

HYDROGEN DEMAND IN SCOTLAND: A MAPPING OF INDUSTRIAL AND TRANSPORT APPLICATIONS

Executive Summary

Hydrogen is an emerging global market opportunity and one of the options in countries' efforts towards sustainability and energy security. Some of the highest emitting sectors are the most difficult to decarbonise, including heavy industry and transport.

Scottish Enterprise commissioned consultants to produce this study on hydrogen demand in Scotland in order to identify, quantify and map the potential domestic offtake of hydrogen in the transport and industrial sectors. Domestic heating was not in scope. The aim is to identify potential offtakers of hydrogen and inform the development of Scotland's hydrogen hubs. It also provides techno-economic information about hydrogen as a decarbonisation option for these customers' processes and energy needs, as well as barriers and opportunities for hydrogen in each sector.

The two studies were carried out by different consultants and comprised both a literature review of prior reports and new research. Both used distinct methodologies. The findings are not intended as prescriptive views of how the nascent hydrogen economy will develop, but to help the market grow by sparking commercial discussions and policy ideas.

Scope and Methodology:

- The **Industrial** segment of the report, conducted by Element Energy (an ERM Group Company) evaluated the existing research on industrial hydrogen demand in Scotland, covering the following sectors: Chemicals, Oil and Gas Refining, Cement, Glass, Paper and pulp, Distilleries, Food and Drink, power generation, non-domestic heating (crematoria, universities, hospitals and care homes) and mobile power generators. The report assessed **the total potential hydrogen use if the industrial processes in scope that can fuel switch to hydrogen (from a technical feasibility perspective) did convert to hydrogen**, while excluding some sites which have publicly announced alternative non-hydrogen plans to decarbonise (including CCS). Specific maps were created for each of the 13 proposed Regional Hydrogen Energy Hubs.
- The **Transport** segment, conducted by Ricardo, reviewed cumulative findings from literature on national hydrogen and hydrogen-based fuel uptake scenarios for aviation, shipping, ferries, road vehicles and rail (passenger and freight). Shipping demand was estimated with a split for hydrogen and ammonia, and aviation demand was split into hydrogen and e-kerosene. New scenarios were developed from the ground up using publicly available data for some subsectors, as well as for agriculture, construction and forestry. **Scenarios for Low, Medium and High uptake were developed for timelines reaching until 2045**. The mapping exercise also researched the routes covered by heavy goods vehicles and ferries.

A StoryMap version of this summary with a link to an interactive map of H2 assets is available at <https://rb.gy/3hfv1>. It will be updated periodically, allowing you to navigate all regions in Scotland and view demand by sectors of interest.

We encourage hydrogen project developers and offtakers to use the map to find and approach potential partners. Scotland's hydrogen hub partnership groups may also find these estimates useful to build a business case for investments.

INDUSTRIAL DEMAND

Hydrogen is regarded as having strong potential as a decarbonisation technology for industrial sectors covered by the study, as it can be combusted to either provide high temperature direct heat, to raise steam for use in indirect heating and to produce electricity. Whilst hydrogen-fired industrial equipment is not yet mature, there is widespread research into fuel switching to hydrogen, with technical feasibility expected by 2030.

Only industrial sites with annual emissions >10,000 tCO₂ (NAEI 2019) and non-domestic sites with >2million kWh/year of energy use were counted in scope. However, all Scotch Whisky distilleries were included, as most emit less CO₂ than the threshold and the sector was considered to be of interest across all site sizes. For the non-domestic buildings sector, a threshold of 2,000,000 kWh/year of energy (combined heating and electricity) was used.

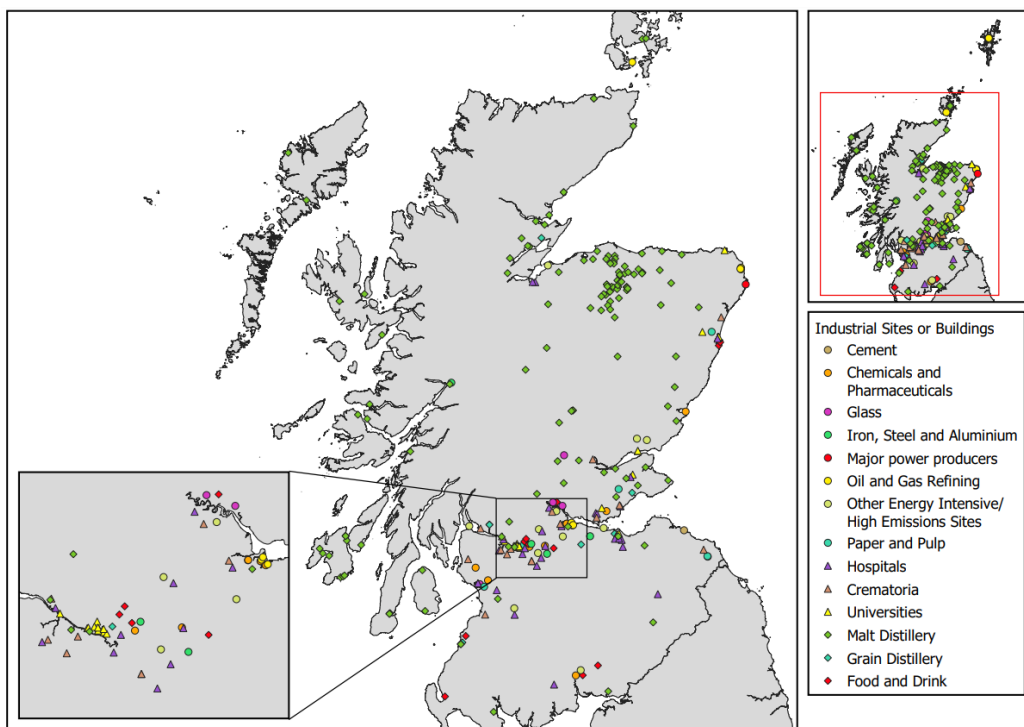


Figure 1: Map of Scotland showing the sites within the Sectors of Interest included in the assessment

Industrial sectors that were identified as holding a higher likelihood of hydrogen adoption were: Oil and Gas Refining, Chemicals and Pharmaceuticals, Distilleries and Glass. For all sectors but distilleries, this was because of the high temperature heating requirements (which hydrogen is regarded as being comparably more suited for). Meanwhile, net zero pathways modelled by the Scottish Whisky Association found that hydrogen would have a central role in decarbonising the distilleries sector.

Key alternative decarbonisation technologies to hydrogen include carbon capture and storage, biomass and electrification. Both hydrogen and biomass are regarded as feasible for most heating profiles, though hydrogen is regarded as more competitive for high temperature heating requirements. Electrification is a suitable option for low temperature heating, but requires the replacement of existing equipment and installation of grid connections, whilst hydrogen and biomass can be utilised with only partial changes to industrial equipment.

There are a variety of drivers that will determine the use of low-carbon hydrogen as a decarbonisation pathway. In the short term, opportunities for hydrogen end use and supply development are likely to be driven by the Regional Hydrogen Energy Hubs approach, and the location of hydrogen production

on sites in wind curtailment or close to substations for offshore wind. Hydrogen use in industry will also be driven by improvements to the maturity of hydrogen fired appliances, with an earlier uptake that could be focused in sectors which already have skills compatible with hydrogen use and that can be run with hydrogen/natural gas blends.

A total potential use of 13.5 TWh/year (405,000tH₂/year) of hydrogen in industry and non-domestic heating per year was estimated by the Industry study based on current energy demands. An important fraction of this belongs to the Oil and Gas refining and Chemicals and Pharmaceuticals sector (which also includes petrochemicals). Sites in these two largest sectors of potential demand are mainly located in the Grangemouth area. The distilleries sector also could have a significant use of hydrogen distributed across Scotland. As shown, there is little hydrogen potential use in the non-domestic buildings sector.

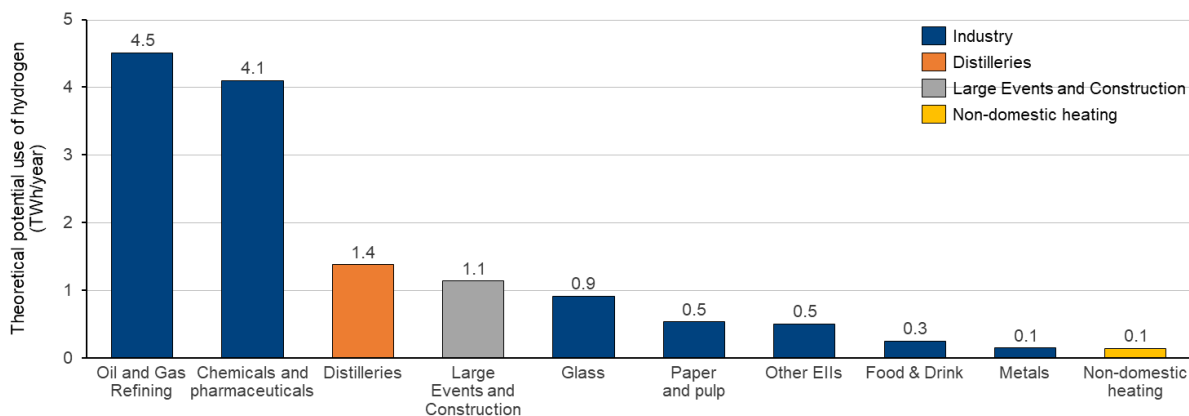


Figure 2: Assessed theoretical potential use of hydrogen (TWh/year) by each of the Sectors of Interest. Other EILs include iron, steel and aluminium, other non-metallic mineral products, print products, rubber, and veneer sheets and wood-based products

TRANSPORT DEMAND

Hydrogen has a role to play in decarbonising parts of the transport sector, particularly where electrification cannot serve operational requirements. Fuel cell technologies are mature and commercialised but have not yet experienced growth in adoption. The primary reason for this is due to vehicle cost and limited access to refuelling infrastructure. As the market scales up these barriers will shrink. However, the fuel costs of hydrogen are expected to keep the total cost of ownership of fuel cell vehicles higher than battery electric vehicles.

Hydrogen will especially support hard-to-decarbonise sectors such as international shipping and aviation. Shipping requires energy dense, compact fuels that do not impede on freight load capacity. Aviation additionally requires light fuels to maximise in-flight efficiency. These can come in the form of hydrogen-derivative fuels such as ammonia, synthetic methanol and synthetic kerosene. Ferries that have a schedule and travel short, fixed routes are better suited for hydrogen, while the shortest routes can use electricity.

On land, hydrogen is expected to play a role where electricity cannot reach, whether that be due to insufficient electric vehicle range, short time availability for refuelling or the cost and availability of electricity infrastructure. Heavy duty vehicles, including road freight and refuse collection vehicles, may be suited to hydrogen as they need to travel long-distances or to rural locations, and some busses are expected to operate 24/7 without the opportunity to recharge.

Off-road sectors face similar challenges to on-road. The temporary nature of construction means that there is a limited investment proposition for implementing electric infrastructure. Agricultural practices occur in rural environments, often at the very extreme ends of the power grid, and forestry in no-grid environments. To solve these challenges, mobile hydrogen refuellers are being developed which can provide an all in-one transportable solution.

The main driver to adopt hydrogen vehicles is the national regulatory push to decarbonise. This is supported by further drivers such as the beginning of restrictions on the sale of new combustion engine vehicles from 2030, tax breaks and introduction of clean air zones by local government. There are also business lead activities such as net zero objectives and sustainable procurement practices.

The potential demand of hydrogen in the transport sector in this study’s medium scenario was 12.5 TWh/year by 2045. The full range of demand was from 7.1 TWh/year in the low uptake scenario and 19.5 TWh/year for the high uptake scenario. The shipping sector has the highest demand with a medium scenario uptake of 4.66 TWh/year. Most of this demand is based between the five ports located within the Firth of Forth. HGVs, ferries and aviation also have higher demands but have competing technologies or fuels that reduce their uptake potential.

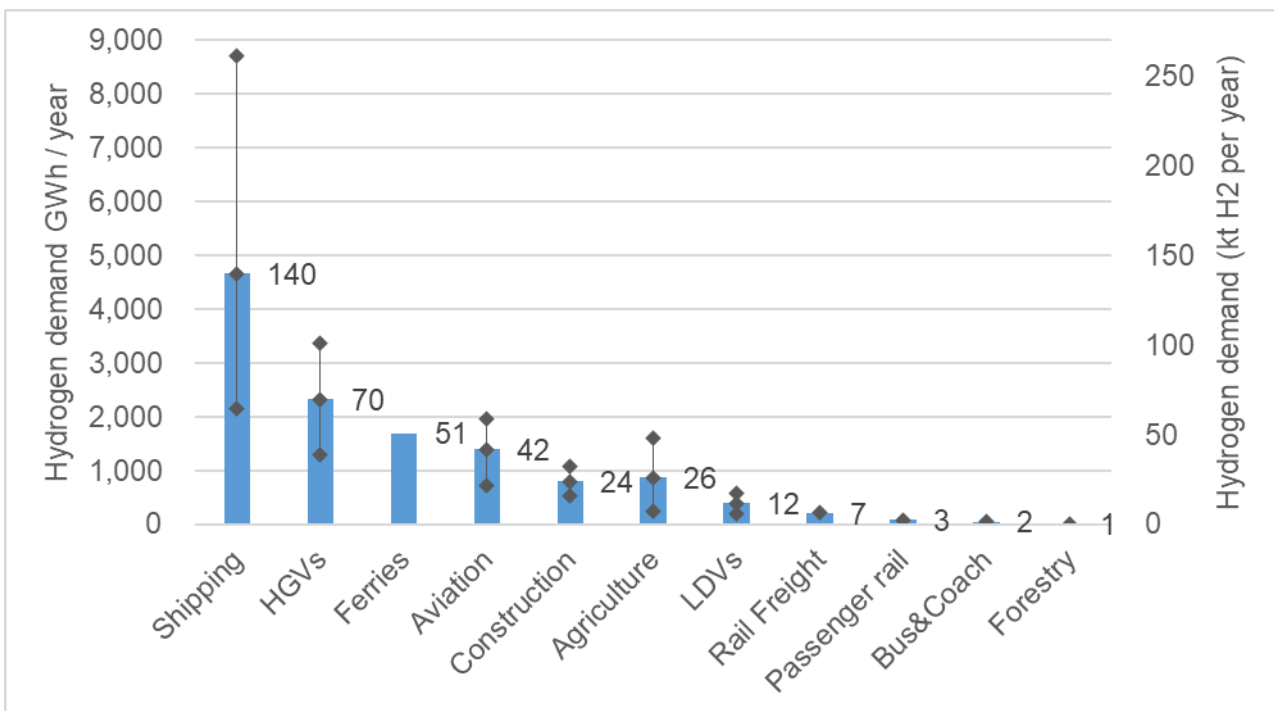


Figure 3: Ranges of potential demand scenarios for hydrogen-derived fuels, indicating low, medium and high uptake, by transport sector by 2045.

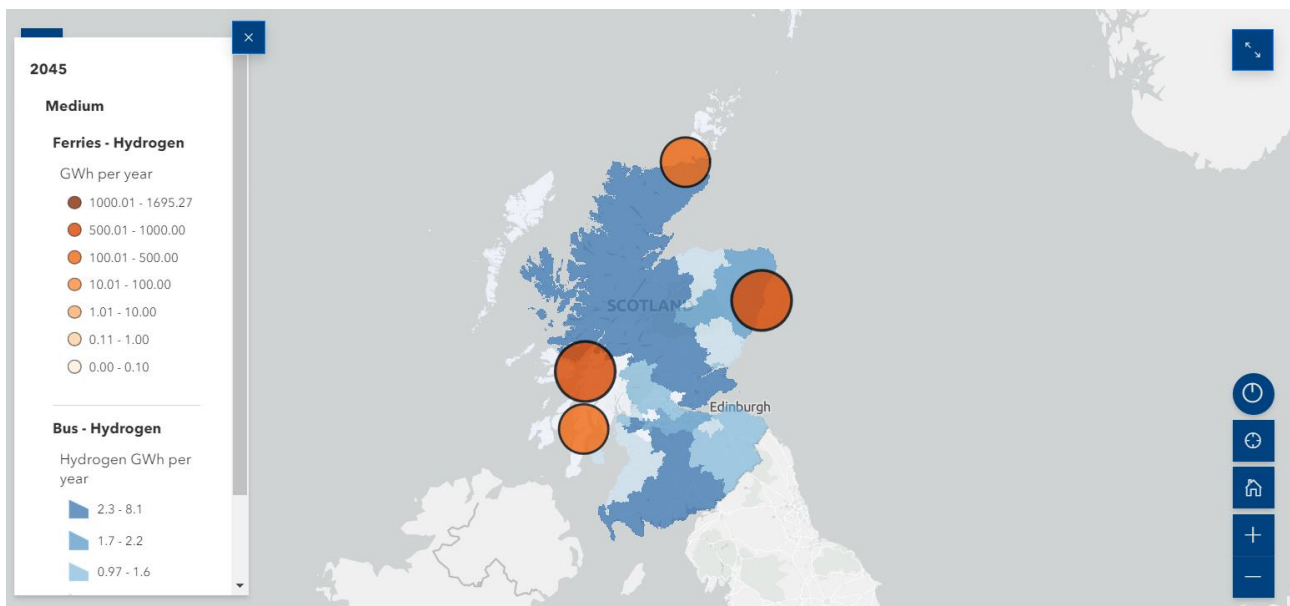
If the “medium” estimates of both reports are aggregated, the result is a potential for a domestic demand of 26TWh worth of hydrogen by 2045. In 2019, Scotland’s total energy demand was calculated at 161TWh.

MAPPING

The distance between hydrogen supply and demand is an important factor in reducing hydrogen's total cost for customers. This study sought to map potential industrial and transport offtake to clarify potential relationships and strategic plans within Scotland's regional Hydrogen Hubs.

The sectors that represented the largest potential hydrogen offtakers in both Industry and Transport were: Oil & Gas Refining and Chemicals and Pharmaceuticals (approx. 8.6TWh combined), and the waterborne transport sectors if shipping and ferries are viewed jointly (approx. 6.3TWh combined). These sectors will require larger distribution infrastructure and a shift in the maritime industry's fuel choices. The HGV sector, distilleries, aviation and the mobile generation sectors represent a smaller but still sizable demand, with short-term opportunities for de-centralised supply via hydrogen deliveries and fuelling stations.

It is unsurprising that, geographically, the highest concentration of demand is in the Central Belt, particularly where industry is clustered like Grangemouth and Fife, and in cities with the highest population density. Other hubs show hotspots of demand around key transport links or connections to the offshore energy industry, such as Ayrshire, Cromarty Firth, the North East, Orkney and Shetland. It is notable that the Moray local authority area is not strictly yet covered by the Cromarty hub despite having a concentrated cluster of distilleries and has ambitions to become a hub of its own. Moray and Islay represents an opportunity for hydrogen producers looking for customers in the distillery sector.



Sample view of transport mapping.

CONTACT US

Scottish Enterprise will use this data alongside Scottish Government and our fellow development agencies to further develop hydrogen policies and schemes.

To discuss any details of this report, or suggest how we can support industry, please contact SE's hydrogen team at SEHydrogenEconomy@scotent.co.uk.