RAMBOLL

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EXECUTIVE SUMMARY

Globally, it is increasingly recognised by governments and industry that hydrogen has an important role to play in delivering carbon emission reduction ambitions and supporting the transition to Net Zero.

In the UK, hydrogen has been identified by national and devolved governments as a credible key pathway for achieving Net Zero Targets. Indeed, the UK's Hydrogen Strategy[1] suggests that 250 – 460 TWh of hydrogen could be needed by 2050, making up 20 – 35% of the UK's final energy consumption. The primary role of this hydrogen would be to replace (or extensively displace) natural gas in parts of the energy system, and / or to act as an energy storage medium.

In the context of this study, only low / zero carbon hydrogen is considered, and in the current landscape, the associated hydrogen production processes comprise:

- Green hydrogen production (Electrolysis with renewable electricity); and,
- Blue hydrogen production (Steam hydrocarbon (methane) reformation coupled with carbon capture).

Such hydrogen production produces very substantial quantities of waste heat and, to date, very little attention has been given to this significant by-product, and the opportunities it presents if captured and utilised.

This study seeks to address this knowledge gap, and the scale thereof.

Indeed, as the scale of hydrogen production infrastructure grows, the quantity of available waste heat will also grow.

This presents substantial opportunities, including the decarbonisation of both existing and new district heating networks, with associated opportunities to:

- Increase energy efficiency and revenue to hydrogen producers; and,
- Increase the availability of low cost, low carbon waste heat for heat users and suppliers (e.g. district heat network operators).

In terms of increasing the availability of low cost, low carbon waste heat for heat users, it has been estimated that by 2050 the quantity of waste heat arising as by-product of hydrogen production could be between 31 to 144 TWh[2].

This is equivalent to:

- *Up to 131% of the UK domestic space heating demand[3]; and,*
- *Up to 27% of the total UK heating demand[4].*

Further, the literature review indicated that recovering waste heat from some hydrogen production processes (particularly green hydrogen production) should not have any negative impact on process efficiency. Indeed, various literature sources suggest that *the system efficiency of electrolyser plants can increase by 14 to 32% by recovering waste heat*.

This directly contradicts the opinion that hydrogen production and heat networks are in competition with each other, and these observations suggest there are clear and potentially very significant synergies between the hydrogen and heat sectors.

[1] 'UK Hydrogen Strategy' (Department for Business, Energy and Industrial Strategy, 17 August 2021). Available online at: https://www.gov.uk/government/publications/uk-hydrogen-strategy

[2] Based on the UK's Hydrogen Strategy projection of 250 – 460 TWh of hydrogen by 2050, and assuming a production efficiency of 80%, and a heat loss between 10 – 25% of input energy.

[3] Assuming UK domestic space heating demand between 110 – 250 TWh (to achieve Net Zero Targets). Source: 'Future Energy Scenarios' (National Grid, July 2021). Available at: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021/documents

[4] Assuming total UK heating demand of 540 TWh. Source: 'Opportunity Areas for District Heating Networks in the UK: National Comprehensive Assessment of the Potential for Efficient Heating and Cooling'. (Department for Business, Energy and Industrial Strategy, September 2021). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015585/opps_for_dhnnca_hc.pdf

An exploration of these synergies provided the focus for this study and involved the identification of waste heat streams arising from any hydrogen production process, and capture and utilisation of this heat within adjacent heat networks. Noting the hydrogen production processes, the study focussed on several identified 'cluster' areas where both the hydrogen and heat sectors are understood to be rapidly evolving in tandem. These areas comprised:

- Aberdeen City;
- Leeds City; and,
- The Humber Region (split into Beverley, Hull and South Humber).

Across each cluster, planned and potential hydrogen production and district heating network developments were identified and mapped.

Subsequently, a technical assessment was undertaken to shortlist a single preferred synergy opportunity to be taken forward into an economic assessment, with the economic assessment undertaken to determine the associated viability of the shortlisted synergy opportunity.

Within the technical assessment screening, the following criteria were applied: waste heat availability; heat demand; proximity / distance of hydrogen production to district heat network; heat quality (heat temperature); hydrogen production growth potential; district heating network growth potential; level of stakeholder interest; timescale to implementation; and, transferability.

Based on the technical assessment, South Humber (from the Humber Region) was selected as the preferred synergy to be taken forward for the economic modelling and assessment. This synergy presents three hydrogen projects planned in close proximity; two very substantial (2 x 100MW) green hydrogen projects, and another large (700 MW) blue hydrogen project. In addition, within the South Humber region, there are also several potential heat networks which have been subject to previous feasibility studies, and identified as potentially viable.

Based on the economic assessment, the Table provides a summary of the impacts of waste heat recovery for the South Humber synergy.

Table: SUMMARY OF THE IMPACTS OF WASTE HEAT RECOVERY FOR THE SOUTH HUMBER SYNERGY

	Hydrogen Production	District Heating Network
Technical	• Improved system efficiency • Reduced auxiliary power consumption • Minimal modification requirements to the plant • Additional space requirements	• Improved efficiency of heat supply equipment • Reduced energy consumption • Additional network infrastructure requirements • Additional thermal storage and controls requirements
Commercial	• Additional revenue streams and savings • Enhanced business case • Improved revenues from hydrogen sales	• Additional capital costs • Lower operating costs • Enhanced business case • Reduced cost to the consumers
Environmental	• Reduced carbon emissions	• Carbon savings • Air quality cost benefits

The economic assessment was performed for a green hydrogen project. However, the synergy concept is also applicable for the blue hydrogen projects.

A main conclusion from the economic assessment is that it is technically feasible to recover waste heat from hydrogen production without negatively impacting the production, and that it is economically attractive to utilise this waste heat to supply district heating networks compared to the counterfactual scenario using air source heat pumps.

In particular, noting the selected South Humber synergy and the associated economic modelling, there is a technically and economically feasible project opportunity.

For the South Humber synergy, the economic assessment also noted that the project presented an attractive business case for both the hydrogen production and district heat network operators, with following key financial results:

- For the hydrogen production operator: Projected IRR of 14%, with a positive NPV.
- For the district neat network operator: Projected IRR of >4%, with positive NPV (compared with counterfactual scenario projected IRR of <1% IRR).

Additionally, in comparison with the counterfactual scenario using air source heat pumps, the South Humber synergy could:

- Reduce the heating cost to the consumers by approximately 20%; and,
- Reduce carbon emissions by over 50%.

The sensitivity assessment suggested that the success of the project is highly dependent on the following factors:

- *High Heat Demand and Availability of Waste Heat:*
  The project is highly sensitive to the availability of waste heat and heat demand. Therefore, the sufficient availability of waste heat and heat load is critical to make the project feasible.
- *Capital Cost:*
  The project is also very sensitive to the initial capital cost. Consequently, following enablers are identified to minimise the initial capital investment:
  - Waste heat temperature higher than the network operating temperature;
  - Lower network operating temperatures (e.g. for new developments and more efficient heating systems);
  - Close proximity of hydrogen projects from heat clusters; and,
  - Availability of grant funding.
- *Heat Sale Rate:*
  Heat sale rate will also have a significant impact on the project performance. In most cases, the heat sale rate will depend on the availability of other low-cost heat alternatives and hence the early assessment of other alternatives and the strategic placement of the project is crucial.

The overarching conclusion of this Study is that significant economic, environmental and social benefits are associated with heat recovery from hydrogen production, and its auxiliary processes.

However, for such benefits to be realised, hydrogen production projects would have to be placed in close proximity to heat clusters. This not only provides an opportunity to develop local clean sources of hydrogen (with the potential to attract new businesses to the area), but also forms a key part of the decarbonisation of energy, and could significantly accelerate the UK's decarbonisation of heat.

The main recommendation, given the significant environmental, economic and social benefits, is to carry out further and more detailed assessment of the synergy opportunities identified.