Net Zero, Energy and Transport Committee
Tuesday 6 May 2025
17th Meeting, 2025 (Session 6)

Evidence session – Plans for future of Grangemouth: hydrogen aspects of the Project Willow study

1. Over two meetings in May, the Committee is taking evidence on proposals for hydrogen-related projects at the Grangemouth site, as set out in the Project Willow feasibility study. The first of these; on 13 May, takes a general look at the hydrogen proposals set out in the study, from a panel of experts with a mixture of experience in academic research and industry.

2. On 20 May the Committee will then hear from two further panels: one representing Scotland's green hydrogen sector; and one representing the blue hydrogen sector or experts in that area (brief description of these terms below).

Background: Grangemouth and Project Willow

3. On 12 September 2024, Petroineos announced its plans to convert the Grangemouth refinery into a fuel import terminal. They cited declining profitability and the need for substantial new investment to keep the refinery running. Petroineos is a joint venture between PetroChina International London (PCIL) and the INEOS Group.

4. On 29 April 2025, it was announced that the processing of crude oil at the refinery had stopped. A reported 430 jobs were lost as a result. The refinery is part of a wider Grangemouth industrial complex employing roughly 2,000 people.

5. A £1.5m feasibility study was commissioned by Petroineos in autumn of 2024 to assess possible future uses for the Grangemouth site as a low carbon energy hub. This plan, conde-named Project Willow, is jointly supported by the UK and Scottish Government. The results were published on 19 March 2025.

6. There are nine 'projects' highlighted by the Project Willow study. The Committee has decided to focus on those (p**rojects 6-9)** involving the use of low carbon hydrogen in some way:

   - **Project 6: Hydrogenated Esters and Fatty Acids (HEFA):** converts Scottish oil seed cover crops into Sustainable Aviation Fuel (SAF) and Renewable Diesel (RD) using low carbon hydrogen. Grangemouth currently supplies aviation fuel to Edinburgh, Glasgow, Aberdeen and Newcastle.
   - **Project 7: Fuel switching:** Replacing natural gas combustion with low carbon hydrogen. The proposed feedstocks for this hydrogen production are renewable power and water and thus, green hydrogen.

- **Project 8: E-methanol and methanol to jet:** using low carbon hydrogen to produce methanol and convert it to Sustainable Aviation Fuel (SAF). The methanol can be used as a low carbon shipping fuel or chemical feedstock.
- **Project 9: E-ammonia:** producing low carbon ammonia from hydrogen for shipping and chemicals. Most shipping currently uses fossil fuels including diesel, heavy/light fuel oil and liquified natural gas (LNG). In order to reduce emissions from shipping there are projections (see Project Willow report page 21) that ammonia could become the primary fuel for shipping.

7. The Scottish Government and Parliament have committed by law to make Scotland "net zero" in carbon emissions by 2045. It is widely agreed that hydrogen has a role to play as a low or no-carbon fuel in this transition to net zero, but there are differences of views as to:
   - how big a role it is likely to play compared to other energy sources;
   - how it is to be manufactured at scale (with a few known exceptions, hydrogen does not occur as a raw resource and must be processed into existence);
   - the best applications for hydrogen fuel in industry, transport, heating etc.

8. These questions all form part of ongoing discussions at political level, in academic research, and within the commercial energy sector. For its part, the the Scottish Government has committed to targets of 5GW hydrogen production capacity by 2030 and 25GW by 2045. It envisages doing this through:

   - Blue hydrogen: producing hydrogen using natural gas. Greenhouse gases emitted during this process are then stored at scale. This process is known as carbon capture and storage or CCS. The Committee has considered the prospects for growing the blue hydrogen sector in Scotland (in particular the Acorn Project, which would involve using depleted North Sea oil and gas reservoirs to store greenhouse gases) during its budget scrutiny, and in a "snapshot" inquiry in 2021-22;
   - Green hydrogen: producing hydrogen by electrolysis, where an electric current splits water into hydrogen and oxygen. The Committee has again considered the prospects for green hydrogen in Scotland during its budget scrutiny and as part of a short inquiry into Scotland's future energy infrastructure needs.

9. The Scottish Government's longer-term ambition is for Scotland to become a net exporter of low or no-carbon blue and green hydrogen.

Meeting on 13 May and next steps

10. On 13 May, the Committee will take evidence (in two panels) from:

    - Dr Nigel Holmes: CEO of Hydrogen Scotland
    - Prof John Andresen: Professor in Energy Systems at Heriot-Watt University and Associate Director of Hydrogen and Low-Carbon Energies within the Research Centre for Carbon Solutions.

- Dr Graeme Hawker: Lecturer in Energy Systems at the University of Strathclyde and author of 'The potential for hydrogen to reduce curtailment of renewable energy in Scotland' for ClimateXChange.
- Dr Simon Gill: consultant with The Energy Landscape and author of the Scottish Future Trust report Green hydrogen in Scotland. Dr Gill has provided a submission for this session: **Annexe A**.
- Prof Mark Symes: Professor of Electrochemistry and Electrochemical Technology and leader of the Hydrogen Innovation Centre at the University of Glasgow
- Dr Jan Rosenow: Jackson Senior Fellow and Leader of the Energy Programme at the Environmental Change Institute, University of Oxford.

11. Panellists are likely to be asked for the overall views on the viability of the 4 hydrogen-related projects set out in Project Willow and what government and industry would need to do to realise them and secure flourishing hydrogen sector in Scotland overall.

12. After the second evidence session on 20 May, the Committee will consider the evidence it has received and possible next steps. Amongst other things, the sessions are likely to be relevant to future scrutiny of the next draft Climate Change Plan, to be laid this autumn, setting out how the Scottish Government proposes to progress towards net zero over the next five years.

13. In considering next steps, the Committee will also take account of the work of the Economy and Fair Work Committee, which is carrying out parallel scrutiny into Project Willow and the future of the Grangemouth site, with a focus on the just transition. It will hear from unions and from UK and Scottish Ministers during May and June.

Clerks to the Committee
May 2025

Developing a hydrogen economy in Scotland

Dr. Simon Gill, The Energy Landscape, May 2025,

1 Introduction

The Scottish and UK Government recently funded an evaluation of Grangemouth's potential as a low carbon manufacturing hub[1]. This identifies nine key investment areas, of which three are focused on hydrogen: Fuel switching from natural gas, e-methanol and Sustainable Aviation Fuel (SAF) production, and e-ammonia production.

For these projects to be realised, and to deliver benefits to Scotland, they will need to be part of an integrated low carbon hydrogen system. That doesn't exist today and needs to be built from the bottom up.

Both Scottish and UK Governments have laid out visions for the development of hydrogen, and both are implementing policies to support its development. Scottish Government is primarily focusing on green hydrogen produced from low carbon electricity and this provides an opportunity to make use of otherwise curtailed wind generation. UK Government is supporting the development of both green and blue hydrogen (produced from natural gas with carbon capture use and storage).

As this paper highlights, developing a hydrogen economy requires coordination across government, across the energy system, and across the development of multiple infrastructure. As such it requires a strategic vision, certainty for investors and continuity of policy.

1.1 The role of hydrogen

Hydrogen will be an important 'vector' for a net zero energy system. It provides a low carbon route to move and store energy on a similar scale to fossil fuel based energy today, it can be used as a direct fuel for hard-to-abate sectors, and it is a building block for aviation and shipping fuels. There are two primary routes to the production of hydrogen: green hydrogen produced via electrolysers using low carbon electricity and water, and blue hydrogen produced by reforming natural gas and capturing the resultant CO_2 emissions.

Low carbon hydrogen can replace fossil fuels in areas of the energy system where alternatives will be costly or technically challenging. Promising roles for hydrogen include:

[1] EY, Project Willow, 2025

Energy transportation: hydrogen can be transported at scale through dedicated pipelines. Where the end-use of the energy is hydrogen or its derivatives (e.g. e-fuels), those pipelines are likely to be a low-cost alternative to the equivalent capacity of electricity lines.

Energy Storage: hydrogen can be stored in much the same way as natural gas and represents one of the only technologies economically capable of storing terawatt hours (TWh) of energy over weeks and months[2]. Currently, the UK has 35 TWh[3] of natural gas storage and 59 TWh of energy storage in the form of crude oil and processed petroleum products[4]. (By contrast, whilst very important for our electricity system, Cruachan pumped storage facility only stores around 0.007 TWh[5]). Hydrogen storage can be combined with hydrogen-fuelled power stations to return energy to the electricity system during periods of low wind and solar availability. **Figure 1 illustrates** where energy was stored in the UK energy system in 2014 and 2019.

Energy resilience: today, most of our energy stores remain in the form of fossil fuels. These allows us to meet our obligations under membership of the International Energy Agency, to have reserves of fuels equivalent to up to 90 days of imports, and prior to Brexit, to meet EU requirements to hold 67.5 days' worth of domestic consumption[6]. These stocks provide resilience against global supply shocks and geopolitical events. The National Infrastructure Commission highlighted the importance of energy resilience in its second national infrastructure assessment, recommending 8 TWh of hydrogen storage by 2035 and a strategic energy reserve capable of producing 25 TWh of electricity by 2040, of which hydrogen would be one of the main options[7].

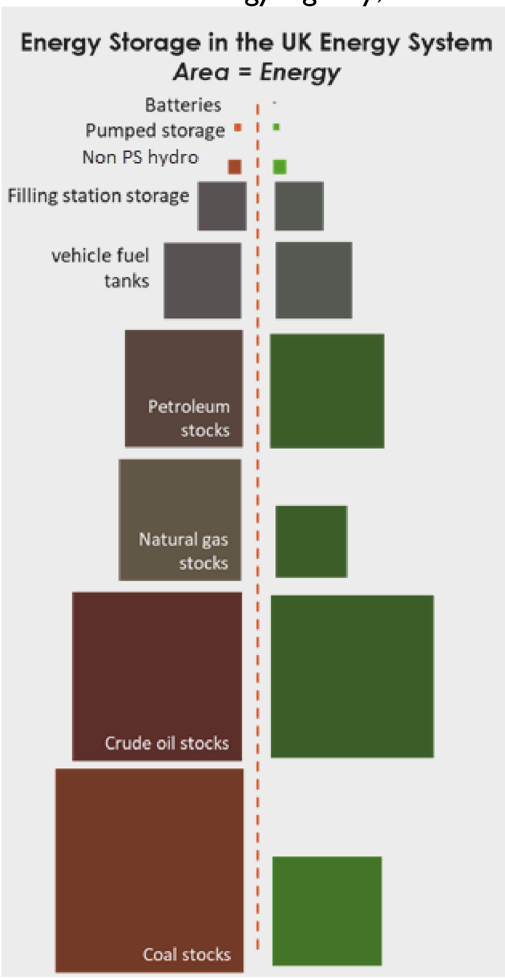

Figure 1: *Energy storage in the energy system, 2014 and 2019.* ***Source:*** *TEL analysis*

Decarbonising hard-to-abate sectors: some sectors of the economy, particularly high-temperature industrial processes, will be very difficult to decarbonise using. These include sectors such as ceramic and cement manufacture, both of which require high-temperature combustion, and chemical processes which use hydrogen as a direct feedstock.

Production of derivatives: hydrogen can be used to create e-fuels such as e-methanol, Sustainable Aviation Fuel (SAF), ammonia and other 'synthetic' fuels. Many are chemically identical to existing fossil fuels and share their characteristics – high energy density,

[2] One study, quoted by UK Government, suggests that there is the potential for 200 TWh of hydrogen storage in large scale salt caverns, an example of geological storage at scale, UKCCSRS, 2020
[3] Ofgem, GB Gas Storage Data 2025
[4] Digest of UK Energy Statistics (DUKES): petroleum, Table 5.3, 2024
[5] Drax
[6] IEA, United Kingdom's legislation on oil security – Analysis, Accessed May 2025
[7] NIC, Second National Infrastructure Assessment, 2023

transportability, storability – and they can be used with existing equipment such as jet or internal combustion engines.

1.2 The Committee on Climate Change's view of hydrogen in the seventh carbon budget

The Committee on Climate Change's (CCC) advice to UK Government on the seventh carbon budget (CB7) was published in February this year. The advice includes detailed whole-energy-system modelling. Compared with the sixth carbon budget (CB6) hydrogen plays a reduced role. In CB6, hydrogen delivers 220 TWh[8] of energy compared with 93 TWh in CB7[9] (see Figure 2). The reduction reflects the complete removal of hydrogen from the domestic and non-domestic heating sectors and the near-complete removal from surface transport. CB7 also reduces the use of UK-produced hydrogen in the shipping sector, instead assuming that the ammonia used to fuel a significant fraction of that sector in 2050 is sourced from the international market rather than UK production.

The trend reflects a growing expectation that other means of decarbonisation, primarily electrification, should be prioritised where alternative technologies (electric cars, vans and increasingly HGVs and heat pumps) exist. However, even with reduced whole-system volumes, the remaining uses of hydrogen remain critical to net zero.

2 Challenges of hydrogen

To realise the benefits of hydrogen, there are several important challenges which need to be overcome.

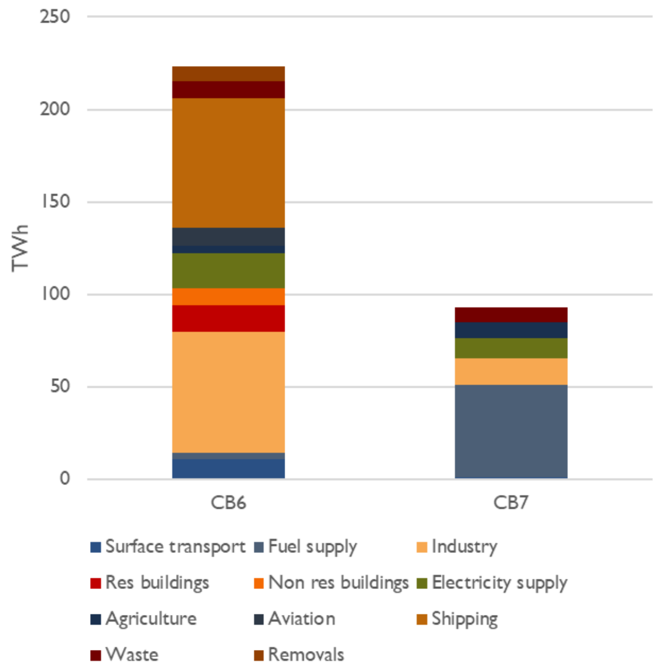

***Figure 2:** Hydrogen use in CB6 and CB7. **Source:** CCC*

Cost: today, the cost of producing low carbon hydrogen is high. The first Allocation Round (AR1) of UK Government's HPBM saw contracts signed at an average price of £241 / MWh (2022 prices)[10] for green hydrogen production. Government is placing a strong emphasis on the need to reduce these prices in future allocation rounds.

Feedstock prices: a key driver of hydrogen cost is the underlying cost of the energy going into the hydrogen. One of the drivers for the high prices in AR1, which was focused on green hydrogen, is the cost of electricity and the format of the HPBM contract which leads to developers needing to lock in fixed-price

[8] CCC, Sixth Carbon Budget Dataset, 2020
[9] CCC, Seventh Carbon Budget Dataset, 2025
[10] UKG, Hydrogen Production Business Model / Net Zero Hydrogen Fund: HAR1 successful projects (published December 2023) - GOV.UK

electricity for the 15 years of the support contract. For blue hydrogen, production costs will be intimately tied to natural gas and will therefore suffer the same risk of price-volatility driven by the global market.

Long-term pathway uncertainty: whilst there is consensus that low carbon hydrogen will play an important role in a net zero economy, the pathway to 2045 is less clear. Key to this is the role that blue and green hydrogen will play at different stages. Each have different characteristics, and each impose different requirements on the supporting infrastructure needed to integrate each into the wider energy system. Achieving sufficient certainty to support the development of assets that can take up to a decade to develop and have economic lives of three decades or more, is a major challenge.

The need for supporting infrastructure: hydrogen production and use are only the two end points of a hydrogen system. A mature hydrogen system could include a national hydrogen transmission system, local and regional pipelines, and significant hydrogen storage. This will support a competitive and liquid market which is itself likely to drive down the cost and increase the investability in the sector.

Coordination across the energy system: stepping back, hydrogen will also need to coordinate with the development of the electricity system for green hydrogen, and for blue hydrogen both the natural gas and evolving CO_2 transportation, storage and utilisation systems. This coordination is only likely to be delivered via a full a strategic planning energy system approach. Such an approach is developing at a GB scale, with Scottish involvements – see Section 3.1 for details.

Gaining investment in innovative projects at scale: investments in hydrogen production assets or the conversion of industrial processes to accommodate hydrogen use are capital intensive. Raising investment for these areas requires certainty.

3 Supporting the development of the hydrogen system

Whilst Scottish Government are playing an important role in the development of the hydrogen economy, through grant funding, project support, and the development of a strategic vision, much of the underlying financial support required by the sector comes from UK Government mechanisms. The hydrogen system consists of five infrastructure groups, shown in Figure 3. 'Business Models' have been, or are being, developed for production, networks (transport) and storage, with the use of hydrogen either directly or through its derivatives benefiting from support higher up the chain, and through bespoke capital support mechanisms.

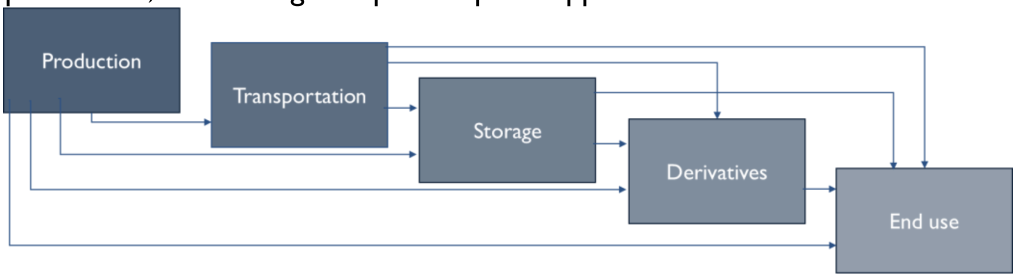

***Figure 3:** Passing energy through a hydrogen system. The elements of a hydrogen system. **Source:** TEL and SFT.*

Hydrogen Production: supported by UKG's **Hydrogen Production Business Model (HPBM)** which aims to make low carbon hydrogen available to end-users at a price that is competitive to natural gas. Five contracts for AR1 projects have now been signed, including two in Scotland, with Final Investment Decision (FID) expected later this year[11]. The AR2 process is also underway, with 27 projects shortlisted, eight of which are in Scotland, including one at Grangemouth[12]. In addition to the HPBM, blue hydrogen production is being supported through industrial clusters schemes in England.

Hydrogen network: as natural-monopoly assets, UK Government intends to fund hydrogen networks through a RAB-based **Hydrogen Transport Business Model (HTBM)**. Details are yet to be given, and a consultation is expected soon. However, there is a need to progress plans, and some funding has been made available by Ofgem through the natural gas network price control. National Gas is developing a national hydrogen transmission network design – Project Union – including a leg from St. Fergus via Grangemouth and down to Teesside in England. A £98m request for a Front End Engineering Design (FEED) study for the leg linking Scotland with North East England is with Ofgem with a decision expected later this year[13]. And SGN has been testing the potential to convert a high-pressure pipe between Grangemouth and Edinburgh from natural gas to hydrogen in its 'LTS Futures' project[14].

Hydrogen storage: to be supported through the **Hydrogen Storage Business Model (HSBM)** which aims to support large-scale storage as part of a developing hydrogen system. Initial storage projects are likely to be in England, with the appropriate geological conditions for salt-cavern storage (one of the first options likely to be developed at scale) found in East Yorkshire, Cheshire and Dorset. The ability of the HSBM to support a Scotland hydrogen system will therefore be dependent on the network connections between Scotland and England.

Hydrogen Demand: the outcome of the business models described above could be that hydrogen is available to end-users at a price that is competitive to fossil fuels, therefore there is no specific demand 'business model'. However, the use of hydrogen in many applications is highly innovative and will require significant capital investment, and continued grant and load funding from both Governments will be critical.

3.1 A GB-wide strategic approach to energy system planning

In addition to hydrogen-specific support mechanisms, the development of a hydrogen system needs to form part of a whole-energy system strategy. Over the past eighteen months UK Government has placed a much stronger focus on strategic planning. This has grown out of a report from the Electricity Network Commissioner in 2023 which recommended the development of strategic whole system planning to coordinate the development of electricity generation, flexibility, demand and networks[15]. The strategic approach has been embedded in the new National Energy System Operator (NESO) which has been given the task of developing both a Strategic Spatial Energy Plan

[11] LCCC, Low Carbon Hydrogen Award Scheme Register, accessed May 2025.
[12] UK Government, HAR2 shortlisted Projects, April 2025
[13] National Gas, Project Union St. Fergus to Teesside FEED Re-opener, 2024
[14] SGN, LTS Futures, Accessed May 2025
[15] UK Government, Winsor Report, 2023

(SSEP) and from that a Centralised Strategic Network Plan (CSNP). These are expected to include consideration of hydrogen production, consumption, networks and storage.

SSEP: a Great Britain-wide blueprint for the development of large-scale generation and storage of electricity and hydrogen. As part of that, the SSEP will map potential electricity and hydrogen generation and storage infrastructure for GB. Expected: Q4 2026.

CSNP: an independent, coordinated, and long-term approach to transmission network planning in Great Britain. It will plan to develop and assess electricity, gas and potentially hydrogen transmission networks[16]. Expected 2027.

The SSEP and CSNP will therefore play an important role in coordinating the development of a hydrogen system alongside the evolution of electricity and the transition away from unabated natural gas. Critically, the SSEP has been jointly commissioned by the UK Secretary of State, Scottish and Welsh Governments and means that Scottish Ministers have a direct opportunity to influence and oversee the development of these strategic plans[17].

4 Conclusion: the 'so what' for hydrogen in Scotland

The development of a vibrant Scottish hydrogen sector is possible. If it can achieve, it can support a more efficient and effective energy system. However, delivering that outcome requires strategic thinking and significant long-term coordination. In particular:

- To realise specific hydrogen projects such as those proposed through Project Willow, and for those projects to be economically viable and capable of sustaining a net zero economy, they will need to be part of **a maturing national hydrogen system**.
- That system will need to **drive down the cost of hydrogen production** and efficiently link hydrogen production and end-use through networks, storage and markets.
- To access the **significant scale of hydrogen storage**, a **Scottish hydrogen system needs to be linked to the rest of GB** where salt cavern storage and other geological storage options are, most likely to be developed in the next fifteen years, are available.
- As such the development of a **national hydrogen network** is likely to be crucial for a successful Scottish hydrogen sector**.**
- Delivering the investment needed will require **greater clarity on the pathway for hydrogen**. This needs to include more information on the **expected balance between blue and green hydrogen** at each stage of the transition.
- Where hydrogen is to be used in the form of derivatives – e-ammonia, e-methanol, and synthetic SAF – this needs to be **coordinated with the transition from fossil fuel use in the aviation, shipping and off-road vehicle sectors**.
- The development of both the Scottish and GB-wide hydrogen system needs to be part of a **long term, stable, strategic whole energy system plan**.

[16] NESO, Strategic Energy Planning: A summary, 2025
[17] Strategic Spatial Energy Plan: joint letter to NESO from the UK, Scottish and Welsh Governments