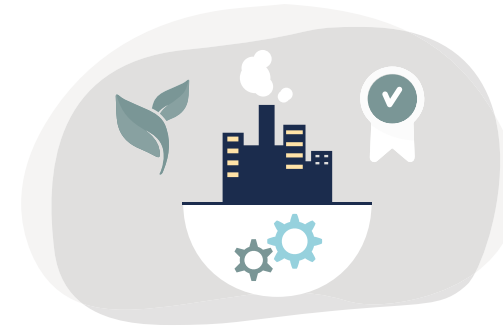
The first **Work Package 5a** is a report on commercial sector appliances considering the implications of converting commercial sector appliances from natural gas to hydrogen. The report has considered the existing market and identified any knowledge gaps and barriers to conversion that may need to be addressed.

Work package 5b, is the development of commercial appliances. An engagement session was held in May 2019 to bring together commercial manufacturers and also other interested parties to discuss the development of a number of commercial hydrogen gas appliances. BEIS is appointing contractors to develop a number of commercial appliances:

- Lot 1: Catering and production heating
(e.g. chargrill, griddle, hob, fryer etc)
 - Production heating
(e.g. cremation furnace and bunsen burner)
- Lot 2: Dry space heating
(e.g. fired heaters, radiant heaters, unit air heaters)
- Lot 3: Wet space heating
(e.g. boiler cascade)
- Lot 4: Combined heat and power
(e.g. heat led CHP unit)

WORK PACKAGE 6

Industrial Appliances



A draft version of Understanding Industrial Appliances report has been presented by authors Element Energy, Jacobs Consulting and Cardiff University.

The aim of the study is to investigate issues relating to potential future conversion of industry from natural gas to full hydrogen for heat. Constraints to be analysed include those around safety, functionality and cost of hydrogen conversion and use in industry. The study also documents knowledge gaps and proposes necessary trials and appliance development work.

The report will provide a comprehensive understanding of applications of hydrogen for heat in industry, including costs, technical and commercial requirements, timeframes, barriers and opportunities.

Highlight dates

2018

- 25 May, PIN published for understanding commercial and industrial appliances
- 26 July, ITT published for understanding commercial and industrial appliances
- 11 October, ERM (Environmental Resources Management) appointed to produce a research report on commercial sector appliances

2019

- 21 May, WP5b commercial appliance engagement event
- 2 August, WP5b ITT published

Highlight dates

2018

- 25 May PIN published for understanding commercial and industrial appliances
- 26 July, ITT published for understanding commercial and industrial appliances
- 15 October, Element Energy awarded contract to write research report on understanding industrial appliances

2019

- 10 April, understanding industrial appliances presentation and workshop

Safety Assessment



This is a key work package of the Hy4Heat programme. It focuses on assessing the safe use of hydrogen gas in domestic properties and buildings. This includes, for example, gas leakage accumulation and ventilation of gas releases in different enclosed spaces within a typical domestic property.

Experimental testing is being undertaken to support the safety assessment, and information from GDNOs is also being collated to support this work. This information will then feed into the quantitative risk assessment (QRA) and consequence assessment to support the overall safety assessment. Arup will be undertaking the QRA which is a formal and systematic risk analysis approach to quantifying the risks associated with the use of hydrogen for heating and cooking in domestic properties and buildings.

This year BEIS has appointed DNV GL and Steer Energy to conduct a range of comparative experimental tests, using both natural gas and hydrogen, that simulate scenarios found in domestic environments to quantify the relative risk of using hydrogen versus natural gas - as part of demonstrating and de-risking the use of hydrogen for heating in UK homes and businesses. The Health and Safety Executive is engaged with the programme and will be providing independent review and scrutiny.

Highlight dates

2019

- 13 March, ITT published
- 5 June, experimental testing contractors appointed

Steer Energy will undertake experimental testing:

- Research and evidence gathering to compare the fitness for purpose of fittings and general pipework within a typical domestic property for both hydrogen and natural gas

DNV GL will undertake experimental testing:

- Research and evidence gathering to compare the movement and accumulation of both hydrogen and natural gas:
 - within confined spaces within a typical domestic property
 - of leaked gas within a typical domestic two-storey property with a cellar and loft conversion
- And research and evidence gathering to compare
 - the ignition risk from different gas concentrations for both hydrogen and natural gas

Demonstration Facilities



BEIS is looking to appoint contractors to develop demonstration facilities to show hydrogen appliances. An engagement event was held to bring together appliance developers, marketing and creative agencies, hydrogen experts and other interested parties to discuss the kind of facilities that could be used to demonstrate the hydrogen gas appliances developed under the Hy4Heat programme.

To encourage engagement we are aiming to display the appliances in domestic 'showroom' settings to display to the wider energy industry audience (beyond appliance developers and those directly involved in the Hy4Heat programme) the appliances developed to use hydrogen. These fixed and movable facilities will display the newly developed appliances within the context of the hydrogen decarbonisation pathway and provide an opportunity to gather stakeholder feedback regarding the acceptability of appliances and people's views about the potential of using hydrogen for heating and cooking.

We're aiming to demonstrate appliances at COP26 in Glasgow, November 2020.

Highlight dates

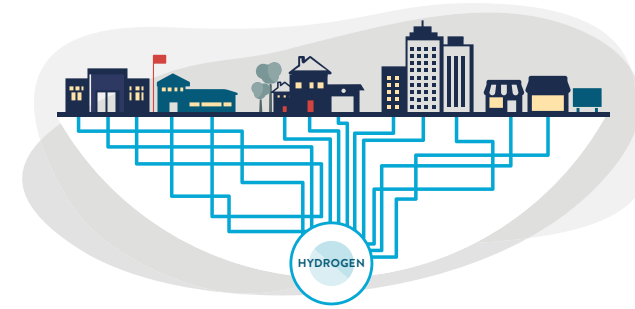
2018

- 14 August, appliance manufacturers surveyed about access to testing facilities

2019

- 20 September, PIN published
- 30 October, Stakeholder engagement event held

Potential Community Trials



Any community trial, if BEIS decides to progress to this stage, will take place after the Hy4Heat programme is finished.

Market research has begun to inform the development of work package 9 and to assess the potential issues associated with setting-up a community hydrogen trial. As well as a review of the current studies, literature and reports relating to community energy trials, a small number of focus groups have been held with members of the public. These four focus groups, with sets of approximately eight to ten people in each, discussed how willing they would be to participating in a community trial, and considered what barriers and challenges would be faced and how they could possibly be overcome.

Highlight dates

2019

- 5 & 6 November, focus groups

Engaging and Communicating with Stakeholders

Since the beginning of the Hy4Heat programme we have endeavoured to ensure industry stakeholders have been given the opportunity to assist shape the work and have been informed and consulted every step of the way.

We identified stakeholders as any individual or group that:

- May have influence, or may be decision makers
- May have information and/or resources needed
- Could be affected by the programme's delivery or outputs
- Has a general interest in the programme

At the start we established a formal stakeholder advisory panel with independent and industry experts as well as academics, Ofgem, the HSE and representatives from gas distribution network operators. This group meets quarterly and acts as a sounding board, giving comments and suggestions on technical and general issues, as well as providing independent scrutiny and challenge.

In 2018 the group recommended that we create a website, and this has since become one of our most important information resource centres as well as a means to engage a wider stakeholder audience. Good engagement is rooted in effective communication and we now have some well established channels to share updates and get feedback through emails, social media, surveys, face to face meetings and presentations.

The principles behind our stakeholder engagement activity are to:

- Engage collaboratively
- Encourage knowledge sharing and collaboration
- Be transparent and clear in our communications
- Maintain a consistent and fair representation of the programme
- Use channels that are inclusive and accessible
- Track, measure and report on our engagement communications

In late 2017 the programme could identify some 60 individuals outside the delivery team who'd expressed an interest in the Hy4Heat programme. A couple of years later and this number has increased tenfold to some 600 people from approximately 400 organisations, who've signed-up to receive regular updates about the programme. We engage with this group through quarterly newsletters, website updates, industry presentations and engagement events.

Our aim is to encourage early involvement with relevant stakeholders to inform the planning, design and success criteria of the programme's work packages. In May 2019 we held an engagement event with commercial appliance manufacturers and trade body representatives ahead of a WP5b ITT being published for commercial appliance and component development.

In October we held an engagement with creative agencies, market research organisations, touring exhibition experts and other stakeholders to inform them of our requirements for hydrogen

appliance demonstration facilities and to seek their guidance and suggestions on how best to achieve them.

Early next year, 2020, we will be holding a large stakeholder engagement event to provide an update on the programme as well as create a space to hear other people's views and provide industry networking opportunities.

Companies and organisations that are part of Hy4Heat

- Almaas Technologies
- Arup
- Baxi Heating UK
- BEIS
- Birmingham Burners (Walsall) Ltd
- British Standards Institute
- Brunel University
- Cardiff University
- Charlton & Jenrick
- Clean Burner Systems Limited
- COMBAT
- DNV GL
- Element Energy
- Embers
- Enertek International Ltd
- Facultatieve Technologies
- Falcon Food Service
- Focal Point Fires
- Gazco
- Glen Dimplex Home Appliances
- Health and Safety Laboratory
- Institution of Gas Engineers & Managers
- Jacobs
- KIWA
- Legend Fires
- Loughborough University
- MeterSit
- National Physics Laboratory
- Nortek Ltd
- Parry Catering
- Pietro Fiorentini
- Powmatic
- Progressive Energy
- Rexaloy Burners
- Samad Power Ltd
- SolidPower
- Steer Energy
- Teddington Controls
- University of Leeds
- Valor Fires
- Worcester Bosch
- Worgas
- Yo Energy

Hy4Heat Progress Key Dates

- 10 December 2018 Hy4Heat presented at COP24 in Katowice, Poland
- 20 December 2018 First Hy4Heat annual progress report published
- 30 January 2019 BSI confirms that the Hydrogen Appliances Standard will be PAS4444 (WP3)
- 13 March 2019 ITT for safety assessments for the suitability of hydrogen in existing buildings (WP7)
- 28 March 2019 ITT for developing Hydrogen smart meters (WP10)
- 14 May 2019 Phase 2 kick off for domestic hydrogen gas appliance (WP4)
- 21 May 2019 Commercial appliance engagement event (WP5)
- 4 June 2019 DNV GL and Steer Energy appointed as contractors for safety assessments (WP7)
- 24 July 2019 Hydrogen purity report presented at IGEM house (WP2)
- 31 July 2019 Contractors appointed for development of hydrogen smart meters (WP10)
- 2 August 2019 ITT for commercial hydrogen appliances published (WP5b)
- 20 September 2019 PIN published for the provision of hydrogen appliance demonstration showrooms (WP8a)
- 30 October 2019 Stakeholder engagement event for demonstration showrooms (WP8a)
- 7 December, Presentation at the 2019 United Nations Framework Convention on Climate Change COP25



www.Hy4Heat.info
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