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Grangemouth Hydrogen Hub

Report for Scottish Enterprise

May 2021

Report Contents

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Introduction

Study Background

- The Scottish Government's Declaration of a Climate Emergency has accelerated its action plan to deliver net zero greenhouse gas (GHG) emissions in Scotland by 2045.
- The use of hydrogen and carbon capture and storage (CCUS) become crucial elements in solutions to achieve or exceed net zero objectives.
- The UK Government seeks to establish the world's first net-zero carbon industrial cluster by 2040 and at least four low-carbon clusters by 2030. **Grangemouth is therefore a nationally significant industrial complex and, to some extent, in direct competition with other clusters for investment and development support.**
- The Scottish Government's Hydrogen Policy Statement recognises the important role that hydrogen will have in supporting wider decarbonisation efforts. It includes an ambition to develop 5 GW of green hydrogen production by 2030.
- Its supporting Scottish Hydrogen Assessment notes that industrial and transport sectors are most likely to lead the uptake of hydrogen in Scotland
- The market assessment also recognises that the hydrogen supply chain will best evolve via production hubs that meet industry, transport and heat needs simultaneously.
- Growing international demand for hydrogen offers potential export market opportunities for a mature Scottish hydrogen sector

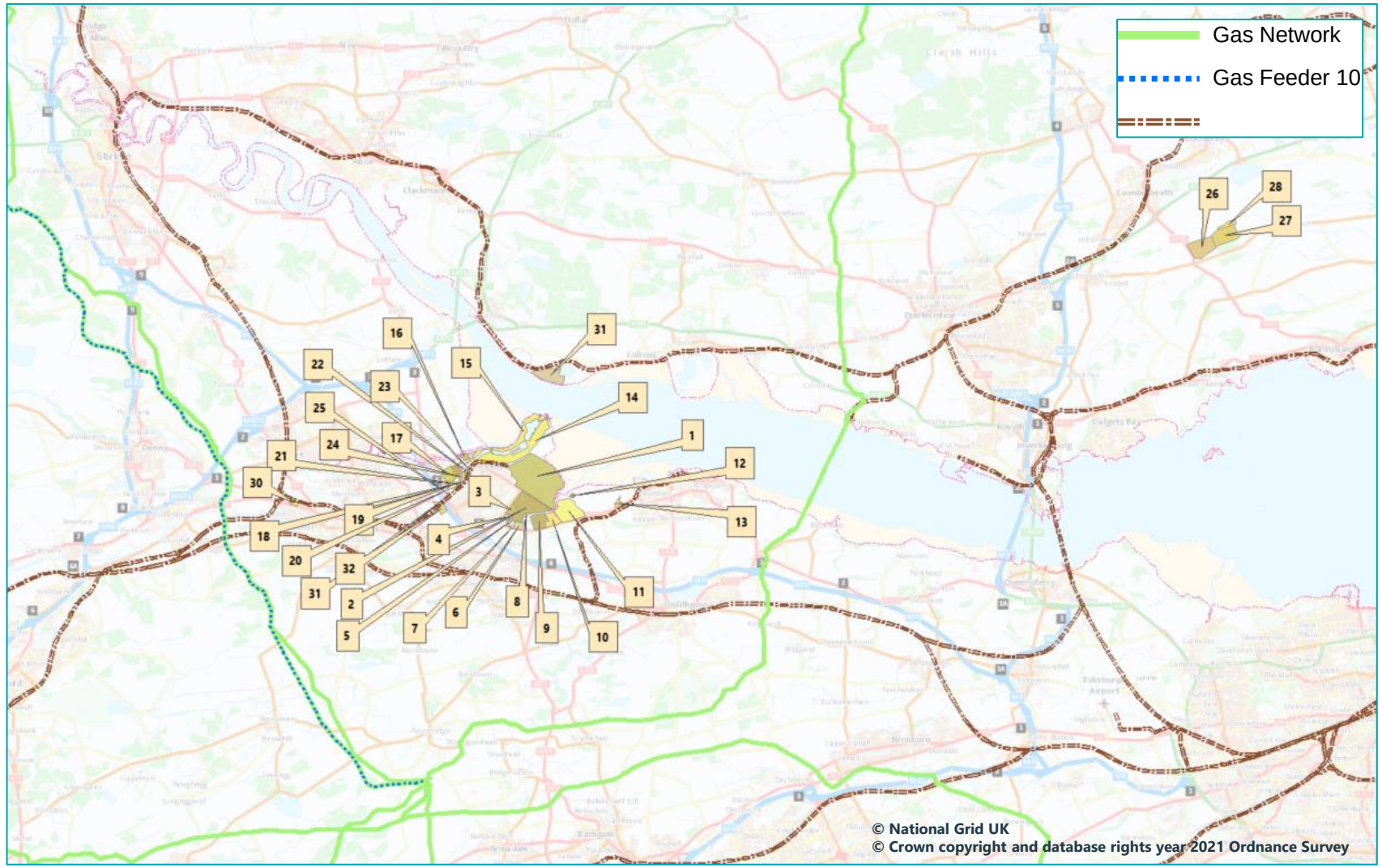
Study Objectives

- Use structured interviews with relevant stakeholders to understand their current position in terms of planned integration of hydrogen in economic activities in Grangemouth and strategic investment opportunities.
- Understand immediate views on capacity to grow hydrogen-led changes in industrial production, heat and transport sector requirements.
- Build a picture of emerging projects in the region and aspects of hydrogen production (grey, blue or green) that influence current and future feedstock/materials flows.
- Link, where possible, national projects (e.g. infrastructure pipeline investment) including SNZR outcomes, to local thinking to understand potential impacts (decarbonisation, complexity, timeframe, GVA opportunity).
- Map high level hydrogen enabling decarbonisation scenarios, giving a trajectory view to 2030, 2040 and 2045.
- Illustrate, in broad terms, how Grangemouth could become a production hub in terms of hydrogen production, transport/export/storage, and end use.

Overview of Grangemouth site

01 Grangemouth Oil Refinery - Petroineos
02 Ineos
03 Polymer Logistics Scotland
04 Verdo
05 Boc Gases
06 Dow Chemicals
07 Hewden
08 SP - Grangemouth Substation
09 Ineos
10 Versalis - Polimeri Europa
11 Ineos - Kinneil Terminal
12 Kinneil Kerse Wastewater Treatment
13 Kinneil Kerse Recycling Centre
14 Grangemouth Docks - Forth Ports and Eddie Stobart
15 Grangemouth Docks - Forth Ports and Eddie Stobart
16 Rossco Property
17 Piramal Healthcare
18 John Mitchel
19 Calachem
20 Piramal
21 H.W. Coates
22 EasySpace
23 Falkirk Council
24 International Timber
25 Celtic Renewable
26 Mossmorran Natural Gas Liquids (NGL) Plant
27 Fife Ethylene Plant
28 Gas Road Loading Terminal - Avanti
29 Syngenta
30 Alexander Dennis
31 Logannet – Talgo
32 Malcolm Rail
33 Malcolm Logistics

Wider Study Stakeholders



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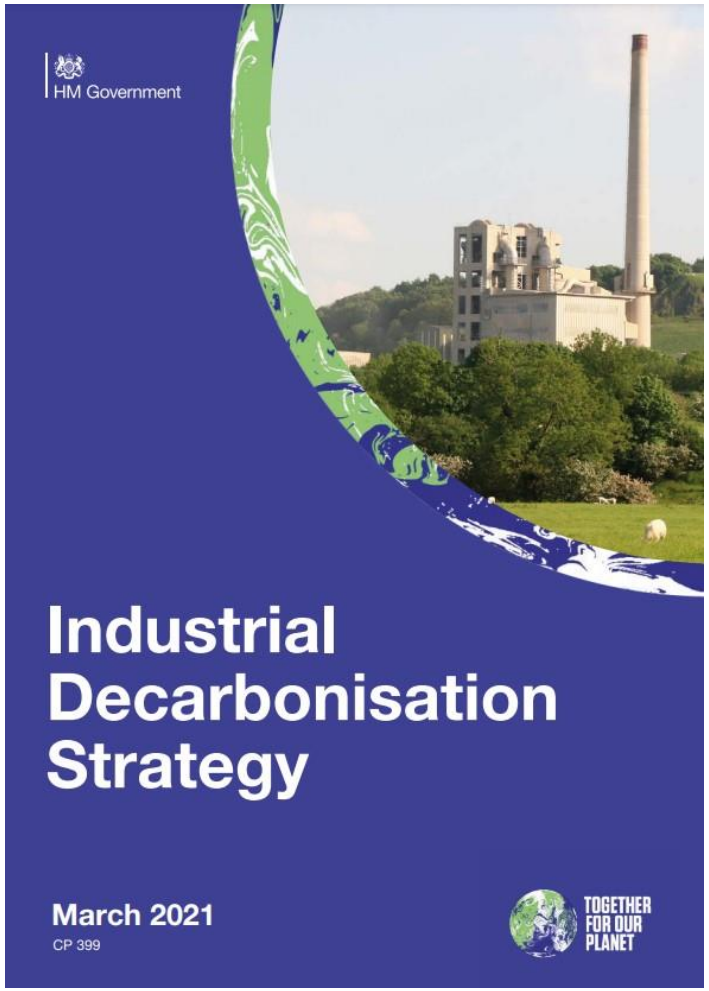
National View

Industrial Decarbonisation Strategy - UK

- Document sets out UK Government view of what a low carbon industrial sector in 2050 looks like
- Builds on ***10 point plan for a green industrial revolution*** and the ***Energy white paper: powering our net zero future***
- Specific detail regarding how Industrial Clusters such as Grangemouth decarbonise



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Technology Strategy - UK

- Hydrogen has a key role in enabling the economic transformation of the UK industrial region
- Focus on low-regret deployment of key technologies such hydrogen and CCUS, which is robust to future uncertainties such as industrial demand, technical challenges, and fuel prices
- Support increasing amounts of fuel switching to low carbon hydrogen during the 2020s
- Support low-regret fuel switching to electrification in industry during the 2020s

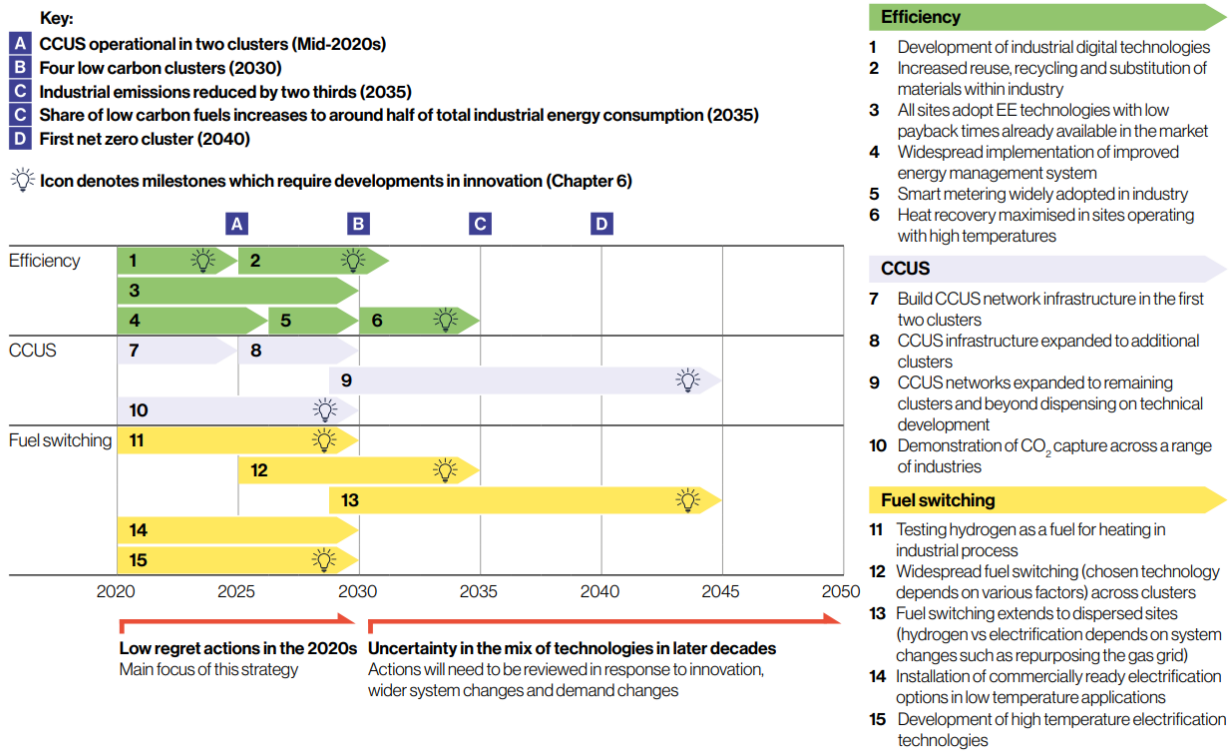
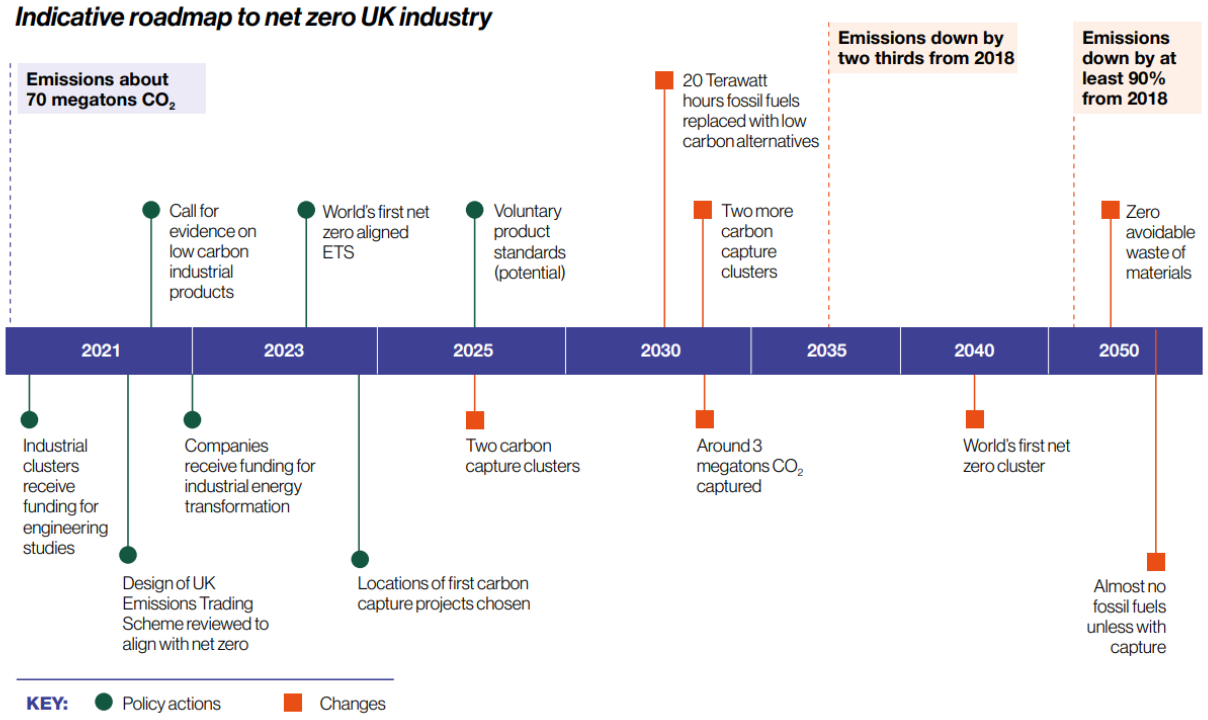


Figure 4.1: Overview of technology strategy for the next three decades

Industrial Clusters

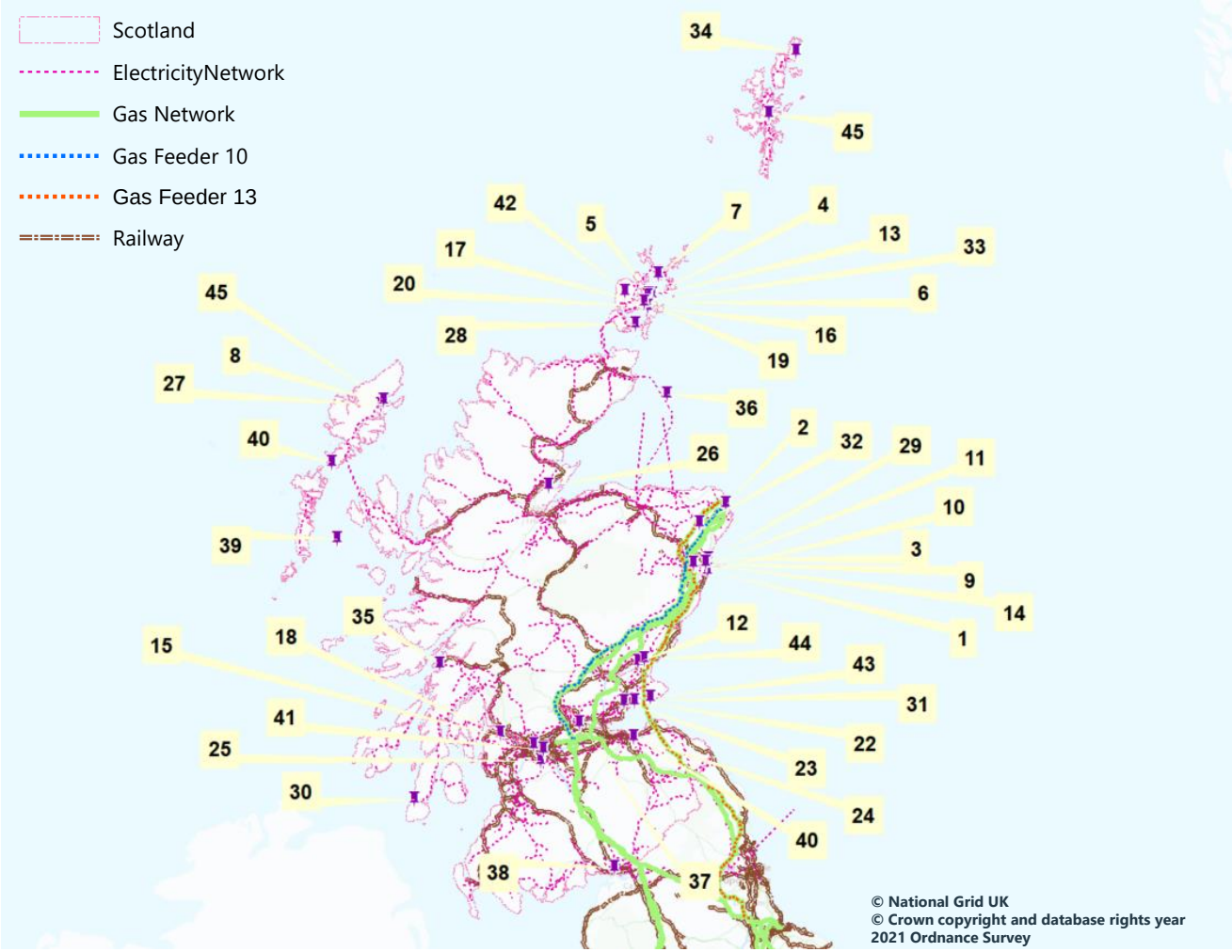
- **Key target: four major industrial regions with decarbonisation infrastructure by 2030.**
- Investment:
  - £40 million (Industrial Decarbonisation Challenge Fund)
  - £172 million (UKRI-led Industrial Decarbonisation Challenge)
  - £8 million (blueprints to achieve net zero emissions)
  - £20 million (development of an Industrial Decarbonisation Research and Innovation Centre)
  - Support the deployment of infrastructure at two carbon capture clusters by the mid-2020s through the £1 billion CCS Infrastructure Fund. A further two clusters will be supported to deployment by 2030.
  - £240 million Net Zero Hydrogen Fund for capital co-investment in new low carbon hydrogen production.



Industrial Decarbonisation in Scotland

- Scottish Government continues to target hydrogen investment in Scotland aligned with UK Government strategy
- Examples include:
  - Energy Transition Fund (£62 m) supporting net zero projects such as ACORN and the Aberdeen Hydrogen Hub
  - Emerging Energy Technologies Fund (£100 m towards hydrogen)
  - Scottish Industrial Transformation Fund (£34 m)

Scotland's Hydrogen Projects 'At a glance'



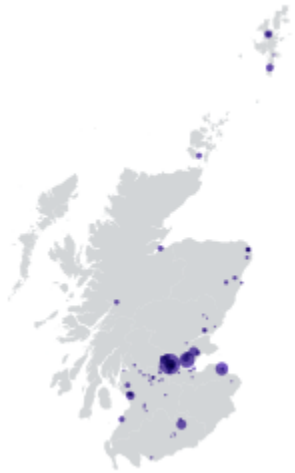
01 Aberdeen Hydrogen Centre (ACHES)
02 Acorn / Aberdeen Vision
03 AECC
04 BIG HIT - Heating
05 BIG HIT - Vehicle refuelling
06 BIG HIT - WTG, Heating
07 GENCOMM - AD
08 H2 Aberdeen - H2 busses
09 H2 Aberdeen - Vehicle refuelling
10 H2 Aberdeen - Vehicle refuelling
11 H2 busses
12 H2 busses
13 HyDIME
14 Hydrogen Fuel Cell Buses
15 Hydrogen Gritters
16 HyFlyer
17 HySeas
18 HySeas III
19 HySpirits
20 Kirkwall Airport Decarbonisation
21 Kittybrewster Refuelling Station
22 Levenmouth Community - Bright Green Hydrogen
23 Levenmouth Community - Vehicle refuelling
24 Logan Energy HRS
25 Myers Hill Wind Turbine Test Site - TUV Nel Ltd
26 North of Scotland Hydrogen Programme
27 Pure Energy - H2SEED
29 SGN H100. Heating gas network - Aberdeen City
30 SGN H100.Heating gas network - Machrihanish
31 SGN H100.Heating gas network - Methil
32 Skelmonae Green Hydrogen
33 Surf 'n' Turf - Hydrogen training
34 The PURE Project
35 TimberLINK
36 Dolphyn ERM
37 Caledonia Clean Energy Project
38 Chapelcross
39 SWIFTH2
40 Hydrogen Hebrides
40 Hydrogen refuelling Station
41 H2 buses
42 REFlex
43 East Neuk Power-to-Hydrogen
44 MSIP Dundee
45 Shetland Hydrogen Hub
45 Green Hydrogen Hub

Scottish Government - Hydrogen Policy

- The Scottish Government wants to enable Scotland to take a pioneering role in a growing global industry. While the sector is dynamic a broad timeframe is:
- In the 2020s – **Building capacity**. Support for low-carbon hydrogen production and transition of existing supply chain companies to develop and manufacture new technology in the hydrogen value chain. Establishing hydrogen demand in transport and industrial applications.
- In the 2030s – **Production at Scale**. scaling up and developing large scale hydrogen for domestic use. Developing floating hydrogen production and an export industry for hydrogen and its derivatives.
- By 2045 – **Scaling up and global expansion**: Scale up of green hydrogen for domestic use and for export; development of international hydrogen refuelling hubs and infrastructure connecting Scotland to Europe.

Government Targets and Hydrogen Potential

Island and rural communities benefit from the collocation of green hydrogen supply and demand, which can accelerate decarbonisation



Industrial clusters that are already hydrogen users can opt for blue hydrogen to support their decarbonisation.

Dense population and extensive infrastructure provide opportunities for scale economies from aggregating demand.

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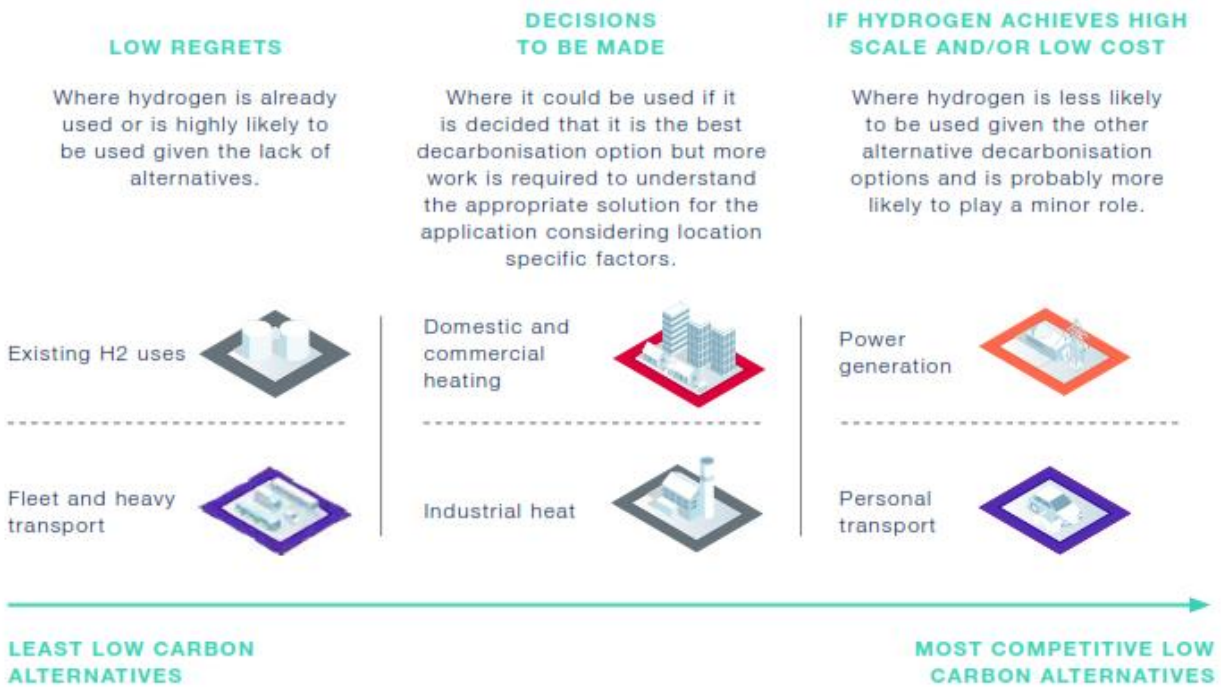
Exploring ambitions and development pathways

- The Scottish Government's H_2 ambitions are: at least 5 GW of renewable and low-carbon hydrogen by 2030 and at least 25 GW by 2045
- Industrial hydrogen users potentially unlock capacity to produce hydrogen at scale
- Fleet transport offers most likely short-term demand (HGV, bus, rail and ferries)
- Domestic heating more challenging and later development
- Offshore renewables provide further scope for hydrogen production at a scale that enables exports



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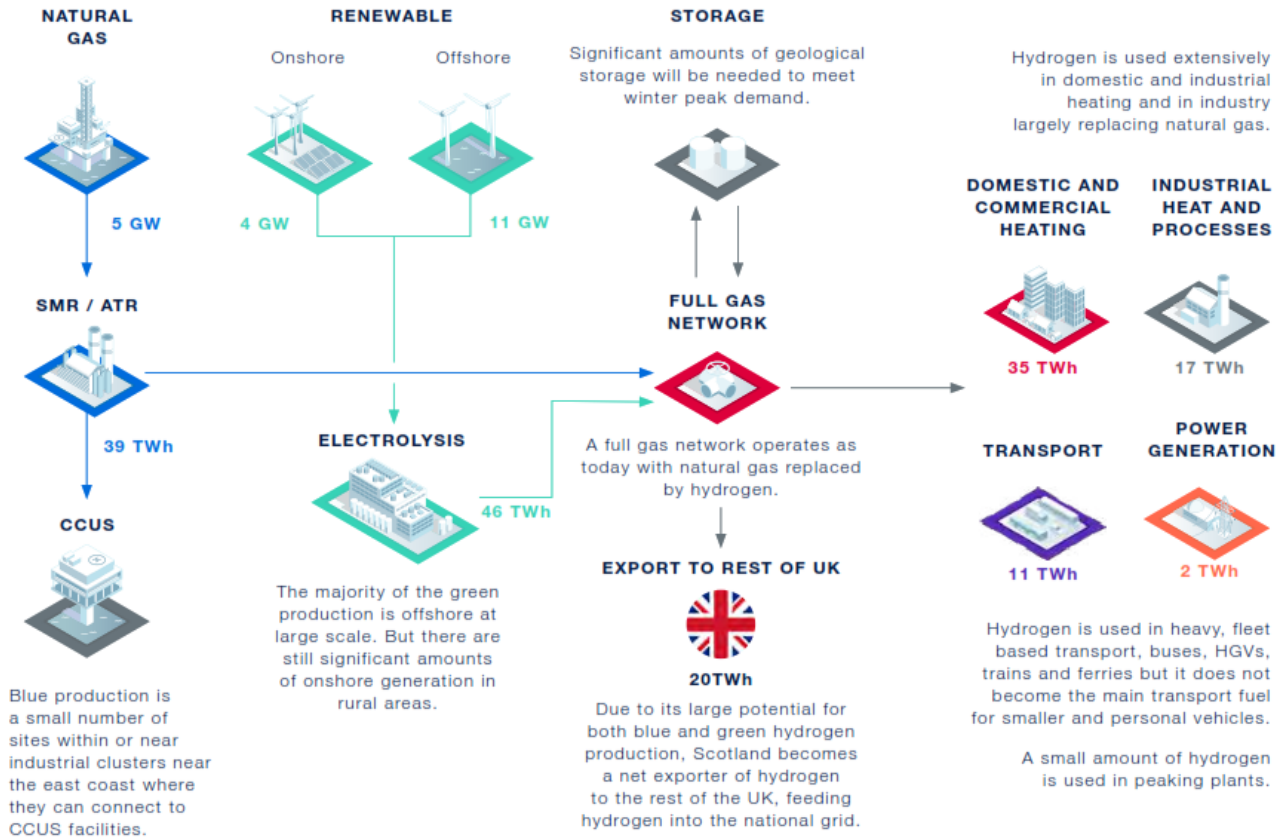
Scottish Hydrogen Assessment

- Explores potential development pathways
- Three scenarios developed that look at net economic benefits of production, transmission, supply and export of hydrogen

Hydrogen Economy

Context	Hydrogen widely used
Demand	Mainly domestic & commercial heating, industrial processes, and transport with a small amount used in power generation. Due to large potential, Scotland becomes a net exporter to rest of UK
Production	Small scale blue hydrogen production, majority is green hydrogen from onshore and offshore renewables
Challenges	• Large scale infrastructure investment required • Regulatory change to support conversion of natural gas • Financial support schemes to make hydrogen for heating and industry cost effective



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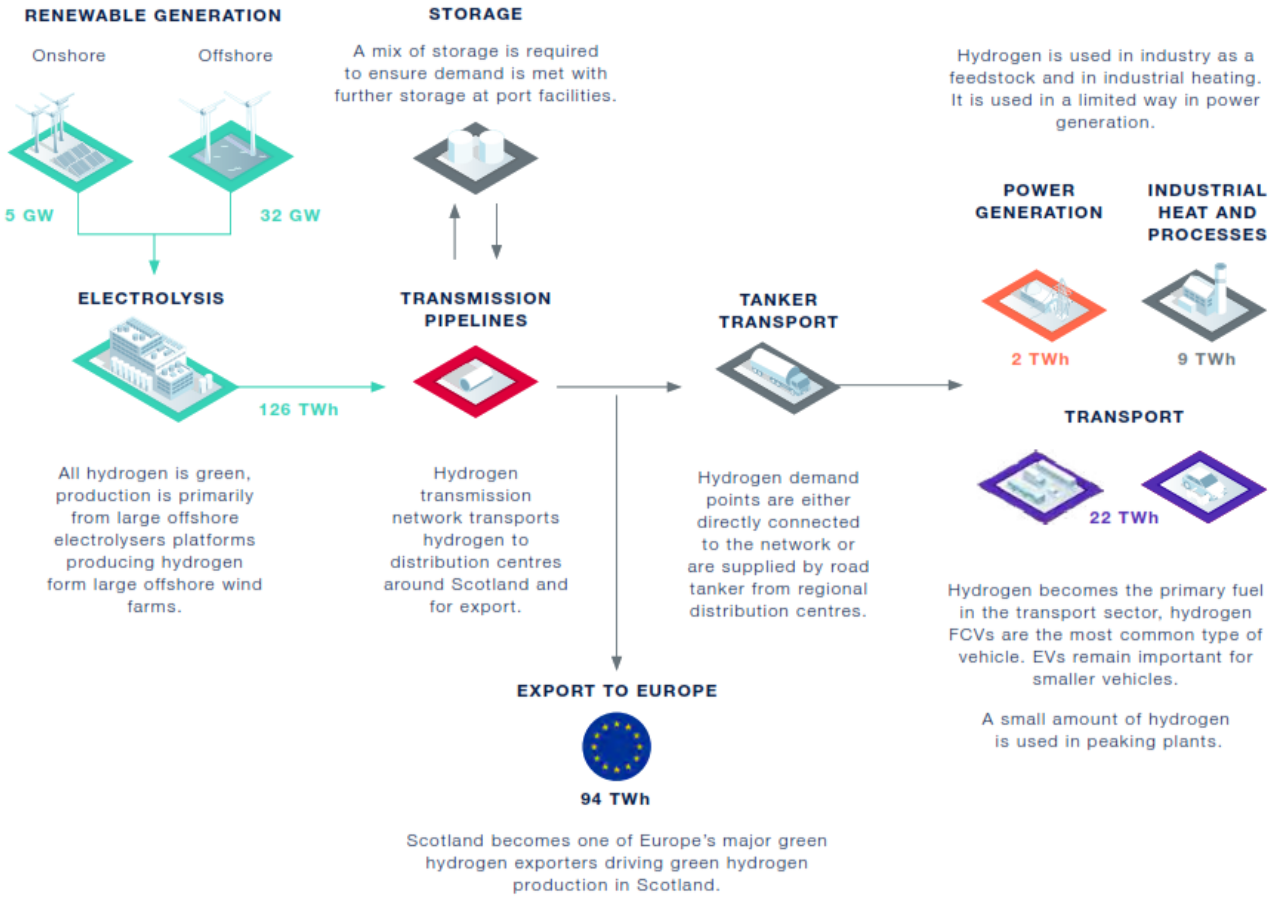
Green Export

Context	Hydrogen is used to harness much of Scotland's renewable energy
Demand	Major export to Europe and extensive uptake by local transport sector
Production	All hydrogen is green hydrogen, primarily from large electrolysers fed from large offshore wind farms
Challenges	• Significant investment in onshore and offshore renewables • Competition in export markets • Short term domestic market needs to grow to sustain longer term export ambition



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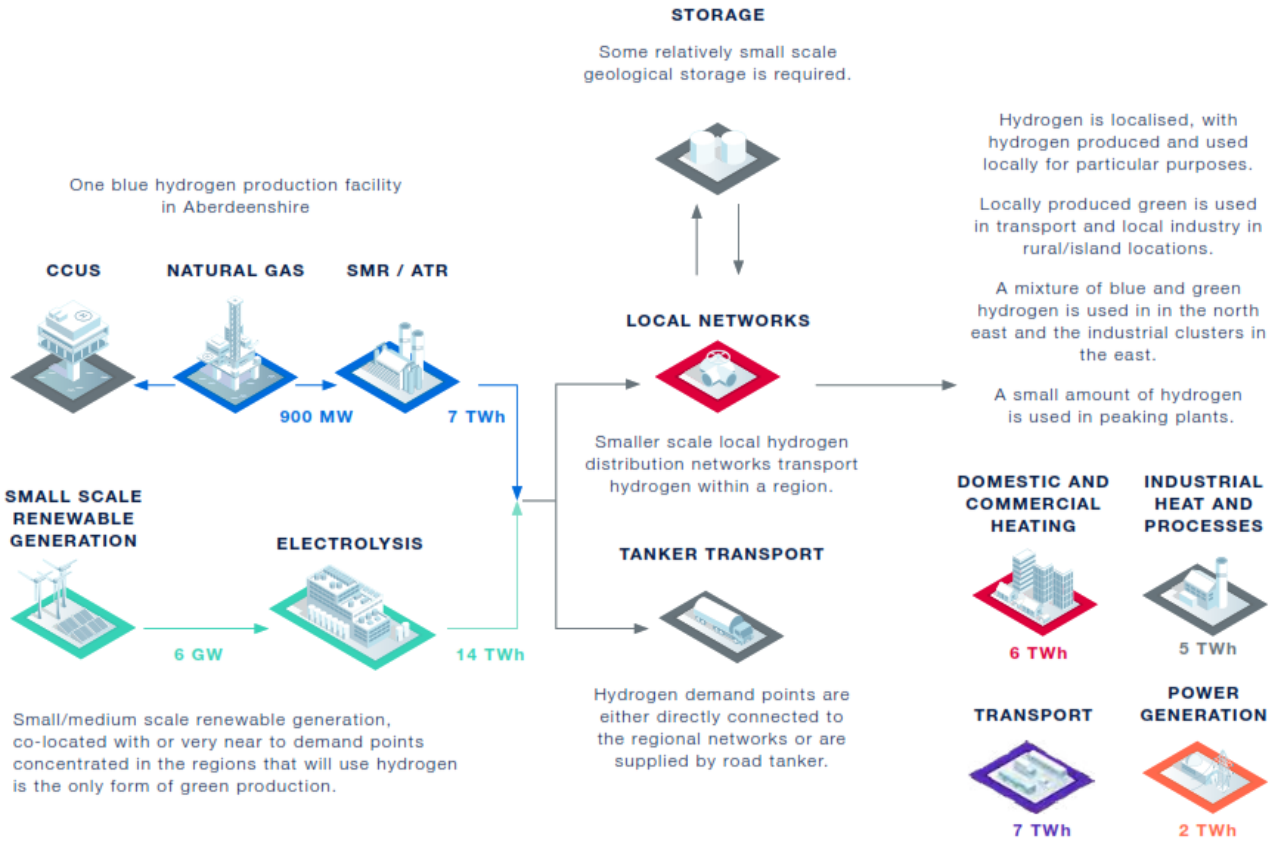
Focused Hydrogen

Context	Hydrogen production and use is regionalised
Demand	Hydrogen locally used in transport, local industry and heating, with small amount of power plant use
Production	Regional blue hydrogen production point, with small to medium scale green hydrogen from nearby renewables
Challenges	• Smaller scale assets so lower economies of scale • HGV refuelling stations need co-located hydrogen production and grid electricity



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Grangemouth – Stakeholder Engagement

Stakeholder Engagement

- In order to develop an understanding of current activities specific to the Grangemouth cluster and surrounding areas a series of stakeholder interviews were undertaken by the Wood team.
- Each interview was free-ranging but structured around some base questions
- The objective in each case was to gain understanding of:
  - Existing hydrogen activities and initiatives already explored by an organisation
  - Level of appetite / ambition to participate in hydrogen sector (consumer or supplier)
  - Initial view of wider market support and opportunities/barriers to further development
- Summaries of these discussions are provided in the following slides

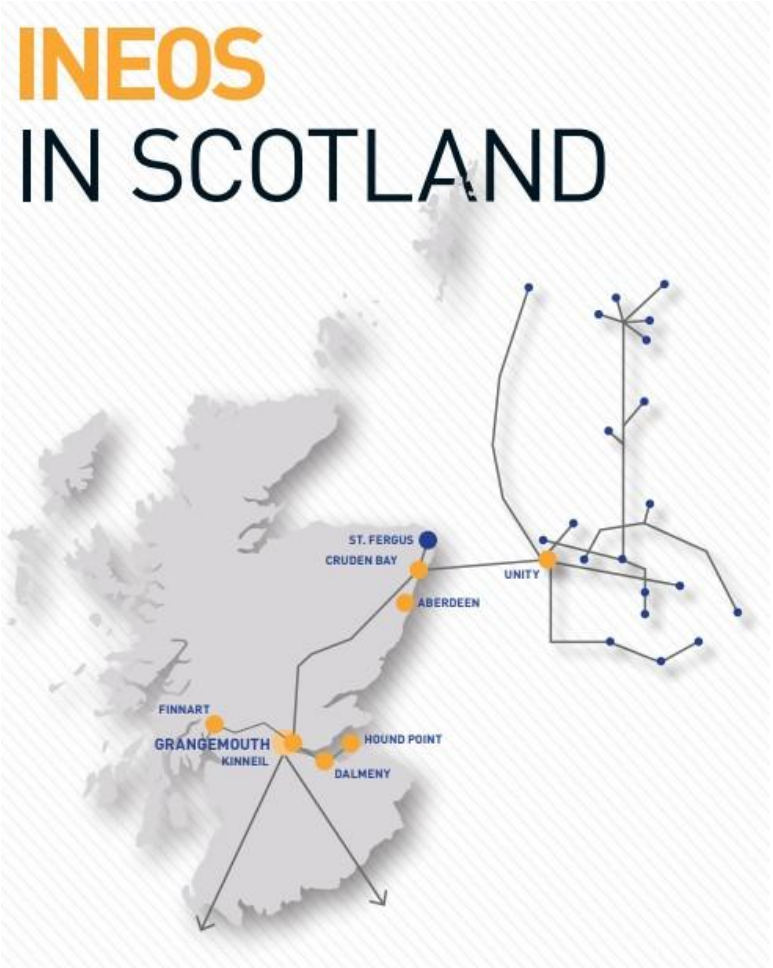
Manufacturing base

Overview of sites

INEOS at Grangemouth

INEOS FPS

- Operate transport assets for movement of oil and gas from North Sea
- Initial processing at Grangemouth and Kinneil
- Ethylene pipelines extend to NW and NE England



Shell

- Operate the Fife Natural Gas Liquids (NGL) plant at Mossmorran
  - Process separates raw products from the North Sea into propane, butane and ethane
  - The ethane is then supplied to the neighbouring ExxonMobil operated Fife Ethylene Plant (FEP)
- Products from the site are used more widely in providing sources of heat for homes not on the natural gas grid and production of car tyres
- Site is subject to Oil & Gas UK target to halve operational GHG emissions by 2030

Operator commentary

Site Operations - #1

Current Position

- Hydrogen production on-site is currently used in self-supply
- Current production output can be up to 200 tH_2 per day as a by-product from major processes
- Hydrogen currently an expensive feedstock so not used more extensively
- No existing infrastructure allows for hydrogen storage or transport via pipeline off site
- Would consider export to local consumers if infrastructure was available to do so
- Supportive of third party operators seeking development areas within wider Grangemouth site for hydrogen projects

Site Operations #2

Areas of Future Interest

- **Refinery Perspective** - Have looked with SGN at the possibility of investing in Steam methane Reformer (SMR) for production of hydrogen. Initial focus would be decarbonising own fuel usage; future might include export off site. However, need further investigation of means of CO_2 capturing process. Most likely require a pipeline to offshore storage, that does not presently exist.
- For hydrogen to be used in larger quantity would need to do more investigation on technical aspects such as transport of hydrogen to burners, flame composition and burner performance.
- **Chemicals perspective** **-** Business case for increased use of hydrogen as fuel for energy production being explored. Main challenge is timeline of change. Need an affordable and reliable source of hydrogen to justify design modification of burners to accommodate more hydrogen rich fuel. Without cost effective hydrogen fuel source expensive burner modifications become redundant.

Site Operations #3

- All options for hydrogen on the table at present with blue hydrogen a potential area of interest
- There are no specific plans for hydrogen production in the area at present
- The company intends to be a significant player in the emerging hydrogen economy
- Company would want to understand and respond to demand for hydrogen across the various sectors
- There would be interest in tying in with network development and viable routes to market for hydrogen production and use
- Company recognises the importance of micro scale early adopters in the green hydrogen economy (transport hubs for example) and are keen to be participants

Site Operations #4

- Have supported high-level studies regarding potential hydrogen markets but have no immediate plans for hydrogen production at present
- See a role for hydrogen in wider decarbonization efforts; blue hydrogen may be the lowest-cost option to decarbonize some sectors, including feedstock & high temperature heat for industry.
- The company is focused on decarbonizing its assets; contingent on an appropriate business case, it could consider being both a producer and consumer of hydrogen
- Scottish government appears to recognize the importance of the development of a hydrogen economy and the role of both electrolyser and CCUS enabled hydrogen
- Consistent pan-UK policy support, including carbon pricing, investment incentives and commercial frameworks, is a critical requirement to facilitate deployment of low carbon hydrogen
- Policy should let market prices drive the selection of solutions, provide flexibility for future adjustments to react to developments in technology and climate science, minimize complexity and administrative costs, maximize transparency, promote global participation, and ensure a uniform and predictable cost of GHG emissions across the economy.

Fuel Producers

Fuel Producer #1

Primary activity of organisation	Use a thermochemical process to convert municipal solid waste (MSW) into a syngas. This syngas is subject to further chemical processing to produce the base liquid fuels that can then be processed either as jet fuel or biodiesel. The process by which fuel is produced requires hydrogen. On-site hydrogen production is insufficient so Producer's processes are net importers of hydrogen. The gasification process also currently consumes large volumes of natural gas.	**Future View and challenges**	Target market is aviation fuels given the likely longevity of the market sector. The change in weight ratios associated with hydrogen/electric aircraft design makes development of medium/large aircraft challenging. Sustainable aviation fuel market therefore projected to remain stable in medium term. Don't see same certainty in market for HGV or bus/coach fuel.
Activities to date	Under the terms of the current Renewable Transport Fuel Obligation (RTFO) qualifying bio-based fuels must deliver a minimum 65% GHG emission saving in comparison to the fossil fuel alternative. The first UK production facility is proposed to be located in order to gain access to carbon capture storage and hydrogen generation infrastructure developed via the HyNet North West project. This provides capacity to explore how best to meet 65% target via: • Green electricity • Biogas or hydrogen to feed burners on gasifiers • Natural gas and blue hydrogen through use of carbon capture and storage Ongoing work on the NW England project is scheduled to result in final investment decision in Q4 2022 with development build out completed 2025 to enable operation in 2026	Policy view	Positive view of existing direction of Scottish Government policy position in hydrogen and carbon capture storage. Further supporting assistance to deliver system infrastructure to support transport of hydrogen and CO2 capture will accelerate hydrogen market. Initiatives such as the DfT's 'Green Fuels, Green Skies' seen as positive competitions that assist market innovation and development.

Fuel Producer #2

Primary activity of organisation	The fermentation process uses bacteria to ferment carbohydrates (e.g. starch and glucose) to produce the three chemicals Acetone, Butanol and Ethanol. Have revived the process and modified it to enable production based on inexpensive feedstocks – potatoes, draff and pot ale. The outputs of the process are all useful feedstocks for other industrial processes and as a vehicle fuel: • Butanol – Paints/coatings and biofuel • Ethanol – Medicinal uses, plastics production, biofuel • Acetone – plastics production and cosmetics • Animal feed – a solid residue from the fermentation process can be supplied as animal feed Hydrogen is a co-product of the fermentation process.	**Future View and challenges**	End uses of hydrogen need to take holistic view of net carbon benefits. See potential for haulage in/out of operating plant to be fuelled using hydrogen. Don't see hydrogen and ABE products in competition since biobutanol has wider chemicals market as well as transport sector potential. May have future interest in supplying hydrogen to transport.
Activities to date	First industrial scale production plant is currently being built at Grangemouth and will be operational in 2021. This offers capacity to produce 1 million litres of biofuel per annum No discussions with potential hydrogen customers to date. Agnostic regarding future uses for hydrogen. Internal work has looked at the potential uses for all of their co-products in a study funded by Zero Waste Scotland. Could utilise hydrogen for production plant in a fuel cell, combustion, or selling it as a product. Hydrogen could be sold to transport systems if suitable or could produce syngas. First full-scale plant will utilise hydrogen on site (no decision yet in what form, potentially conversion to syngas)	Policy view	No specific view on existing policy at Scottish Government or UK level.

Public Sector

Falkirk Council

Primary activity of organisation	The Council delivers services for the community within the Falkirk area. One important element of this is the economic development of the area, including work with industrial partners at Grangemouth. The Council is therefore involved in discussions with UK and Scottish Government, notably through the Falkirk Grangemouth Investment Zone Growth Deal.	**Future View and challenges**	Hydrogen for domestic heating won't be in play until after 2030 and likely not before 2035. Expectation that Council build the heating systems such that they can be retrospectively fitted out for hydrogen. Do not expect to see hydrogen used in district heating as not suitable for Falkirk area. A lot of the progression won't be undertaken until after the 5 year demo at Fife H100 completes. Aspirations for heavier articulated (waste service delivery) using hydrogen. Likely not for light goods vehicles. At least a year before things move forward with funding/studies.
Activities to date	To date there have been a small number of studies: • Couple of projects/studies regarding hydrogen for transport. • Northern Connections Interreg project - through this primary focus was CCU(S) but within this context Council has researched hydrogen's applicability in relation to industry partners. E.g. to feed into partner's processes.	Policy view	No specific Council policy on hydrogen at this point. Hydrogen will feature as part of the Local Heat and Energy Efficiency Strategy (LHEES). Council expects to see hydrogen use in transport first, heating later. Concurrently there will be something going on with the Sustainable Campus (private/industry led hydrogen solution). Officers are trying to discourage the reliance on hydrogen as the only solution to climate mitigation. Not expecting hydrogen to be a solution to Council's climate change mitigation. But do expect it to be built into local economic development and reduce area carbon footprint.

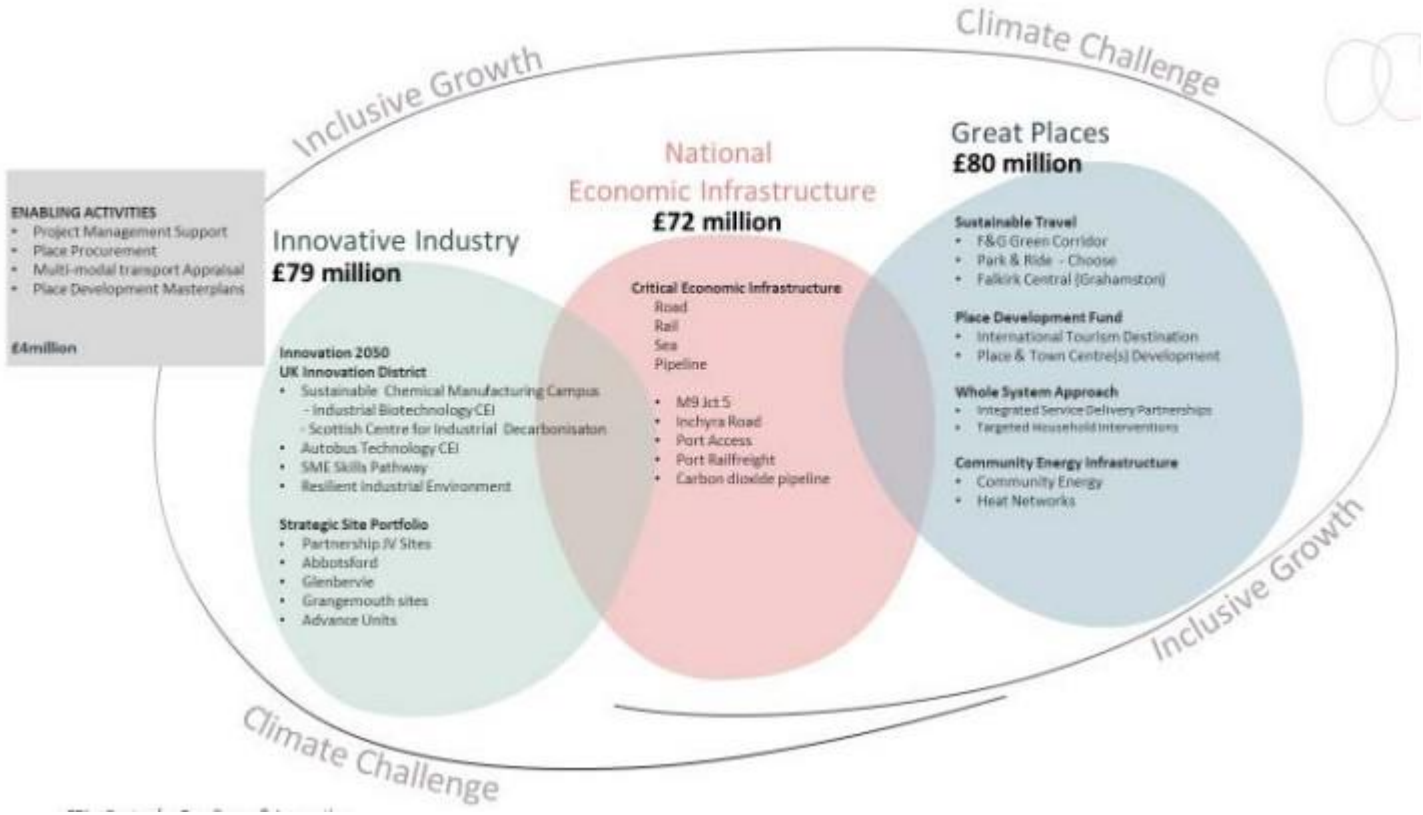
Falkirk Council

- Falkirk Council are keen to explore opportunities for Council assets to participate in overall solutions, which aid in tackling area wide issues, such as fuel poverty and decarbonisation
- Work undertaken, in line with the Just Transition Commission, hopes to recognise opportunities for new industries and partners to help grow a Grangemouth Industrial Cluster in a fair and economically beneficial way to all stakeholders located within this area. Falkirk Council is working to develop these opportunities in partnership with bodies such as NECCUS to encapsulate all viable solutions.
- Hydrogen development and investment in Grangemouth is a prime focus for Falkirk Council, given Grangemouth is a key strategic zone of national importance.

Grangemouth Investment Zone

- Work ongoing to develop workstreams associated with the Growth Deal
- If this is delivered, then it would include:
  - the development of carbon capture utilisation (CCU) technology
  - development of the port's freight handling capacity and the extension of rail freight facilities and capacity for energy related development
  - Support for wider freight and passenger movement on the Forth
  - The improvement of the town and the port's accessibility through improved trunk road and sustainable transport connections
  - Energy solutions, including district heating, to provide affordable, low carbon energy to the local community

Grangemouth Investment Zone - Overview



Transport Scotland

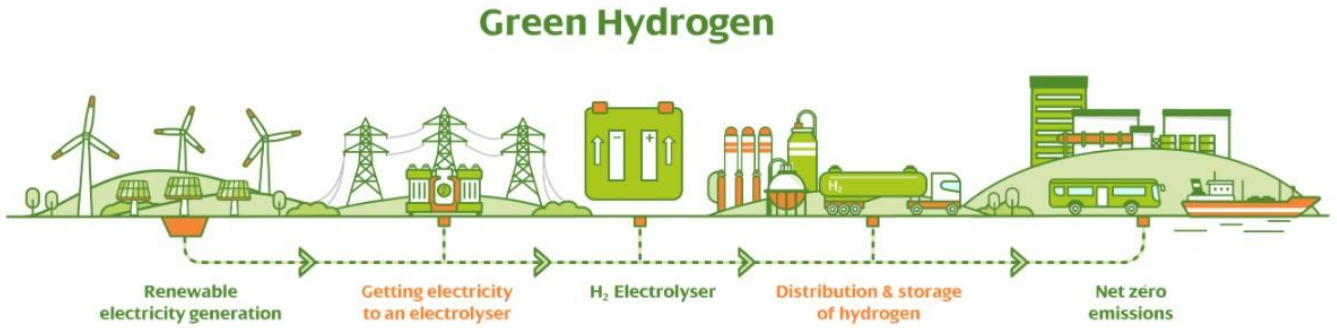
- Scottish hydrogen train to run by November 2021 - testing and commissioning to be complete in time for COP26 meeting in Glasgow
- Opportunity to build skills and experience in supply chain serving wider market in UK (many mid-life rolling stock that could be converted to hydrogen)
- No market ready hydrogen rolling stock options currently available (freight or passenger stock)
- Looking to turnkey solutions (manufacturer builds train, secure fuel supply and provide maintenance programme)
- Scottish rail decarbonisation strategy recognises that electrification is too costly for entire network
  - Hydrogen therefore likely to be dominant solution for networks in NE, NW and SW currently wholly reliant on diesel
- Uptake of hydrogen will need different operating logistics in respect of fuelling infrastructure and how operations teams support rolling stock
- Key issues is supporting infrastructure (access to hydrogen supply and how it is moved to depots/maintenance points

Utilities / Infrastructure

Scottish Power

Primary activity of organisation	Beyond core services in supporting grid electricity systems, the organization is interested in green hydrogen production and plan to develop a vertically integrated hydrogen business linking new renewables projects with hydrogen production, storage and supply assets	**Future View and challenges**	See green hydrogen as a crucial element in achieving net zero targets. The challenges associated with hydrogen production are: • High cost: energy from renewable sources, which are key to generating green hydrogen through electrolysis, is more expensive to generate, which in turn makes hydrogen more expensive to obtain. • High energy consumption: the production of hydrogen in general and green hydrogen requires more energy than other fuels. • Safety issues: hydrogen is a highly volatile and flammable element and extensive safety measures are therefore required to prevent leakage and explosions.
Activities to date	'Green Hydrogen for Scotland' – a partnership of ScottishPower Renewables, BOC – a Linde company, and ITM Power – brings together industry-leading names in the renewables and clean fuel industries to offer an 'end-to-end' market solution for reducing vehicle emissions through the provision of green hydrogen. The partnership's first project, 'Green Hydrogen for Glasgow', is designed to provide carbon-free transport and clean air for communities across the city, which wants to become the first net-zero city in the UK by 2030. A proposed green hydrogen production facility located on the outskirts of the city will be operated by BOC, using wind and solar power to operate a 20 MW electrolyser, delivered by ITM Power. The project aims to supply hydrogen to the commercial market within the next two years. Recognise that early projects are likely to be on a small scale with hydrogen offtake most likely coming from the transport sector (esp buses, RCVs etc)	Policy view	Continue to support UK and Scottish Government action in this area. Through targeted funding at national level, such as Growth Deals, there is scope to accelerate deployment of hydrogen. If hydrogen demand was emerging in the Grangemouth area they would potentially identify suitable locations in the general area to develop small scale onshore wind and PV projects to power (through renewables PPAs rather than private wires). Kincardine Power Station site (still owned by SP) was mentioned as a potential location for PV. They believe that this small scale hydrogen production could be commissioned in 2-3 years if demand identified Long term aspiration would be the siting of large scale electrolysis in the Grangemouth area linked (by PPA) to GW scale offshore wind project being considered by SPR

Scottish Power



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SGN

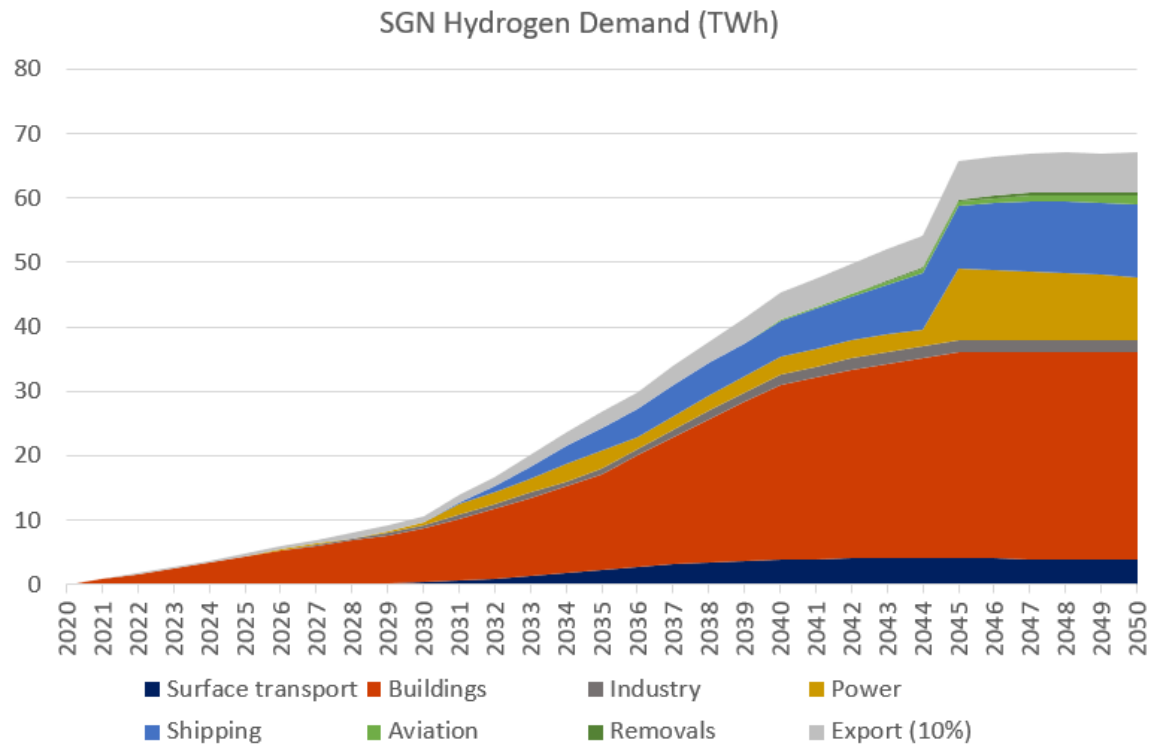
SGN's North East Network & Industrial Cluster Development project is a feasibility study investigating the potential to reconfigure SGN's gas distribution network in the north east and east coast of Scotland to separately transport hydrogen to end users and captured carbon dioxide (CO_2) to geological stores.

The Project consists of four sequential feasibility phases:

- Phase 1 Background and literature review.
- Phase 2 Hydrogen use and carbon dioxide generation.
- Phase 3 System configuration.
- Phase 4 Analysis and conclusion.

SGN – Assessing CO_2 and hydrogen scales

- The study has quantified the challenge of CO_2 capture and transportation to storage for the study area. Last available data from 2017 indicates that 11.1 million tonnes per year of CO_2 was emitted by these point sources.
- Projections of hydrogen demand have also been developed to assist system capacity assessment



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SGN – Future systems optioneering

- Using the CO_2 generation and potential hydrogen opportunities in the SGN study area an extensive optioneering exercise has looked to determine the optimal system re-configuration of SGN's gas network to carry hydrogen to end users and CO_2 from emitters to long-term geological storage.
- The methodology utilised multi-criteria decision analysis (MCDA) following established UK Government standards and best practice; using an industry recognised multi-criteria decision-making process to facilitate the identification and assessment of options.
- A list of 13 system re-configuration options were subject to the full MCDA assessment. Five of these were identified from a combination of observations and assumptions made by members of the Project team covering the reuse of existing facilities and infrastructure including National Transmission System (NTS) feeder pipeline 'F13'

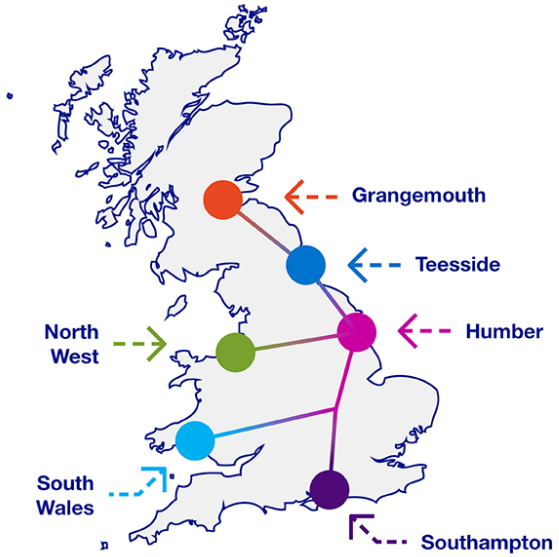
National Grid / SPEN

- New Energy Plant (NEP) on INEOS site will assist in alleviating some of local grid constraints
- Further investment in local grid network proposed out to 2025

wood.

National Grid - FutureGrid

- Ongoing work is looking at the potential for a 'hydrogen backbone' providing hydrogen transmission capacity between Industrial Clusters (including Grangemouth)
- FutureGrid testing facility in Cumbria (operational in 2022) will continue work looking at real world testing of transmission networks to assist re-purposing for hydrogen
- This complements existing test facilities as part of the H21 project



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Forth Ports

- Forth Ports is the largest port group in Scotland, operating 7 strategically located ports, providing fast and efficient access to major industry hubs and 70% of the Scottish population

Grangemouth	Leith	Dundee	Rosyth	Burntisland, Kirkcaldy, Methil
Largest port within the Scottish group, home to Scotland's largest container terminal, and oil and gas terminal infrastructure	Situated just 3 miles from the centre of Edinburgh it is the largest enclosed deep-water port in Scotland.	Market leader within emerging offshore renewables market.	Scotland's best connected port. With unrivalled logistics links and excellent marine capability.	These Fife satellite ports each offer their unique strengths; all of the Fife ports can deliver solutions for a range of sectors

- Following strategic investment in each port, Forth Ports Scotland has grown to employ and support over 10,000 direct, indirect and induced jobs within the economy, and directly generates over £550 million of economic value.
- Within the rapidly evolving net zero context of the UK recognise that the Firth of Forth area has huge potential as a net zero industrial cluster and a strategic location for hydrogen production.
  - Scotland's largest industrial cluster
  - Strategically located in Scotland's Central Belt,
  - Logistical hub linking the North Sea to European and global markets,
  - North Sea access: energy source and carbon sink
  - Wide range of port and marine loading infrastructure with tanker access

Forth Ports

- Recent investment includes extending railhead with dual sidings
  - This opens up capacity for longer freight trains
- This bolsters existing rail services that link Grangemouth with Tilbury docks – avoiding significant GHG emissions associated with bulk goods movement by road

Transport

Emerging Picture

- Innovation occurring across Scotland

Rail

Diesel to hydrogen replacement

HGV

Fuel cell drive trains

Public Transport

Hydrogen fuelled buses

Marine

Hydrogen vessels

Flight

Hydrogen fuel

Transport company #1

Primary activity of organisation	**Haulage activities include:** • Container transport via fleet of sliding, step frame, tipping or lightweight skeletals (20, 30 and 40ft trailers available across all types) • Curtainside trailers for palletised cargoes, timber and general haulage requirements. • Tankers for bulk goods, non hazardous loads and ADR regulations transport. • Bulk ISO tanks delivery and loading services, together with import / export arrangement. • Rigid vehicles equipped with demountable bodies, lorry mounted cranes and tail lifts. Also operate warehouse facilities and container services facilities. Area of activities is whole of Scotland and North of England	**Future View and challenges**	Main issue at present is capital cost and availability of hydrogen vehicles on the market. Currently understand secondary market value of a 5 year old vehicle – but no similar market for low emission vehicles See electric leading change in fuel for lighter vehicles and hydrogen for larger vehicles. Need sector to move in unison – otherwise higher investment costs by one haulier will see them undercut by competitor running cheaper diesel fleet Don't see supply of hydrogen as a major difficulty – viable capital cost for new hydrogen vehicles is major issue given no likelihood of customers paying a premium for hydrogen fleet.
Activities to date	Have looked at variety of options including an LNG vehicle. See LNG as fossil fuel option so haven't pursued further. Turnover of vehicles is typically based on age and mileage. Continue to feel moral pressure to look for low emission vehicles. Have recently been looking at expanding the business and took account of potential additional electricity demand linked to electric vehicles in designing facilities. Continue to be asked about low emission vehicles by customers – though not setting minimum requirements at present	Policy view	Need some strong market signals to give confidence in investment costs of new vehicles. Fuel subsidy position also needs to be looked at – perhaps revise fuel duty to make fossil fuels much more expensive and look for a price per km travel model. Need all hauliers to be able to broadly change at same rate to avoid undercutting by remaining diesel fleets.

Transport company #2

Primary activity of organisation	Global leader in the design and manufacture of double deck buses and is also the UK's largest bus and coach manufacturer. Offers single and double deck buses, with vehicles in service in the UK, Ireland, Europe, Hong Kong, Singapore, New Zealand, Mexico, Canada and the United States.	**Future View and challenges**	Need further development of thinking about fuelling infrastructure - how hydrogen supply is secured, transported and fuelling points maintained Aftercare offering by manufacturer crucial to successful uptake. Leasing models and maintenance packages likely to be important aspect of overall market.
Activities to date	Continue to develop hydrogen fuelled designs for double-decker buses Have seen significant increase in demand for low emission vehicles in past 18 months. Now around 50% of new sales (against anticipated 25% share of production vs ICE models). Majority sales of low emission vehicles are electric at present – don't have mass production hydrogen bus at present Anticipate demonstrator hydrogen vehicle to be operating in time for COP26 with a view to full production by 2023 See hydrogen as offering a long term advantage over electric vehicles in terms of fuelling capacity and logistics for lengthier routes Keen to see local use of hydrogen vehicles in Falkirk and Grangemouth area.	Policy view	Consider Scottish Ultra Low Emission Bus Scheme (SULEB) Rounds I & II as a success – though no significant breakthrough for hydrogen on those funding rounds. A similar funding round focussed on hydrogen could stimulate the market.

Transport company #3

Primary activity of organisation	Operator of logistics delivery across UK. Fleet of goods vehicles used in road haulage and integration of multi-modal freight movement notably via rail. Operator is active in the Grangemouth area with significant volumes of freight passing into and out of the site daily.	**Future View and challenges**	Scale of investment in alternative vehicles is difficult to achieve at present given uncertainty in respect of both re-sale value and aftercare packages offered by OEMs. Challenge for battery electric options is to avoid too great a compromise in respect of reduced payload when designing battery requirements (and therefore range).
Activities to date	Existing diesel vehicle fleet is turned over every 4 years. This ensures that the business maintains a new and efficient fleet. Maintain regular dialogue with preferred OEMs to keep pace with latest developments in fuel efficiency and vehicle design. Previous investment in LNG vehicles saw these operate for a couple of years. The single source fuel supplier withdrew fuel delivery service which means vehicles are now laid up. An electric fleet vehicle is on order. The main concern with future electric solutions is the loss of payload (ca. 1 tonne) as a consequence of the weight of batteries required. This has significant cost implications.	Policy view	Will need a supportive policy environment to enable a shift in investment.

Knowledge networks / transfer

NECCUS

Primary activity of organisation	An association supporting industrial decarbonization (c. 15 members). NECCUS work involves a variety of things, including trying to link projects and clusters to the wider Scotland area. NECCUS are leading Scotland's Net Zero Roadmap (SNZR). It is 1 of 6 UK Government funded Cluster Pathway Plans being conducted. The SNZR cluster is looking at c. 30 industrial emitters on East Coast (area from Lothian to Aberdeenshire); Grangemouth contributes approximately one third of the total cluster emissions. The output of the study will be an energy systems model with a view of required infrastructure to take decarbonization forward, linking with local hubs. NECCUS also take an active role in advocating next step requirements and maintaining active dialogue with Scottish government.	**Future View and challenges**	Hydrogen's usefulness can only be established by identifying and evaluating alternatives. For example: High Heat Industry - It appears that Hydrogen is the only realistic fuel source for fuel switching. Electricity can't currently support these high heat processes; low TRL options also appear inefficient. Transport - In urban areas, EVs look like they will fulfill the demands of short journeys and abundant fueling places easily. However, rural areas where distances covered are larger or fewer charge points more useful for hydrogen. HGVs and marine transport also look likely candidates for a hydrogen role. District Heating - For Scotland it looks as if Hydrogen may be useful for decarbonising the heat network. Grangemouth is well positioned for a lot of the industries that may require hydrogen, and with local buy-in could become a useful distribution centre of hydrogen. For hydrogen to properly take-off, it needs demand and it needs Leaders. Grangemouth is likely to be one of these leaders. Building hydrogen networks is the biggest impediment to success. The skills required to operate, produce and distribute hydrogen are available. Hypothetically, there are numerous pipelines running from Aberdeen to Grangemouth. If you dedicate just one of these pipelines to hydrogen this would kick start a hydrogen network and be able to deliver serious amounts of hydrogen.
Activities to date	NECCUS offer their services to a variety of projects, whether to make up an expert panel or to offer experienced opinions and views. Only lead SNZR presently. A large part of their work is also to dissect the work done by other studies and disseminate the key points to their members, ensuring they're aware of key developments and results without them having to spend the time reading through all the outputs.	Policy view	NECCUS believe that realistically the Scottish Government do not have sufficient powers to make the necessary policy changes needed, they are not devolved. Believe that there is good alignment within the Scottish Government on what is needed to reach decarbonisation goals, and hydrogen is a part of that. It needs to be UK government decisions that drive action (e.g. can't make change to Scottish gas network if not also followed in rest of UK).

wood.

The Interdisciplinary Centre for Circular Chemical Economy (NIC3E)

Primary activity of organisation	NIC3E is the UKRI Interdisciplinary Centre for Circular Chemical Economy. NIC3E is part of £30 million government investment, funded by the UKRI Strategic Priorities Fund, with DEFRA and BEIS, to move the UK towards a circular economy in the textiles, construction, chemical and metal industries. The NIC3E consortium is made up of 7 universities and numerous organisations, including: Cardiff University, Loughborough University, Heriot-Watt University, Imperial College London, Shell, Unilever, Scottish Enterprise, ExxonMobil, Zero Waste Scotland and Chivas Brothers.	**Future View and challenges**	NIC3E will be selecting a range of businesses from different sectors for case studies. Will look at a business's activities as well as its customers. The 2 main points addressed in a case study will be: - What motivates the business to decarbonise and what are their capabilities to address this? - How can circularity meet the performance requirement of the business? Development of NIC3E: - Jan - June 2021: Looking into circular economy literature further to enhance understanding of requirements. - Summer 2021: Prepare questions for businesses and create structure for Case Studies. - End of 2021: reflect on findings and share with businesses The businesses for case studies have not yet been chosen. A full supply chain map will need to be constructed and organisations at different points on the map will be chosen. Grangemouth could be one of the case studies.
Activities to date	NIC3E is focused on the chemicals sector. NIC3E want to transform the UK chemical industry's linear supply chain model into a fossil independent, climate-positive and environmentally friendly circular economy. NIC3E believe they can achieve this by creating a novel circular resources flow of olefins and their complementary feedstocks, which is of overwhelming importance to the chemical industry, accounting for >70% of all organic chemical production.	Policy view	NIC3E has a focus on new enabling technologies, recognizing that there is no 'one-size-fits-all' approach. Various new technologies to recover chemical feedstocks from end-of-life materials are required, including: Bio Thermal (Waste biomass to alkanes and olefins), Electrochemical (CO_2 to olefins) and Hydrogenolysis (Waste Polymers to alkanes). Need to look at whole system approach, advancing the knowledge on the evolving chemical value-chains over their entire life cycle, instead of looking at individual points (Process integration, LCA & Social justice).

IDRIC

Primary activity of organisation	The Industrial Decarbonisation Research and Innovation Centre (IDRIC) has been formed to support the UK Industrial Decarbonisation challenge (IDC) of the Industrial Strategy Challenge Fund (ISCF), which aims to establish at least on low-carbon industrial clusters by 2030 and the first net-zero carbon cluster by 2040. IDRIC works with academia, industry, government, and other stakeholders to deliver the multidisciplinary research and innovation agenda needed to decarbonise the UK's industrial clusters.	**Future View and challenges**	The future scale of electrification is heavily dependent on the levelized cost of energy and therefore price to consumers. Different industrial sectors face different challenges in their decarbonisation options – hydrogen can support some while others may need different solutions (e.g. biomass). Efficient use of these resources needs a national approach that successfully ties together local and regional projects in an integrated decarbonisation approach.
Activities to date	There are 9 multidisciplinary integrated programs (MIP) that address different research and innovation priorities, such as system planning and infrastructure, operating net-zero industrial clusters, scale up opportunities, energy vectors, CCUS, large scale deployment of hydrogen systems as well as policy, skills and knowledge exchange. In generic terms, the projects (relevant to hydrogen) address: • Scalability of electrolysers: how much we can scale them up. And with that scalability, what are the potential opportunities or challenges that are created around electrolysers. • Where hydrogen storage opportunities are closer to industrial clusters: large quantity of hydrogen to be produced, we need suitable storage and may need different solutions at scale. • How hydrogen may be recovered from certain processes happening in industry and how they may integrate into specific industries, (e.g. steel, refining and chemical industries). • Clusters deploying infrastructure: integration of pipelines and distribution logistics of hydrogen supply. • Fuel flexibility if we convert combustors into using hydrogen or hydrogen mixtures instead of natural gas.	Policy view	Agree with Scottish Government position that hydrogen has a significant role to play in achieving net zero targets. Important that all actors in the sector maintain view of what is a very fluid space. This ensures that there is a clear view of how best the research and innovation sector can support wider decarbonisation objectives.

wood.

IBioIC

Primary activity of organisation	IBioIC is a networking and support organisation that connects industry, academia and government to bring biotechnology processes and products to the global market. IBioIC has an Industrial Network of approximately 125 companies that are invested in industrial bio-technological processes. In the main IBioIC support companies that are conducting industrial biotechnology work for sustainability reasons. However, sometimes organisations are also doing industrial biotechnology work as it is the only solution and not just for sustainability e.g. healthcare and vaccinations. IBioIC use their academic base to support companies in their work, network (put companies together to help development) and fund the academic element of their work.	**Future View and challenges**	IBioC would most likely ride the Hydrogen wave, rather than drive it. By this, we mean that the activities being undertaken in the biotechnology sector are not large enough to drive the use of hydrogen (e.g. emissions in this field that need to be reduced are significantly smaller than those in the heating sector). However, feel that they would certainly take advantage of hydrogen landscape developing and would make the most of it. The hydrogen market as it is, is not really limiting IBioIC and its current work. As discussed previously, if cheap hydrogen was available then it would be of more interest and would create more opportunities for biotechnology works but is not currently constraining working.
Activities to date	In IBioC line of work, have seen that naturally occurring systems can use Hydrogen as an input. If green Hydrogen can become cheap enough for it to be economically feasible, there is definitely an opportunity for it to be used in fermentation processes to create feedstocks. For example, the use of CO_2 & H_2 in producing ethanol. More broadly, could be useful in augmenting existing processes. Bio-ethanol production from sugar (whether that be sugar beet or sugar cane) still results in some CO_2 release from the process. An interesting element is looking at capturing this sort of CO_2. Hydrogen could be used as a reductant in this process and used to reduce CO_2 release. Exploring potential for a sugar beet refinery to produce bioethanol and feedstocks for biobased chemical production. Initial study suggests it is feasible to produce sufficient bioethanol to meet current demand for 10% blending in petrol volumes. This needs further work to engagement with Grangemouth site, initially in terms of identifying land availability for siting of the bio-refinery.	Policy view	The proposed sustainable manufacturing campus should be a facility that can demonstrate all the technologies discussed and prove that these fairly well known and standard technologies can be used in a sustainable way. This relies on cost effective green or blue hydrogen, which needs potential market incentives to achieve in the short-term. Green or blue hydrogen would be necessary to make this work, but it would have to work economically. Presently, fossil fuels are too cheap in comparison to make an economic case.

wood.

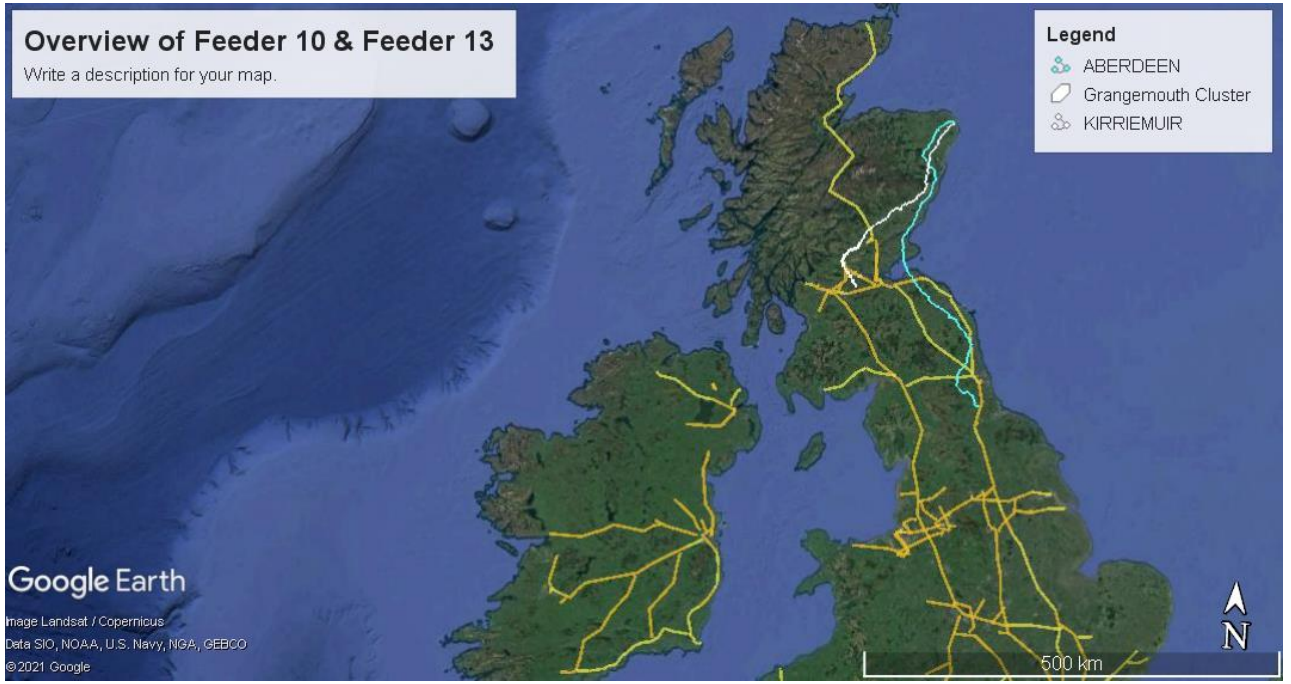
Infrastructure Overview

Supporting Infrastructure

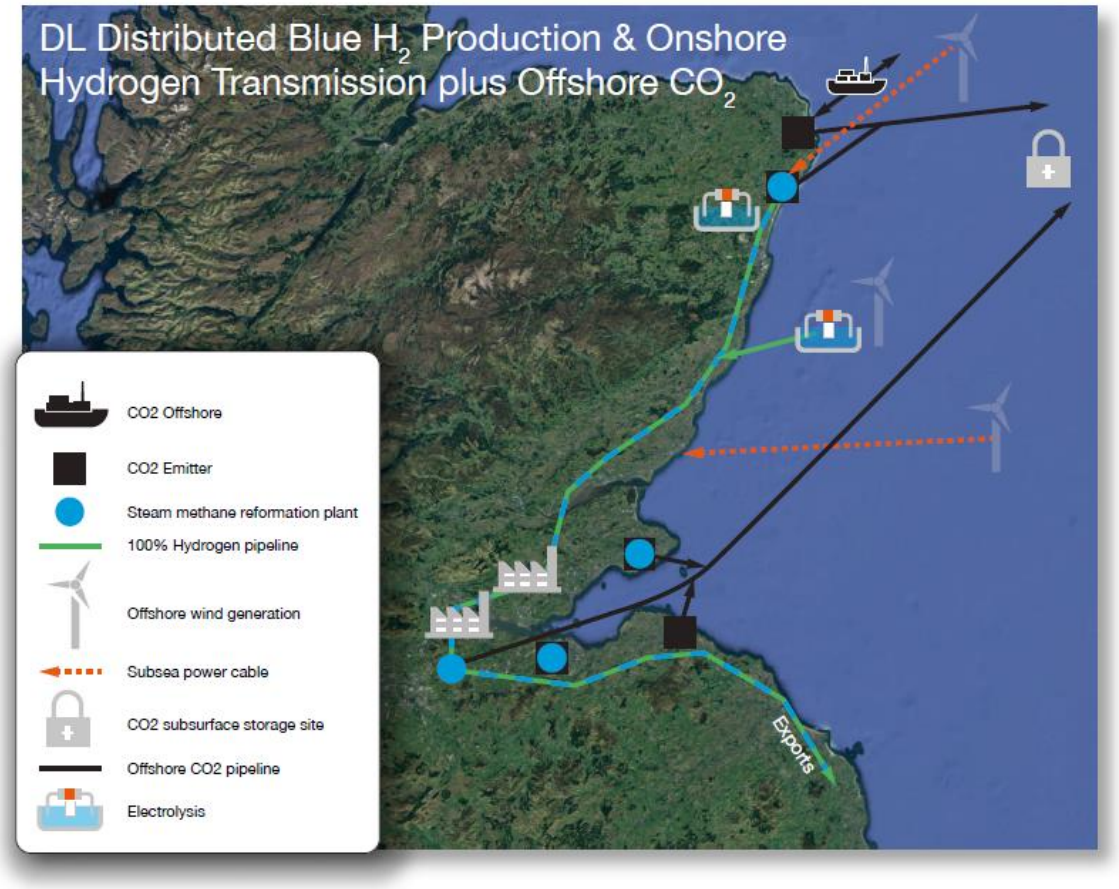
- The Grangemouth site provides a critical hub for the movement of oil and gas related products
- The scale of its operations means that it has an important role to play in developing the hydrogen economy and supporting carbon capture storage (CCUS)
- This is shown by the fact that the Grangemouth Refinery, the Grangemouth Olefins plant and the Kinneil Terminal form three of the largest industrial emitters in Scotland. These are supported by combined heat and power (CHP) plants, and together with the Versalis plant, the Grangemouth complex emitted 3.8 million tonnes CO_2 in 2017
- The following slides bring together information relating to key infrastructure that can play a role in supporting hydrogen development

Existing Natural Gas Pipelines

- There are two major natural gas transmission routes as shown here
- Around 25% of all UK gas is received by processing plants at St. Fergus and then injected into the transmission network



SGN – Potential Future System Vision



The ACORN project at St Fergus is one of several blue hydrogen production sites that could emerge in the East of Scotland

The carbon capture storage associated with blue hydrogen production can stimulate offshore subsurface storage and CO_2 transfer

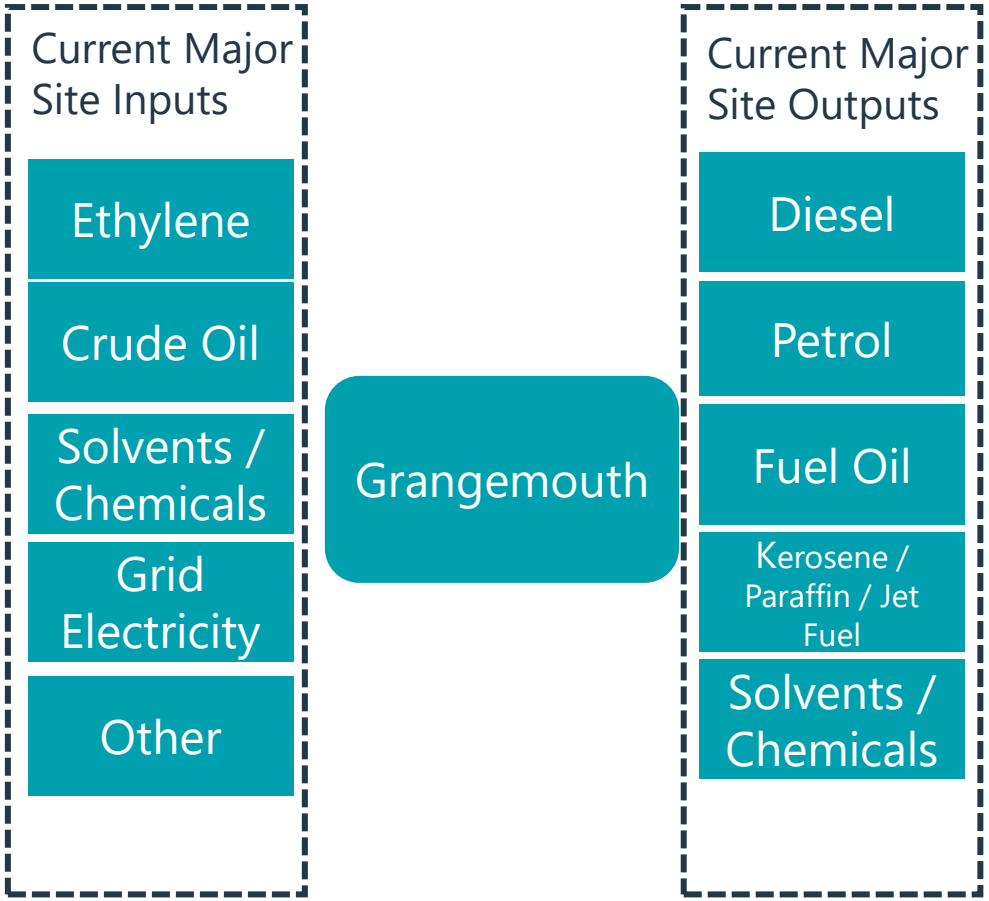
As offshore renewable generation capacity increases this offers scope to support increased green hydrogen production (onshore and/or offshore)

Re-purposing existing natural gas networks can enable large-scale supply of hydrogen for industrial and domestic consumers

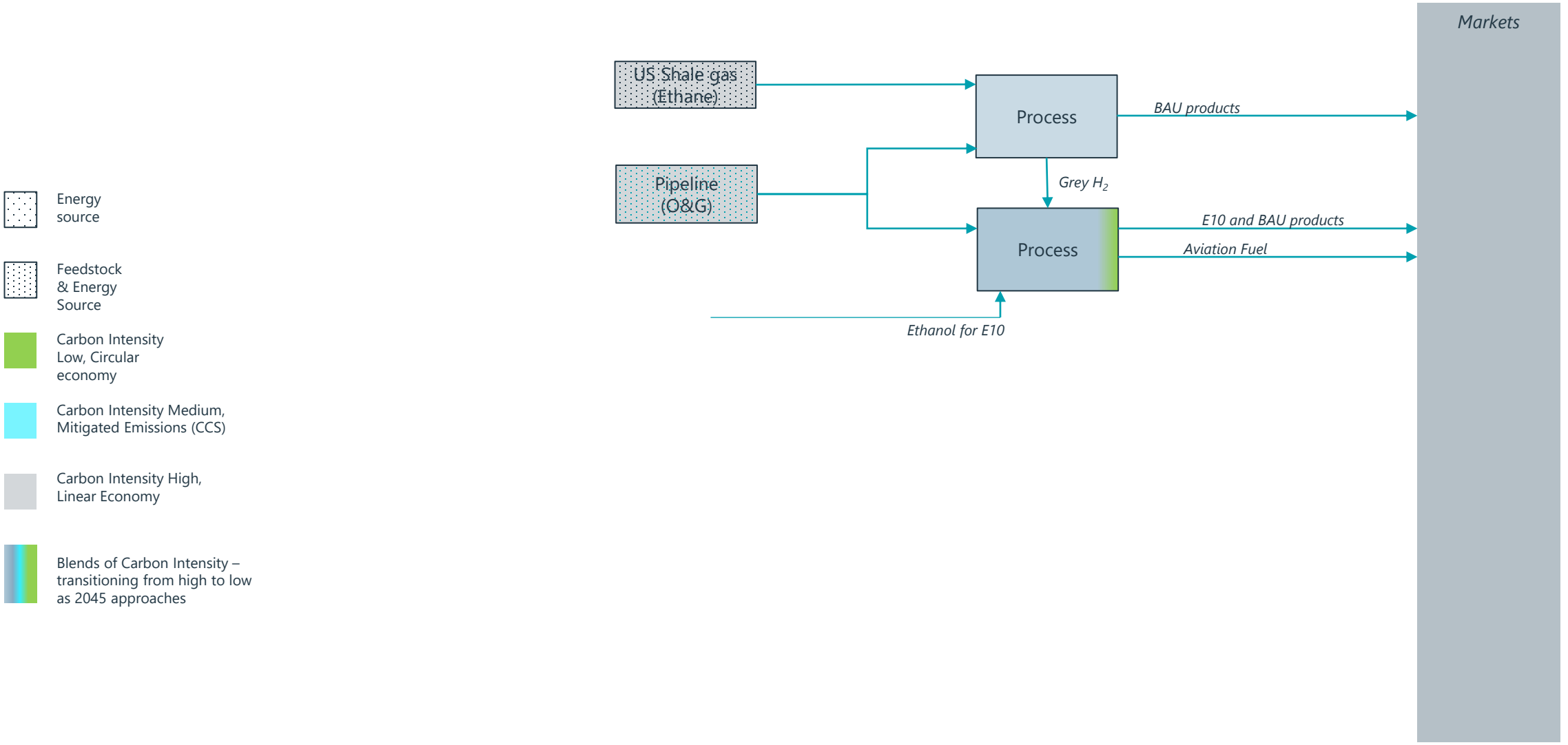
wood.

Grangemouth Site Evolution

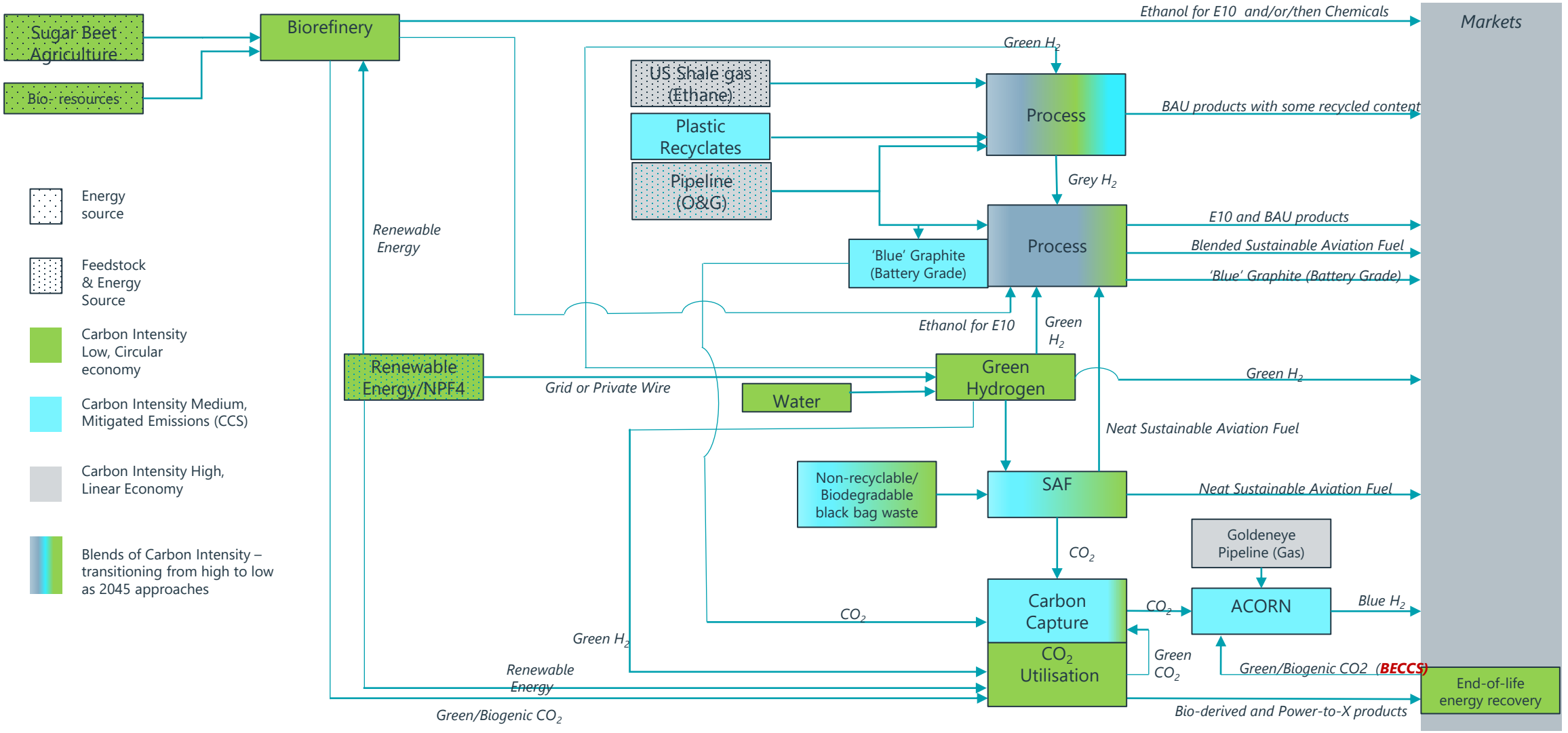
- Existing reliance on fossil fuel networks is evolving
- Present focus of production serves conventional transport and chemical needs
- Changes in the Grangemouth cluster, supported by wider projects in the energy and transport sectors can deliver a shift to low carbon operations
- This shift could lead to a diversified set of target markets
- The future shape of these opportunities is illustrated on the following slide



Current View of Grangemouth



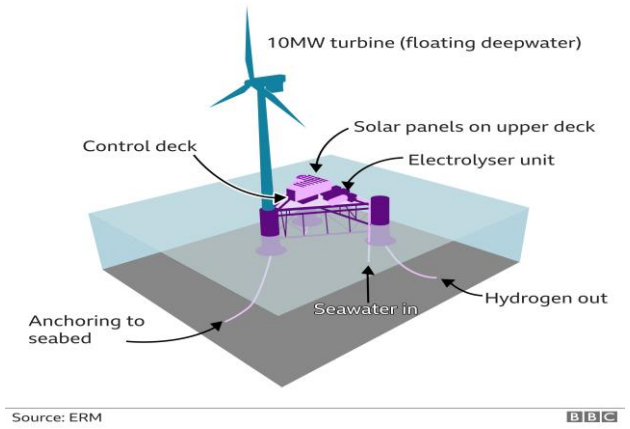
Potential Future View of Grangemouth



Infrastructure Summary

- Existing reliance on fossil fuel networks is evolving
- Gas network likely to be blended hydrogen mix in mid 2020s
- Hydrogen production ramped up by 2030
- Hydrogen fuelling infrastructure for bus and HGV increasing through 2020s
- Pipelines for CO_2 transport and capture and wider distribution of hydrogen by 2030s
- Offshore renewables provide source of power for onshore green hydrogen by 2030

SGN H100 Fife



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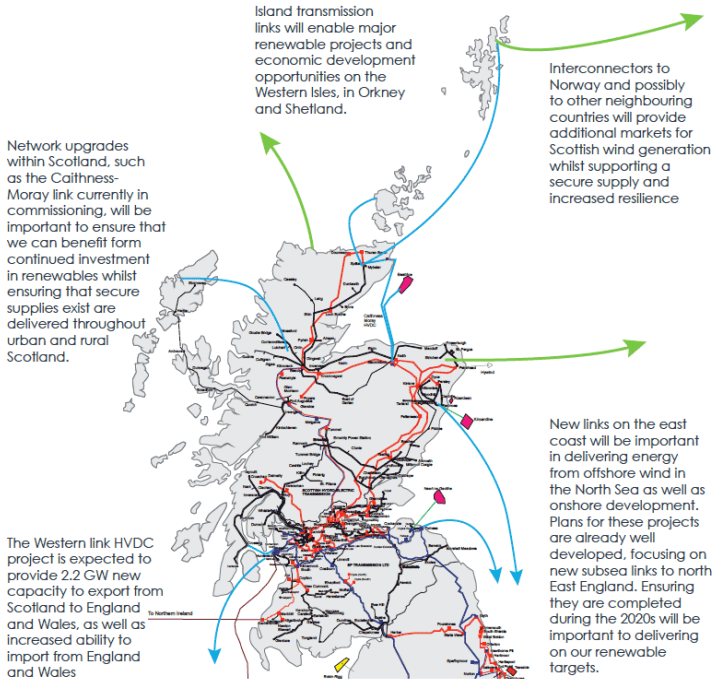
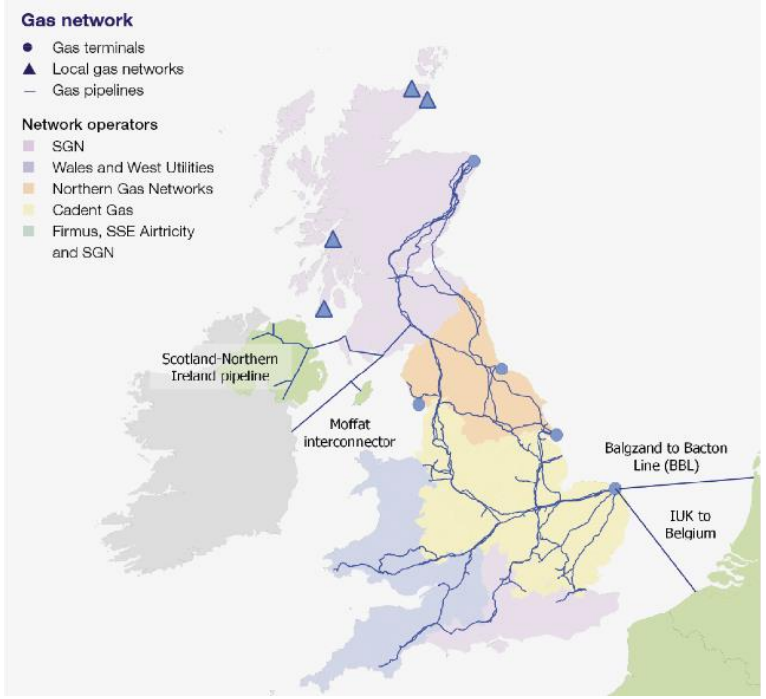
Summary

Summary of analysis

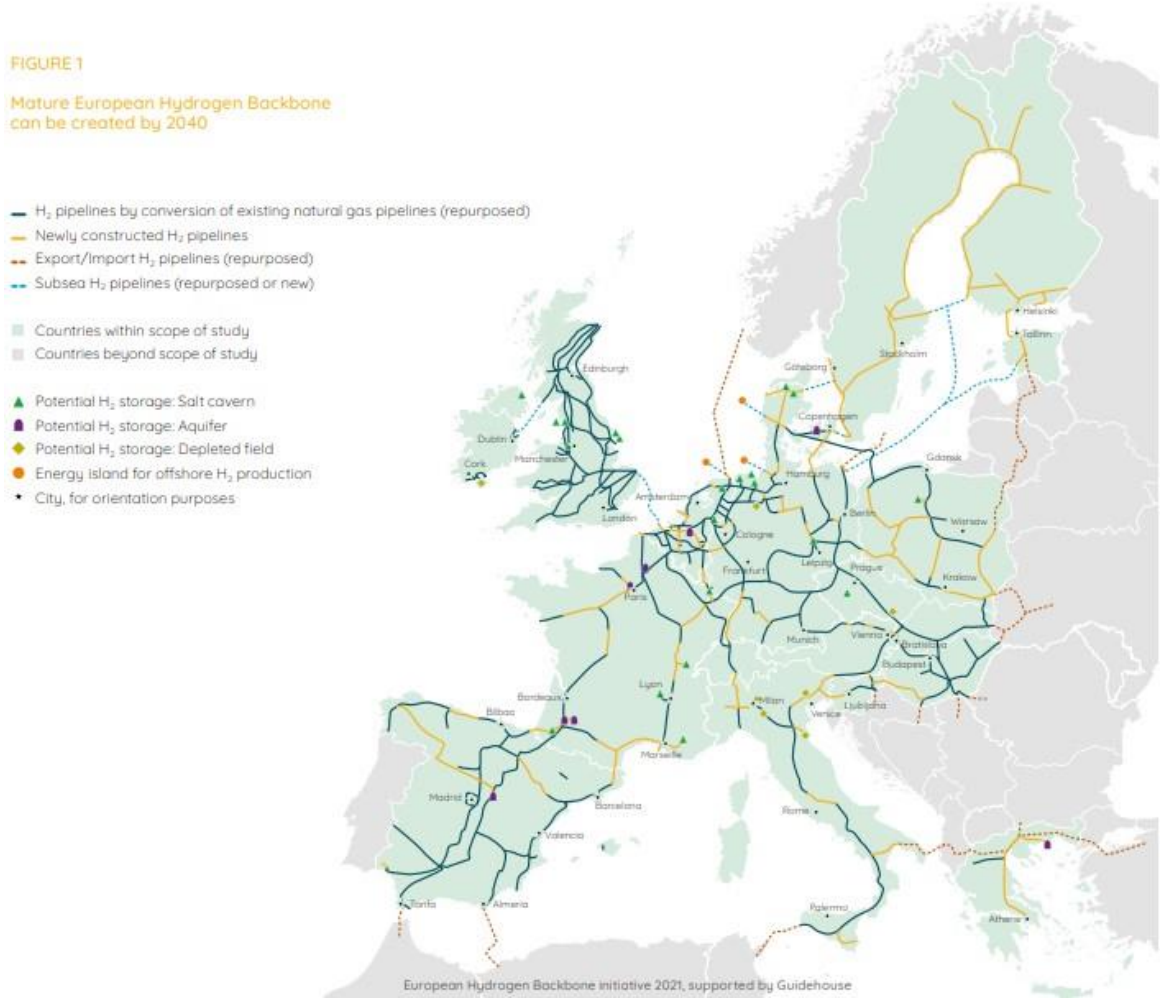


- UK and Scottish Government net zero targets provide a challenge to the Grangemouth Industrial Cluster and associated operations
- The changes in power, heat and transport systems in Scotland (and wider UK) will result in significant changes



Hydrogen Export Market View

- None of the stakeholders engaged in this study have considered export market opportunities at this stage
- EU Hydrogen Strategy is ambitious (e.g. 6 x increase in green hydrogen capacity in next 4 years) and wants blue hydrogen to support decarbonisation of industry
- Scandinavia also sees hydrogen future
- Repurposing of gas networks could offer European hydrogen backbone operating 2030+
- Competitive market for hydrogen will be heavily influenced by fiscal policy short term (e.g. carbon contract for difference linked to EU ETS)



Low Carbon Pathways

- Phasing out of internal combustion engines (ICE) could reduce demand for refinery products (petrol and diesel)
- This means a changing dynamic for Grangemouth:
  - Reduced fossil fuel demand for transport
  - Changing logistics model (fewer fossil fuel tankers and decarbonising HGV/LGV supporting cluster)
  - Competitive pressures to decarbonise processes within cluster
  - Opportunity to lead deep decarbonisation in industry and transport

Evolving Logistics Chains

Rail

- First hydrogen train to be operational Q4 2021
- Electrification of main rail routes leaves freight and NE/NW/SW ‘spurs’ reliant on hydrogen

Marine

- HyDIME test for Shapinsay ferry
- SWIFTH2 links hydrogen production costs and ferry routes
- Fuelling infrastructure evolving at ports/harbours

HGV

- Hydrogen fleet growing
- Also biofuel/LNG options
- Limited EV uptake

Evolving Transport Fuel Needs

Dominant Fuel
Significant Fuel
Niche / Minor Fuel
Future Market Opportunity

	2021	2025	2032	2045
Light duty vehicles < 3.5 t	ICE	ICE	BEV	BEV
	Hybrid	Hybrid	**Hydrogen**	**Hydrogen**
	Battery Electric (BEV)	BEV	Net zero fuels	Net zero fuels
Heavy Goods > 3.5 t	ICE	BEV	BEV	BEV
	Hybrid	**Hydrogen**	**Hydrogen**	**Hydrogen**
	BEV	ICE / Hybrid	ICE / Hybrid	ICE / Hybrid
Bus and coach	ICE	ICE / Blended fuels	BEV	BEV
	ICE – blended fuels	BEV	**Hydrogen**	**Hydrogen**
	BEV	Hydrogen	Hybrid	Net zero fuels
Marine	MFO	MFO	Battery Electric	Battery Electric
	Low Sulphur Fuels	Low Sulphur Fuels	**Hydrogen / Ammonia**	**Hydrogen / Ammonia**
		Battery Electric	Methane / Diesel ICE	Methane / Diesel ICE
Rail	Diesel	Diesel	Electric / Battery	Electric / Battery
	Electric	Electric	**Hydrogen**	**Hydrogen**
Air	Jet Fuel	Jet Fuel	Jet Fuel	SAF
	Sustainable Aviation Fuel (SAF)	SAF	SAF	**Hydrogen**
		Electric	Electric	Electric

Note: Details collated from Sustainable Aviation Fuel Road Map (UK Air Industry), Rail Decarbonisation Action Plan (Scottish Government), Decarbonising European Shipping (Transport & Environment) and Roadmaps developed by Advanced Propulsion Centre UK

Evolving Hydrogen Demand

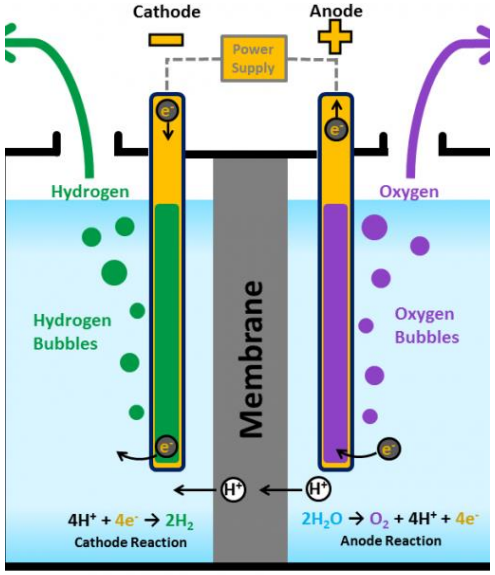
	2025	2032	2045
Industrial	Blended hydrogen (heat)	Hydrogen for heat established Hydrogen in process evolving	Hydrogen for heat established Hydrogen in process established
Road (> 3.5 tonnes)	Hybrid HGVs operational	Hydrogen HGV commercially available	Hydrogen HGV widely adopted
Road (bus)	EV buses with early adoption hydrogen	Hydrogen buses well established	Hydrogen buses widely adopted
Rail	Demonstrator trials complete	Hydrogen used in regional networks	Hydrogen used across all non-electrified network
Maritime	Short hop ferry trials complete	Hydrogen / ammonia vessel designs	Hydrogen / ammonia vessels adopted
Air	Limited short haul hydrogen trials	Some adoption for short haul; hydrogen used in fuel production	Well established short haul market; hydrogen used in fuel production
Domestic	Initial hydrogen for heat demonstrators	Large scale blended methane / hydrogen networks	Full hydrogen network operational

The changing transport sector fuel needs outlined in the previous slide offer several pathways to increased uptake of hydrogen

wood.

Spatial Planning Influence

- Industrial Cluster
  - Re-purposing land in Grangemouth cluster for supporting development
    - Sustainable Manufacturing Campus (CCU)
    - Hydrogen production
    - Renewable generation
- Regional
  - Net Zero Firth of Forth
  - Growth Deal Investment
  - Local Plan and associated renewable energy generation



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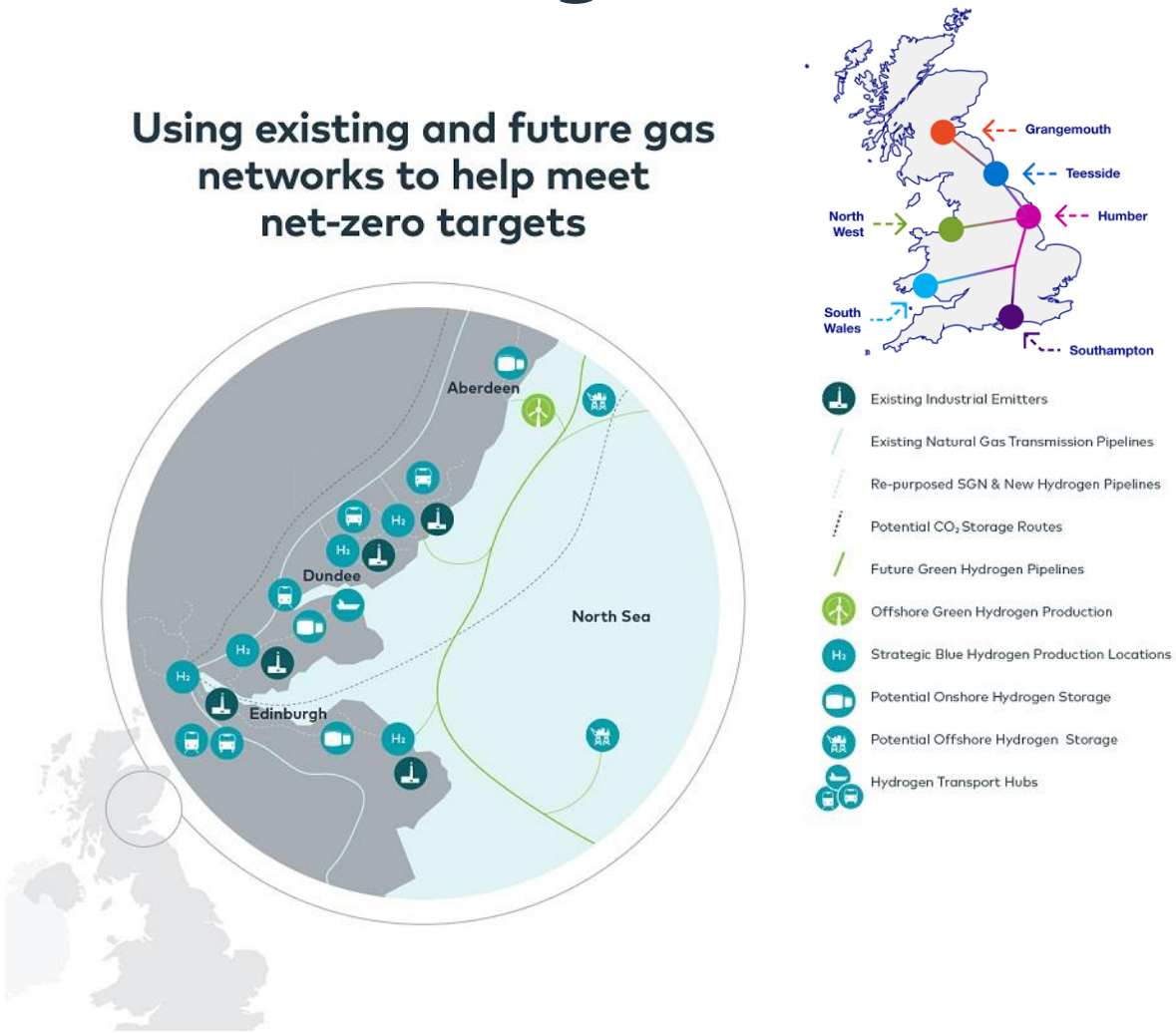
Grangemouth at the core of evolving infrastructure

- Changing gas grid means increasing distributed hydrogen production
- Blue hydrogen production at Grangemouth and elsewhere will mean commercial carbon capture and storage also evolves
- Wider development of a hydrogen backbone between industrial clusters can accelerate the switch from natural gas



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Evolving Hydrogen Supply

- Commercially viable carbon capture storage (CCS) can unlock significant blue hydrogen production by early 2030s (ACORN potentially operational in mid 2020s, Mossmorran, Grangemouth potential subsequent sites)
- Scale-up of other fuel production will generate co-product hydrogen in larger volumes (e.g. bio-ethanol, biobutanol, synthetic biodiesel)
- Ramp up of offshore renewables provides source of power to stimulate onshore green hydrogen production
- Uptake of hydrogen in regional rail networks and HGV fleet will increase fuelling infrastructure and distributed production model

Grangemouth – a hydrogen future

- Hydrogen production and use largely self-sufficient at present
- Evolving process and fuel producers in the area will increase demand and availability
- Land available for hydrogen production can support industrial decarbonisation and offer demand for offshore power generation
- Logistics chain will provide increasing hydrogen demand (hauliers, rail, port)
- Underpinning evolution of national gas network will provide infrastructure for transport of large hydrogen volumes and carbon capture

Grangemouth – challenges for hydrogen development

- No clear statement of fuelling infrastructure requirements for bus, rail, HGV or shipping
- Market ready transport options limited to buses
- Increasing hydrogen production before distribution infrastructure is in place risks stranded capital
- No price premium to drive hydrogen uptake in transport
- Transformation of haulage market difficult without targeted capital funding and revision of fuel duty
- Need to target investment effectively to avoid competitive disadvantage (other UK Industrial Clusters and wider global industrial competitors)

Recommendations

Maintain infrastructure development	• Continued engagement with UK gas operators to drive evolution of gas network and requirements for hydrogen production • Prioritise identification of suitable development areas at Grangemouth site for blue and green hydrogen production
Engage logistics chain	• Dialogue with haulage market to look at existing access to capital and market offerings for hydrogen vehicles • Use Scottish Government / UK Government development funding to take forward hydrogen vehicle designs • Consider collaborative approach to hydrogen fuelled logistics chain serving Grangemouth and neighbouring areas
Build public transport market	• Ensure rail industry development is considered in assessing hydrogen demand and fuelling infrastructure requirements • Build on existing strong demand for low emission bus fleets to support local production of hydrogen buses and deployment across Scotland
Support evolving transport fuel production	• Encourage production of low carbon fuels at Grangemouth site (e.g. synthetic biofuels) to support decarbonisation of transport sector more widely. Production facilities will also provide demand for hydrogen infrastructure in production, transmission and associated carbon capture
Continue fiscal review	• Continue to review taxation position on road fuels • Build confidence in road users towards changing incentives to encourage uptake of low carbon fuels including hydrogen • Consider price per km travel models to accelerate shift from internal combustion vehicles

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Next Steps

- Infrastructure – ensure ongoing studies (SNZI/SNZR, SGN Industrial Clusters, IDRIC) are used to **develop a coherent further investment case for hydrogen**
- Infrastructure – support **collaboration between manufacturers and haulage/rail sectors** to determine fuelling station needs and aftercare packages for hydrogen
- Demand – Support funding routes to attract **sustainable aviation fuel production and development of CCU Sustainable Manufacturing Campus** at Grangemouth
- Demand – **SULEB III** funding round for hydrogen buses
- Demand – Convene **logistics taskforce** to study feasibility of decarbonising freight logistics in/out of Grangemouth cluster (road/rail/port) 'hydrogen zone'
- Supply – Fund **FEED study for blue hydrogen** production facility at Grangemouth
- Supply – Fund **FEED study for green hydrogen** production facility at Grangemouth (including scope of offshore renewable generation)
- Policy – Work with UK Government to incentivise hydrogen/BEV in **revised fuel duty structure**

Annex

Hydrogen Production

Grey Hydrogen	Blue Hydrogen	Green Hydrogen
Hydrogen produced from reforming natural gas. This process produces both hydrogen and carbon dioxide.	Hydrogen produced from reforming natural gas, as for grey hydrogen. However, in this case around 95% of the carbon dioxide produced is captured and stored through Carbon Capture Utilisation and Storage (CCUS) technologies. Blue hydrogen could also be produced using biogas. This could potentially act as a carbon sink to offset sectors that cannot reach zero emissions.	Hydrogen produced by splitting water in an electrolyser powered from zero carbon sources. This process produces hydrogen and oxygen. No carbon dioxide is released.

Stakeholder Engagement List

Stakeholder	Study Participant?	Stakeholder	Study Participant?
INEOS O&P	Y	Fulcrum Bioenergy	Y
PetroINEOS	Y	Celtic Renewables	Y
Shell	Y	Falkirk Council	Y
ExxonMobil	Y	Scottish Government	Y
Calachem	N	Scottish Power	Y
Syngenta	N	National Grid	N
Versalis	N	SGN	Y
Forth Ports	Y	Alexander Dennis	Y
John Mitchell Haulage	Y	Talgo	N
Eddie Stobart	N	Forth Valley College	N
Malcolm Logistics	Y	IBioIC	Y
IDRIC	Y	NECCUS	Y
NIC3E	Y	Transport Scotland	Y

Wider Industrial Stakeholders

- The Fife Ethylene Plant (FEP) takes ethane supplied by the neighbouring Shell site and further processes it to produce ethylene
- Ethylene is the base product used in the manufacture of plastics and so is used in diverse applications such as food packaging, medical equipment and car parts

- The main activities at the site can be summarised as:
  - **Contract Manufacturing Services** – manufacture of agrochemical actives which are used in the protection of crops and specialty chemicals and biocides which are used in a variety of industries
  - **Environmental Services** –on-site large scale effluent treatment plant which treats aqueous waste from industrial processes
  - **Property and Site Services** –offices and laboratory space available for rent and land for sale for industrial development

- Site has four plants dedicated to active ingredient (AI) manufacture, and one finished product formulation and packaging plant
- Insecticides and herbicides are produced on-site and shipped to global clients

- The Versalis site at Grangemouth produces synthetic elastomers and lattices which serve the automotive tyre industry.