UK HSE HYDROGEN FOR HEATING EVIDENCE REVIEW PROCESS

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ABSTRACT

As part of the UK Government's Net Zero targets to tackle Climate Change, the Health and Safety Executive (HSE) aims to reach an authoritative view on the safety of using 100% hydrogen for heating across the UK, to feed into Government policy decisions by the mid-2020s. This paper describes the background and process of a programme of work led by HSE in support of the Department for Energy Security and Net Zero (formerly BEIS) that will inform strategic policy decisions by 2026. The strategic framework of HSE's programme of work was defined between BEIS and HSE.

HSE's programme of work follows on from a previous project which engaged with HSE policy, regulatory and scientific colleagues working with industry stakeholders identifying knowledge gaps for the safe distribution, storage and use of hydrogen gas in domestic, industrial, and commercial premises. These knowledge gaps were subsequently used in discussions with stakeholders to prioritise research projects and evidence gathering exercises.

To review this scientific evidence, HSE developed a review framework and convened Evidence Review Groups (ERGs) to cover all evidence areas, encompassing topics such as quantified risk assessment, material compatibility and operational procedures. These ERGs include representation from relevant divisions across HSE (policy, regulation and science).

The paper explains the structure of HSE's input into the hydrogen for heating programme, the ERG process and timelines, along with the proposed outputs. Additional activities have been undertaken by HSE within the programme to highlight specific issues in support of the review process, which will also be discussed.

1.0 INTRODUCTION

As part of the UK Government's Net Zero targets to tackle Climate Change, the Health and Safety Executive (HSE) aims to reach an authoritative view on the safety of using 100% hydrogen for heating across the UK, to feed into Government policy decisions by the mid-2020s. This paper describes the background and process of a programme of work led by HSE in support of the Department for Energy Security and Net Zero (formerly BEIS) that will inform strategic policy decisions by 2026. The strategic framework of the programme was defined between BEIS and HSE.

Heat in buildings is one of the biggest sources of greenhouse gas emissions in the UK, accounting for 23% of total UK emissions.

As set out in the Energy White Paper[1] the Government believes that low carbon hydrogen may have the potential to offer a strategic option for decarbonising heat in buildings alongside heat pumps and heat networks. However, unlike other technologies, 100% hydrogen for heating is not yet an established technology. Further work is required to understand the feasibility, costs and convenience of transporting 100% hydrogen in the gas grid and using hydrogen for heating and cooking. Further details about the potential role of hydrogen in decarbonising our energy system and the commitments from government to facilitate this can be found in the UK Hydrogen Strategy[2].

[1] Energy white paper: Powering our net zero future - GOV.UK (www.gov.uk)
[2] UK hydrogen strategy (accessible HTML version) - GOV.UK (www.gov.uk)

The UK gas distribution network is split into several geographical regions run by separate gas distribution network companies (GDNs). The GDNs are working together with the Department for Energy Security and Net Zero and HSE to produce the evidence needed for safe operation. The main operators in the UK are:

- Cadent
- Northern Gas Networks (NGN)
- SGN
- Wales & West Utilities (WWU)
- National Gas Transmission [transmission system operator]

Working together, the UK Government and industry have developed a programme of research to identify and fill knowledge gaps.

HSE is the independent regulator for workplace health and safety. A key role of HSE is to enable the safe adoption of new technologies, taking account of potential risks to those who will build, operate and maintain the facilities and any risks to the public arising from these activities. HSE applies its specialist operational, regulatory, policy and scientific expertise to the safety evidence presented by many different industries.

HSE has a long experience of assessing high pressure gas distribution pipelines for hazardous substances advice and of regulating the low-pressure distribution system under the Gas Safety (Management) Regulations 1996 (GSMR). HSE is also the regulator for storage and industrial production of hydrogen under the Control of Major Accident Hazard 2015 (COMAH) regulations. In support of this and commercial customers, HSE's Science Division has developed considerable expertise particularly in fire and explosion hazards.

2.0 SAFETY DEMONSTRATION PROJECT

An initial project [4] was carried out between the Department for Energy Security and Net Zero and HSE. The objectives of this project were to consider the evidence HSE would need to see to provide an 'authoritative view' on the safety of converting the natural gas network to hydrogen.

A structured questionnaire was developed to prompt input from HSE specialists to determine and provide an initial framework on the key demonstrations HSE would expect to see before a hydrogen trial or policy decision progresses. This covered technical questions that needed answering for evidence, policy position and necessary regulation and capabilities. Additional questions covered public engagement as well as competence and capability across industry.

This project consolidated the separate but overlapping sets of safety considerations which HSE would expect to be relevant to a decision to proceed to trial, or wider rollout.

The safety considerations were grouped under the following topics, and the list of questions was then mapped against them, with supporting explanation and known relevant projects at the time.

- System Architecture
- Network Suitability (Materials & Components)
- Risk Assessment
- Capability & Training
- Policy & Regulation
- Conversion Strategy
- Public Behaviour
- Risk Controls
- Standards and Procedures

3.0 EVIDENCE REVIEW PROCESS

The safety consideration documents provided the basis for a multi-year programme of work between HSE and the now Department for Energy Security and Net Zero. This is part of a wider programme of research and development to build the evidence base needed to inform a Government policy decision in 2026 on the potential roll out of hydrogen for heat and gas grid conversion.

This will include assessing the evidence and regulatory framework required for the safe distribution, storage and use of hydrogen gas in domestic, industrial and commercial premises, and contribute to policy proposals for nationwide implementation.

The key objectives of HSE's involvement in the programme are:

1. Evidence: safety evidence and analysis is collated and assessed in time to feed into interim and final decisions, and in the most efficient way possible. This includes ensuring all significant issues are identified and understood as early as possible. Key conclusions and recommendations are articulated with sufficient clarity and authority to enable decision-making
2. Trials: trials can go ahead as planned, with duty holders, ministers, Government and the public confident that they will be run safely. Trials are designed to build on existing safety evidence to inform policy decisions,
3. Future regulation: there is sufficient knowledge and understanding of how the safety of hydrogen heating would be regulated post-conversion, with sufficient preparatory research undertaken to inform decisions and potential regulatory amendments; and keep all options including timely roll out on the table.
4. Communications: All key external audiences understand what the safety evidence tells us and have confidence in it.

HSE is now utilising expertise across the organisation, engaging with key stakeholders and working with industry and the Department for Energy Security and Net Zero to guide the development of an appropriate evidence base, including supporting the programme through regulatory oversight of hydrogen trials.

The outcome of HSE's programme of work is subject to industry and stakeholder participation, financial, resource and time constraints.

The overall systems in scope of this programme consists of:

Production and Storage

- Production is not in scope of this work, but elements do arise in the review
- Storage in salt caverns
- Storage in above ground installations

Distribution and Transmission

- National transmission system (NTS)
- Local transmission system (LTS)
- Storage in line pack (currently for natural gas)
- Compressor stations, running on hydrogen

End use

- Normal residential housing
- Complex residential housing
- Commercial
- Industrial

3.1 Evidence Review Groups

In order to undertake the review of evidence required for hydrogen trials and policy decision, HSE have created a structure for the peer review of evidence by topic area, by creating nine 'Evidence Review Groups' (ERGs), each with members from HSE's science, regulatory and policy divisions.

Some HSE scientists have previous experience of working on hydrogen research projects separately from this programme of work, which puts HSE in a strong position to understand the issues. Reviewer independence is maintained from specific research projects while evidence is being assessed.

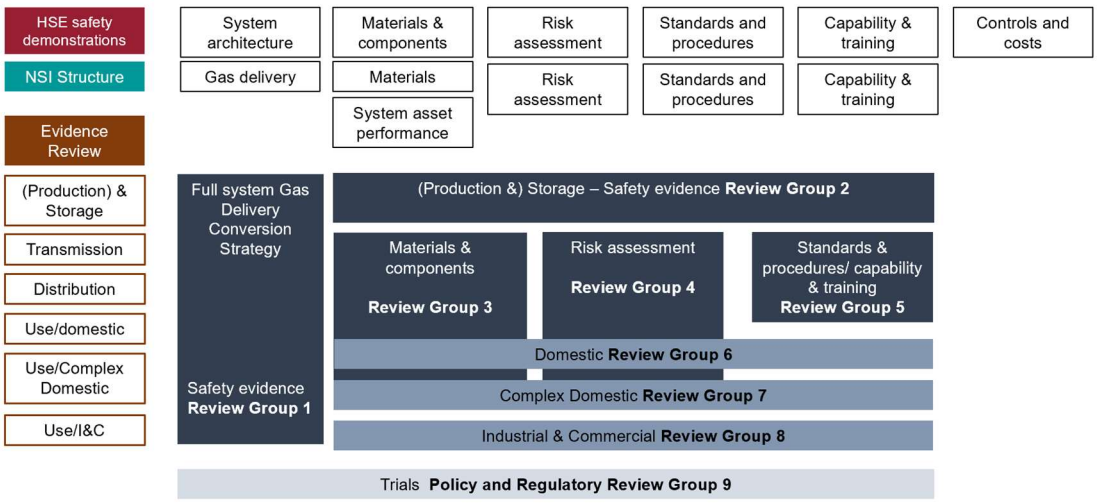

Figure 1 Evidence Review Group Structure

In Figure 1, 'HSE safety demonstrations' outlines the key evidence areas identified in HSE's initial review. 'NSI Structure (Network Safety and Impacts Board Structure)' maps these evidence areas against areas identified by the industry board set up to deliver evidence on hydrogen. Evidence areas are also mapped against corresponding ERGs.

ERGs are based around topic areas and provide a forum and structure for HSE to provide technical input into the HHP. Groups review and provide expert advice on the quality of evidence, and any further technical questions that require review, covering the following:

1. Full system gas delivery conversion strategy: The management of the actual process of changing from supplying natural gas to hydrogen and the potential safety impact on consumers.
2. (Production) and storage: The safety impacts of increased use of hydrogen storage at a variety of quantities and type of storage site.
3. Materials and components: The impact of hydrogen on the materials and components within the existing system which will be repurposed, how these will perform, long-term degradation and failure mechanisms. Additionally, considering suitable materials for new parts of the system and any existing components which may need replacing.
4. Risk assessment: The processes for identifying and assessing the risks of hazards in the new hydrogen environment; the demonstration of risk in people's homes will be particularly critical.
5. Standards and procedures / capability and training: What is needed to ensure a competent workforce, including the need to upskill existing workers or train new workers, training material and assurance processes, and ensuring suitably robust standards are developed for all aspects of the system. This group should consider the number of resources that will be required not only to safely operate and maintain the system but also during the conversion process.
6. Domestic: The impact of hydrogen use in domestic settings, including downstream use and impact on domestic appliances.
7. Complex domestic: Safety impacts of hydrogen use in complex domestic settings such as multiple occupancy buildings. This group will need to coordinate with HSE's Building Safety Regulator.
8. Industrial and commercial: Particular safety considerations which may not be relevant for domestic and complex domestic settings, but arise within industrial and commercial sites, including downstream and non-domestic appliances.
9. Trials (Policy and regulatory group): HSE's regulatory approach to upcoming hydrogen trials, and assessment of safety evidence submitted to HSE in relation to trials (particularly H100[3] and the Village Trial[4]).

HSE and BEIS have also established two joint working groups to 1) track and consider costs and controls that will be needed throughout the system to ensure safety, and 2) consider how a potential hydrogen roll out will be regulated, including developing recommendations for any potential regulatory amendments. No formal consultation on regulatory changes will begin before a policy decision is made.

ERG membership represents policy, regulatory and scientific disciplines within HSE. A number of individuals with relevant experience and knowledge have been identified, including a lead for each ERG from the respective membership pools.

Each ERG has a lead who assists coordination in the assessment of submissions, and responsibilities including to:

[3] https://www.sgn.co.uk/H100Fife, accessed 31 March 2023.
[4] https://www.ofgem.gov.uk/sites/default/files/2022-05/Hydrogen%20Village%20Trial%20Detailed%20Designs%20-%20Decision1651664774599.pdf, accessed 31 March 2023

- Provide a lead point of contact for allocated ERG for enquiries, overview of work being undertaken and acknowledgement of evidence commissioned.
- Coordinate the review of evidence packages submitted to allocated ERG, ensuring the correct resource is involved.
- Liaise with other ERG leads where evidence submissions cut across multiple ERGs.

3.2 Evidence Submission and Review Process

Industry can submit relevant safety evidence to be reviewed and a completed cover sheet that includes questions on the scope of the safety evidence including what safety demonstrations it seeks to demonstrate, and the quality assurance process it has been through.

Evidence may be submitted to ERGs at three stages of progress:

1. Pre-project Stage - HSE provides feedback on the scope of an evidence project before it begins, including the suitability of the project proposal to answer outstanding safety questions.
2. Project ongoing - HSE provides feedback on the progress of an evidence project as it develops, if there are questions key to its progress/ finalisation, including comments on any critical outcomes.
3. Project complete - HSE reviews evidence conclusions and provides assessed status on how far the project closes evidence gaps or raises further questions.

HSE completes a preliminary QA process to establish which ERGs the submission is relevant for, and the status of the evidence (whether it is being scoped, in progress, or completed).

Industry can also indicate any key dependencies which may impact how quickly the evidence needs to be reviewed (i.e. if HSE feedback will help inform further work that is due to take place).

Evidence will then be considered by the Technical Group (chaired by HSE and attended by Department for Energy Security and Net Zero), processed and planned into relevant ERG work plans. Industry will be notified once the preliminary and full reviews are complete.

Once ERGs have been assigned, evidence authors are invited to present to the ERG members on the evidence submission. This meeting allows for initial questions to be answered before the review begins, and initial discussions to take place.

ERG members then review evidence pieces, including a check-point meeting to discuss whether any immediate issues have been identified or other reviewers need to be included.

Industry are then given feedback against the evidence submitted to the groups. Comments and questions are scored to indicate the scale of issues to industry. Once this feedback is shared with industry, a further meeting is held to discuss feedback, allow industry to ask any questions, and to determine whether they wish to submit any evidence in response to the questions and comments provided.

Given this is a new process for HSE and industry and as it is unclear how much evidence will be received in different areas, it is challenging for HSE to provide a timeline in which industry can expect feedback. HSE will review timelines as the review process is established and will prioritise work, considering interdependencies shared by industry and the Department for Energy Security and Net Zero.

Evidence is expected to be submitted to HSE from across the GDNs, commissioned consultancies, and directly from the Department of Energy Security and Net Zero. HSE tracks these evidence submissions against an agreed timeline, including tracking delays.

HSE has agreed to accept evidence for consideration until September 2024. Any evidence submitted past this date will not be considered within the final assessment due to be completed by March 2025.

3.4 Support projects

A number of projects have been carried out in parallel to the review process to support the review and some of the identified issues. These include:

1. Stakeholder mapping – An exercise was undertaken to develop a list of relevant existing and future stakeholders and duty holders. Other stakeholders may be sighted on evidence if appropriate, such as Building Regulation leads from other Departments and industry standards bodies.
2. Other technological changes – Collation of experience of technological changes within the UK and lessons learned, including the conversion from town gas to natural gas and the smart meter roll out.
3. International experience – Literature review snapshot of relevant international hydrogen experience.
4. Safety evidence guidance – Following the development of the safety demonstration documents, workshops were held with industry to gather views and further develop guidance on evidence requirements for a hydrogen trial. Given the evidence base is developing, these documents may continue to evolve throughout the programme.
5. Guidance on ALARP – HSE regulates under principles of reducing risk to 'so far as is reasonably practicable' or SFAIRP/ALARP[5]. This will continue for hydrogen trials, however the Government and industry are also interested in a comparison of the risks associated with natural gas compared to hydrogen. HSE has provided information on the limitations of this kind of comparison given the different risk profiles of the gases. Further information can be found on HSE's website Risk management: Expert guidance - ALARP at a glance (hse.gov.uk)

3.5 Programme Outputs and Timeline

HSE will provide the Department for Energy Security and Net Zero with updates throughout the programme, to outline progress on evidence submission and review. HSE will use these updates to set out any concerns with the evidence base as it emerges and, as far as possible, limitations that may be present within the final Comprehensive Assessment. HSE has agreed to accept evidence for consideration until September 2024. Any evidence submitted past this date will not be considered within the final assessment due to be completed by March 2025.

The GDNs are responsible for ensuring health and safety for trials, and HSE will not be able to legally 'accept' a Safety Case for the trials, nor can HSE ever guarantee safety. However, HSE has agreed to write to the Department for Energy Security and Net Zero and the GDNs upon completion of the safety evidence review with its conclusions. The contents of this letter will include whether the evidence submitted to HSE has demonstrated that the trial can be run safely and compliance with health and safety legislation will be met providing that the safety control measures identified are appropriately implemented. The letter will be titled a 'Letter of Assistance' and will mirror the safety case or exemption process normally undertaken by HSE, applicable to the distribution of natural gas, under the Gas Safety (Management) 1996 Regulations.

3.6 Emerging issues for a natural gas to hydrogen conversion

While we are yet to review most of the hydrogen evidence, there are some issues that have emerged when considering a full system conversion of the current natural gas system to hydrogen.

Some of the emerging issues include but are not limited to:

[5] https://www.hse.gov.uk/managing/theory/alarpglance.htm, accessed 6 April 2023

- Cast iron mains and components – Cast iron material is known to have potentially higher failure rates with hydrogen than with natural gas, and there are existing standards in place prohibiting the use of hydrogen with cast iron. There is an ongoing cast iron risk reduction programme in place to remove high risk materials, but some cast iron may still be in place by the time a potential hydrogen conversion occurs.

- Consequence modelling – There remain uncertainties in aspects of consequence modelling for hydrogen gas dispersion, for example with respect to different physical configurations and the potential for different risk profiles.

- Risk comparison – although QRAs will estimate risk levels to residential occupants from a representative hydrogen network there are always assumptions and uncertainties.

- ALARP and controls – a range of potential control measures will be proposed but there will be much more data on natural gas available than hydrogen making a full evaluation difficult. Some intermediate additional controls might need to be put in place while this uncertainty exists. There are human factors elements, e.g., the motivation to increase ventilation to reduce the potential for flammable gas clouds to be generated from accidental leaks, which is balanced against the reduction in ventilation rates to save energy.

- Competence – A sufficient number of gas fitters will need to be trained for the conversion process to hydrogen. They will need to have sufficient knowledge of both natural gas and hydrogen, and the process of switching between these gases.

4.0 CONCLUSIONS

Following initial work to identify known questions surrounding the potential conversion of natural gas networks to 100% hydrogen, HSE have put in place an evidence review process in support of the decisions.

Evidence is expected to be submitted to HSE from across the Gas Distribution Networks, commissioned consultancies, and directly from the Department for Energy Security and Net Zero. HSE tracks these evidence submissions against an agreed timeline, including tracking delays.

As of June 2023, HSE is at an early stage within this evidence review process and so has not made any final conclusions on the available evidence base. A final assessment is due to be provided in March 2025.

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