Department for
Energy Security
& Net Zero

Hy4Heat Evaluation

Annex B: Case Studies of International Hydrogen for Heating Programmes

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Department for
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& Net Zero

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Introduction

As part of the scoping stage of the evaluation, a review of publicly available information was carried out to scope the extent to which other international programmes are developing similar technologies as the Hy4Heat programme. The main aims of the review were to; a) assess whether Hy4Heat is unique in developing First-of-a-Kind hydrogen heating appliances and b) identify programmes with similar technology aims which may provide opportunities for transferable learning for Hy4Heat implementation or to inform policy development on the next phase of developing community trials.

Annex A: Evaluation Plan and Methods describes the methods used to undertake the review. In summary, the search criteria used for the scoping stage review resulted in an inventory list of 41 hydrogen R&D programmes. From this long-list, a short-list of three programmes were identified for case studies. The case study programmes were selected on the basis of having; more than 2 topics of relevance to Hy4Heat (relating to technology development aims), relatively large budget size and the depth/ ambition of the research of the project/programme. The DESNZ client team then reviewed a draft list of proposed case studies to advise on which were most relevant for providing transferable learning.

The scoping stage review suggested that Hy4Heat is unique in that it deals with multiple interlinked topics in an iterative and holistic way. No other programme was identified which is addressing the same set of work packages. However, the case study programmes contain strands of R&D that are relevant to certain aims of Hy4Heat, including; development of domestic hydrogen boilers, safety tests, development of product standards and work to design community level trials, which may feed in relevant learning on the next phase of community trial design. Three international programmes which were shortlisted for case studies are:

- Rozenburg Power-to-Gas Demonstratieproject – led by the Netherlands Gas Network Operator, Stedin
- Testing Hydrogen Admixture for Gas Applications (THyGA) project - led by the EU Horizon 2020 funded ‘Fuel Cells and Hydrogen Joint Undertaking (FCH JU)’
- German Hydrogen Power Storage and Solution East Germany (HYPOS) programme: H2-netz and H2-Home.

The remainder of this Annex provides case studies of these programmes. Each case study gives an overview of:

- The programme or project objectives
- The structure of the project – how it is funded, who the delivery partners are and timescales for completion
- Project outcomes – what outcomes have been achieved to date and are expected in future
- Key learning from the project – identification of areas of transferable learning to inform implementation of Hy4Heat or the next phase of community trial design.

Rozenburg Power to Gas project

The Power to Gas project is being undertaken in Rozenburg in the Netherlands[1]. The project has been running since 2013 and has been delivered in two phases, with the second phase ongoing. The project involves Research and Development and demonstration activities involving hydrogen blended with natural gas and using 100 percent hydrogen to supply heat to a residential apartment building.

Project objectives

The Power to Gas project has been delivered in two phases. The objectives of the first phase were to:

- Develop technical guidance and procedures for a Power to Gas process;[2]
- Construct and test a Power to Gas system; and
- Demonstrate the Power to Gas system in a realistic environment (converting hydrogen into synthetic (methane) gas and connecting this to an apartment building to supply gas).

The second phase of the project had the following objectives:

- Develop boilers which can use 100 percent hydrogen gas (opposed to boilers using natural gas)
- Utilise the guidance and Power to Gas systems developed in the first phase to produce hydrogen from renewable energy
- Demonstrate the Power to Gas system, using 100 percent hydrogen works in a realistic environment - supplying 100 percent hydrogen gas via a pipe to an apartment building using the newly developed hydrogen boiler. One centrally located boiler provides gas to the entire apartment building (e.g., a heat network system, rather than locating boilers within individual apartments for control by residents)
- Develop odorant for Hydrogen gas.

An overarching objective of the project is social responsibility. It aims to generate and utilise energy at the lowest possible societal costs – which includes the economic cost of production and the environmental impact of generating and using the energy.

[1] https://www.bdrthermeagroup.com/en/stories/first-real-life-application-of-a-hydrogen-boiler-in-the-world

[2] A Power to Gas process involves using electricity to decompose water molecules into hydrogen and oxygen, and then utilising the hydrogen either by blending it into natural gas or using the 100 percent hydrogen generated as a power source.

Structure of the project

Funding

Both phases of the project were privately funded by the Netherlands Gas Network Operator, Stedin, and TKI gas. Therefore, no information about the total cost of the Power to Gas project is available.

Delivery partners

Eight organisations were involved in the delivery of the Power to Gas project. These were:

- Stedin, the Gas Network Operator for the Netherlands, which led and funded the project.
- DNV GL, a multi-national company which provides services in the oil, gas, and renewable energy sectors. DNV GL were the lead delivery partner for the first phase of the project, and led in defining the technical design and control guidelines, validating the chosen technology and safeguarding the safety, system and gas-quality requirements.
- TKI Gas, an organisation which promotes innovative approaches to energy systems, and provided some funding for the programme
- Ressort Wonen, a housing cooperative which made an apartment block (and end users) available for the project
- The municipality of Rotterdam, a city authority in the Netherlands, which made land available to implement the project and have been involved in the project delivery
- Bekaert, an engineering company which was involved in the development of hydrogen ready boilers
- BDR Thermea Group, an engineering company which was involved in the development of hydrogen ready boilers
- Gasterra, an engineering company which was involved in the development of hydrogen ready boilers.

Project timeline

The first phase of the Power to Gas project began in 2013. The demonstration of the Power to Gas system (using the system to provide blended gas to an apartment block) began in late 2014. The second phase of the project began in late 2018. The development of the hydrogen ready boilers has been completed and the demonstration of heat supply in an apartment block began in summer 2020 and is ongoing.

Project outcomes

Outcomes achieved

The key outcomes that have been achieved by the programme have been:

- The production of technical guidance and procedures to generate green hydrogen (and synthetic methane) from water and to utilise this in a residential setting for heating. This guidance and documents covered the end-to-end process of the Power to Gas system (from production to end use). This included the generation of electricity from solar panels, utilising this energy to create hydrogen and synthetic methane gas, the transfer of the gas to an apartment building and the use of the gas to heat homes via boilers
- Successfully demonstrating that the Power to Gas system can be utilised in a residential setting on a continuous basis, using synthetic methane. The synthetic methane produced and used in the trial complied with the specifications that apply to the Dutch gas grid, suggesting this process could be used on a wider scale
- A boiler which utilises 100 percent hydrogen gas developed and put into use in a residential block. This is currently being used in the demonstration project using 100 percent hydrogen. This is seen as a world leading development for the project, to have a hydrogen boiler being used in a residential setting. The boiler has a different specification and functional purpose to the boilers developed through Hy4Heat. The boiler developed to heat the apartment block in Rozenburg is located within a central room in the basement and provides heat to the entire building (a heat network). It was not designed to be located within individual apartments or to be controlled separately by residents.

Planned future outcomes

The remaining outcomes which are to be achieved by the project are:

- Successful completion of the demonstrator trial for utilising 100 percent hydrogen in a residential setting. The demonstration is planned to continue until 2023, to ensure that customer feedback on using hydrogen, and data on the efficiency of the trial can be collected and analysed, to form conclusions around the effectiveness of the trial.
- Odoration – the programme is also undertaking research to add an odorant to hydrogen, to ensure individuals are aware of any leak. This work is intended to be completed by 2023.

Key learning from the project

The technical findings from the conversion of electricity into hydrogen and oxygen demonstrated that the Power to Gas system was 47 percent efficient. The remainder of the energy - in the form of heat - could not be used locally by the system or the apartment block. The entire Power-to-Gas system can be started up from standstill to maximum capacity in approximately 40 minutes for the synthetic gas. This suggests that the approach is feasible to support the delivery of power to an apartment block.

The main area of potential learning is around the development of a hydrogen boiler to supply heating to an apartment block. The first phase of community trials in the UK (a neighbourhood trial) are expected to include detached, semi-detached and terraced houses where individual boilers may be installed. The safety assessment in Hy4Heat focused on the use of boilers within these types of housing. If potential future trials in the UK include apartment buildings, the prototype central heat network boiler developed through the Power to Gas project offers another potential solution. The project is also expected to provide evidence on the safety of using a hydrogen boiler within an apartment block.

Testing Hydrogen Admixtures for Gas Appliances (ThyGa)

The Testing Hydrogen Admixtures for Gas Appliances (ThyGa) project aims to develop and communicate a detailed understanding of the impact of different blends of natural gas and hydrogen on end-use applications in the domestic and commercial sector. It is being delivered by organisations from across Europe, funded through the European Commission Horizon 2020 programme, via the 'Fuel Cells and Hydrogen Joint Undertaking (FCH JU)[3]'.

This project aims to support the wide adoption of hydrogen and natural gas (H2/NG) blends by closing knowledge gaps regarding technical impacts on residential and commercial gas appliances.

The project has six work packages (or strands of research). These are:

- Work Package 1: Coordination and project management
- Work Package 2: Exploration of the impact of the status quo of gas utilisation technologies, which explores the impact of introducing hydrogen blends on existing appliances
- Work Package 3: Experimental work involving testing hydrogen blended gas on existing appliances
- Work Package 4: Impact on the current certification and standardisation framework and addressing the issues, which involves reviewing the existing certifications and standards and identifying how these will need to be altered
- Work Package 5: Recommendations for mitigation procedures – involving identifying and testing mitigating procedures
- Work Package 6: Communication, Dissemination and exploitation. Disseminating the findings of the research to relevant audiences.

Project objectives

The objectives of the THyGA project are to:

- Evaluate the portfolio of technologies in the domestic and commercial sectors and assess the theoretical impact of hydrogen / natural gas admixture in order to determine a quantitative segmentation of the gas appliance market and a selection of the most adequate products to be tested

[3] The FCH JU was established by a European Council Regulation in 2008 as a public-private partnership between the European Commission, European industry and research organisations to accelerate the development and deployment of fuel cell and hydrogen technologies.

- Test up to 100 existing residential and commercial gas appliances in 40 different segments (hobs, boilers, micro-CHP, heat pumps, etc.), which will give information on how European gas appliances will react to various H2 concentrations
- Benchmark and develop pre-certification protocols for different levels of H2 in natural gas for integration in existing standards; these protocols will be validated through tests
- Provide recommendations for manufacturers, decision-makers and end-users along the gas value chain to enable mitigation strategies for retrofit.

The expected impacts of the project include:

- Establishing the maximal concentration hydrogen admixture that can be implemented in the domestic and commercial sector without changing the existing certification of appliances
- Establishing how the existing certification shall be modified to allow higher concentrations, including the related additional costs and the required changes to common gas burners
- Recommendations for revision of European standards (EN) or international ISO standards or drafting of new ones, and a review of the existing testing methods
- Improved knowledge on the effect of hydrogen and natural gas on common burner types including necessary adjustments and design changes.

Structure of the project

Funding

The total budget for the ThyGa project is €2.5 million. It is fully funded through the European Commission Horizon 2020 programme, via the 'Fuel Cells and Hydrogen Joint Undertaking (FCH JU)'.[4]

Delivery partners

The project is coordinated by Engie, with nine consortium partners including research centres, industrial partners, SMEs, and trade associations, which cover the entire value chain. The key delivery partners for the project are:

- ENGIE - a global energy and services group, with global networks and a focus on low-carbon energy. ENGIE are leading the THyGA project and are involved in delivering R&D activities and coordinating the other delivery partners.
- BDR Therma group - a European manufacturer of domestic and industrial heating appliances. They are involved in are involved in delivering R&D activities.
- The CEA (Commissariat à l'Energie Atomique et aux Energies Renouvelables) - a French public government-funded research organisation in the areas of energy, defense

[4] The FCH JU was established by a European Council Regulation in 2008 as a public-private partnership between the European Commission, European industry and research organisations to accelerate the development and deployment of fuel cell and hydrogen technologies.

and security, information technologies and health technologies. They are involved in are involved in delivering R&D activities.

- DGC (Dansk Gasteknisk Center) - a Danish specialist consulting and development company in the energy and environment sector. DGC are providing laboratory testing for the experimental work of the project.
- DVGW-EBI – the research team within the German Technical and Scientific Association for Gas and Water. Their role includes exploring the safe and environment friendly processing, distribution and application of natural gas, and testing, surveying and certifying.
- Electralux – a global leader in the home appliance market. They are involved in are involved in delivering R&D activities.
- GAS.BE - a Belgian association promoting the use of natural and renewable gas. Gas.be are evaluating the impact of H2NG blends on current certification and standardisation networks.
- GERG - the European Gas Research Group, is a non-profit international research association, with a membership of European gas companies. GERG are contributing towards the knowledge management and dissemination of the project.
- GWI (Gaswarme-Insitut Essen) - a German research institute focusing on appliance technology, fuel engineering, industrial engineering and combustion technology. GWI are leading the research into the impacts of maintaining the status quo of gas utilisation technologies.

Project timeline

The programme began in January 2020. It is expected to have a duration of three years (to 2023). Some of the activities have been slightly delayed by the Covid-19 pandemic (for example difficulties in staff accessing labs), but these delays are not anticipated to delay the final end date of the project.

At the time of writing, Work Package 2 had been completed, and the project was currently delivering Work Packages 3 and 4. Subsequent Work Packages are yet to be delivered.

Project outcomes

Outcomes achieved

The project has delivered some key deliverables so far, mainly in Work Package 2. These have been a complete market segmentation of domestic and commercial natural gas appliances in the EU (with over 225 million appliances excluding catering equipment), which showed that nearly all of these appliances (87 percent) were boilers and domestic cookers. A technical report demonstrating the impact of hydrogen blends on the combustion temperatures, and velocities, pollutant formation and safety aspects. The findings from the research suggest that in general, hydrogen-natural gas blends are a viable option to decarbonise the combustion processes in a variety of settings, and that some existing technologies may be used up to certain hydrogen levels without causing safety risks. A process has also been developed to

test the 100 appliances to explore in practice how adding hydrogen to natural gas affects the performance of appliances.

The project has also provided the first deliverable under Work Package 4, which describes the current certification and testing standardisation framework for residential and commercial appliances covered by Regulation (EU) 2016/426. It also identifies the way this framework is impacted by adding hydrogen to natural gas.

A further outcome which has been achieved is bringing together expertise from across Europe and disseminating information. The programme has run a series of workshops and webinars to discuss key topics relevant to the project, with hundreds of participants from across Europe attending these events.

Planned future outcomes

The planned future outcomes of the project are to test the selected 100 appliances to confirm the theories around the effect of introducing hydrogen blends to confirm the combustion and safety findings from Work Package 2. Further outcomes are expected around the standardisation and certification Work Package.

Key learning from the project

The key learning from the project delivery so far has been that introducing blends of hydrogen is theoretically feasible and safe for residential appliances. This will deliver environmental benefits in the form of reductions in pollutants. With over 225 gas appliances in use in Europe, introducing hydrogen blends has the potential to deliver significant environmental benefits.

There is potential for learning to be shared between the ThyGa and the Hy4Heat programmes. The ThyGa project is undertaking research into the standards and certification required to utilise hydrogen in residential settings, which the Hy4Heat programme has already explored in the UK and contributed towards European wide standards. Additionally, there is potential for learning to be shared between the projects due to the prototype development undertaken for the Hy4Heat programme and the appliance testing being undertaken for the ThyGa project.

HYPOS programme

As part of the wider HYPOS programme (Hydrogen Power Storage & Solutions) in Germany, two projects ‘H2-netz’ and ‘H2-home’ are specifically focussing on the decarbonisation of heating with hydrogen[5]. HYPOS is a programme that comprises more than 100 companies, scientific institutes and research institutions from all over Germany and has been funded by the Federal Ministry of Education and Research for over five years as part of the "Twenty20" programme (also funded by the German Ministry of Education and Research). The H2-netz and H2-home projects involve Research and Development activities relating to using 100 percent hydrogen.

The project has not yet disseminated its findings. This is due to the academic nature of the project - peer reviewed reports or journal articles have not yet been published. It is currently uncertain when findings will become available.

Project objectives

- Development and implementation of a distribution network infrastructure with house connection lines for a green hydrogen supply
- Testing through the pilot supply of the planned test site hydrogen “village".
    - The aim of H2-Home is the development and demonstration of an integrative system for the supply of electrical and thermal energy for apartment buildings and commercial facilities using a hydrogen Combined Heat and Power unit (CHP). The hydrogen “village” is a demonstration facility, rather than a trial with occupied residential buildings
- Qualification of high-density plastic pipelines for the distribution network structure and for indoor installations
- Consideration of higher pressures in combination with plastic pipe systems with optimal sustainability, supply reliability, security and efficiency
- Definition and testing of required safety technology identification of an odorant suitable for hydrogen
- Technical and economic evaluation of the overall system using a simulation model
- Derivation of optimization potential for the design, construction and operation of the systems as well as for materials and components.

[5] https://www.hypos-eastgermany.de/en/the-goals-of-the-project/hypos-projects/transportation-and-storage/h2-netz/

Structure of the project

Funding

The total budget for the HYPOS project is €5.3 million. The majority of the funding H2-netz strand (€3.8 million, 72 percent), with €1.5 million for the H2-Home strand (28 percent). The majority of funding (55 percent in total, with 47 percent for the H2-netz strand and 74 percent for the H2-Home strand) came from grant funding. The grant funding was provided by the German Ministry of Education and Research as part of the "Twenty20" programme. The remaining funding comes from match-funding from the participating organisations.

Delivery partners

There are more than 100 companies, scientific institutes and research institutions from all over Germany involved in the delivery of the project. Key delivery partners for H2 Netz include:

- DBI GUT – a research institute in the energy/gas sector.
- HTWK – a research institute specialising in applied sciences
- MITNETZ Gas - a regional gas distribution network operator in Germany
- REHAU – A large, global polymer engineering company
- TUV SUD – a company involved in the delivery of testing, certification, auditing and advisory services.

Key delivery partners for H2-Home include:

- DBI GUT – a research institute in the energy/gas sector
- Fraunhofer IMWS – a research institute with a specialism in hydrogen research
- Technische Universitat Bergakademie Freiberg - a research institute specialising in applied sciences
- Inhouse engineering – an engineering firm specialising in energy management and fuel cell CHP
- Enasys – a multinational company with expertise in energy supply.

Project timeline

The project was anticipated to have a duration of 40 months, running from September 2016 to January 2020. The H2 Home project ran from September 2016 to September 2018 and the H2-netz project ran from November 2016 to January 2020. The project is now completed.

Project outcomes

Outcomes achieved

There is limited information available about the outcomes that the project has achieved, due to the academic nature of the research of the research. However, from the evidence available from the project website[6], and an interview with project leads during the scoping stage of the evaluation, it appears that the following outcomes have been achieved:

- The H2-home project has successfully developed a combined heat and power unit consisting of a fuel cell (5 kWel / 14 kWth), which is being deployed in the hydrogen "village" demonstrator buildings
- The H2-netz project has delivered a demonstrator hydrogen "village" using 100 percent hydrogen which is currently in operation. This "village" was constructed and operationalised in the Bitterfeld-Wolfen chemical park in a 12,000 square meters test field. This "village" simulated the distribution of hydrogen to the connection to demonstration buildings. The overall "village" system comprises the hydrogen pipelines from which the hydrogen is taken to a combined power and heating unit, and then connected to H2-Homes (demonstration buildings, not occupied by residents)
- The "village" testing also included testing the feasibility of using high-density polyethylene pipelines for the distribution network. This has included safety testing of the network
- The testing has also included adding odorants to the hydrogen gas. Three alternatives were tested, with the odour from two odorants considered too similar to natural gas. The most appropriate odorant was considered to be Scentinel® E Gas Odorant, which contains sulphur and was considered as the most appropriate in H2-Netz because of its availability and relatively low cost. The sulphur is filtrated before the hydrogen enters the fuel cell-based CHP unit.

Key learning from the project

The lack of publicly available evidence for this project means obtaining key learning from the project was challenging. However, from the evidence available, the key learning would seem to be that it has been feasible to develop a CHP unit which runs using pure hydrogen, and, subject to the findings from the hydrogen "village" site, this is safe and feasible to use in a residential building setting.

Hy4Heat has developed prototype hydrogen gas boilers for use within individual residential homes. The H2-Netz and H2-Home projects have developed a central hydrogen CHP unit that can provide heat and power to demonstration apartment buildings. The first phase of community trials in the UK (a neighbourhood trial) are expected to include detached, semi-detached and terraced houses where individual boilers may be installed. If potential future trials in the UK include apartment buildings, the central CHP heat network technology developed through the H2-Netz and H2-Homes projects offer another potential solution.

[6] https://www.hypos-eastgermany.de/en/the-goals-of-the-project/hypos-projects/transportation-and-storage/h2-netz/

Another finding from the H2-netz project appears to be that the project has identified a suitable odorant to use for hydrogen, and, subject to findings from the hydrogen “village” demonstrator, a solution for the type of pipes required to transport hydrogen safely around the network has been identified.

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