United Kingdom
Petroleum Industry Association

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Early refinery responses to meet the Net-Zero challenge

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Introduction

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The Net-Zero challenge – UK context

UKPIA

Successive UK governments have long sought to demonstrate leadership on climate change, both nationally and in the development of global and regional European climate change policies.

1992

Rio Earth Summit

The UK provided early support for the United Nations Framework Convention on Climate Change (UNFCCC), which was adopted at the “Rio Earth Summit” in 1992, with the objective to stabilise GHG concentrations *"at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system."*

2008

UK Climate Change Act

The UK became the first country to introduce legislation on GHG emissions reductions with the UK Climate Change Act 2008, committing the UK to a reduction in GHG emissions by at least 80% by 2050 from 1990 levels and requiring the setting of legally binding carbon budgets every five years.

The Act established the Committee on Climate Change (CCC) as an independent, statutory body to advise on emissions targets and to report to Parliament on progress made in reducing GHG emissions and preparing for and adapting to the impacts of climate change.

2018

Climate Change Committee advice

Governments of the UK, Scotland and Wales sought updated advice from the CCC on their long-term emissions targets, including the possibility of setting a new Net-Zero target. In response, the CCC published a report, *“Net-Zero. The UK’s contribution to stopping global warming”* (the CCC Net-Zero Report) on 2nd May 2019 with the recommendation that:

“The UK should set and vigorously pursue an ambitious target to reduce greenhouse gas emissions (GHGs) to ‘net-zero’ by 2050, ending the UK’s contribution to global warming within 30 years.”

2019

UK Climate Change Act amended

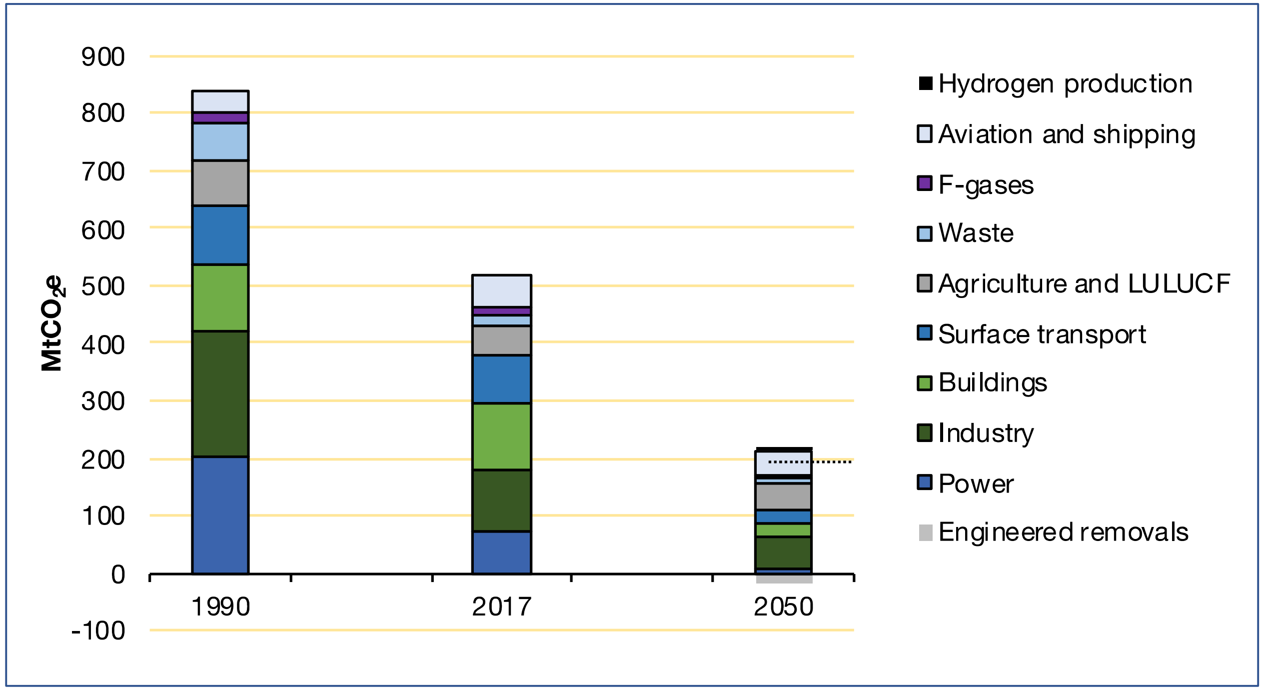
The UK Government moved quickly to become the first major global economy to pass legislation requiring the UK to end its contribution to global warming by 2050, when it amended the UK Climate Change Act 2008 on 26th June 2019, committing the UK to a reduction in GHG emissions by a minimum of 100% by 2050 compared to the 1990 baseline .

The CCC Net-Zero scenarios - Core options

In its Net-Zero report, the CCC set out a number of options that in combination would produce an increasing level of emissions reductions to deliver Net-Zero by 2050.

The Core options identify a set of measures that would broadly deliver the previous target of an 80% reduction in GHG emissions by 2050.

GHG Emissions for the CCC Core options



Source: CCC Net-Zero Report

Note. The dotted line shows net emissions in 2050, taking into account negative emissions.

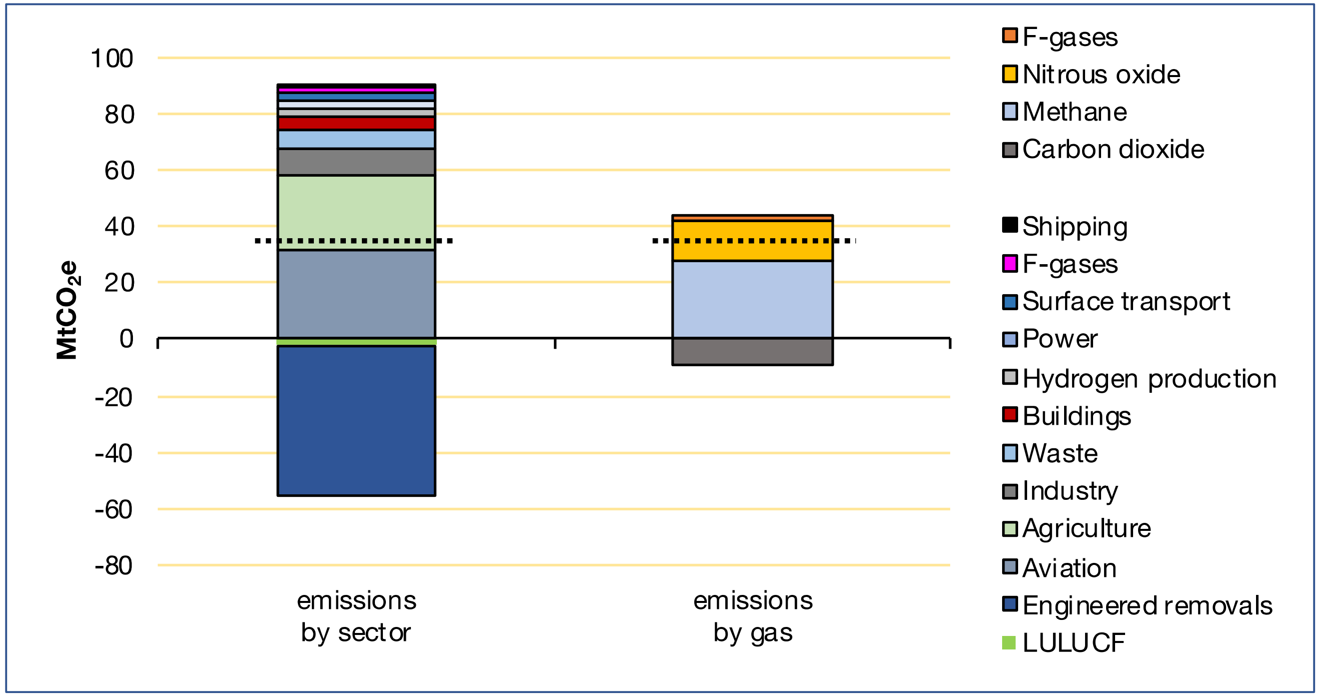
- These options have relatively low costs and delivery barriers
- Existing Government policy has begun to implement policies to deliver these, including:
  - energy efficiency improvements
  - decarbonisation of the electricity supply
  - electrification of the car and light vehicle fleet
  - decarbonisation of industrial and domestic heating
  - some use of carbon capture, utilisation and storage (CCUS)
  - tree-planting and on-farm measures
  - diversion of waste from landfill
  - phasing out of fluorinated gases

The CCC Net-Zero scenarios – Further Ambition options

Under the Further Ambitions options, additional deep decarbonisation measures are used to reduce emissions to 35 $MtCO_2e$ by 2050.

The remaining CO_2 emissions are largely from the aviation sector (31.5 $MtCO_2e$), although a large proportion would be offset by engineered removals.

Remaining GHG Emissions after application of Further Ambition options



Source: CCC Net-Zero Report

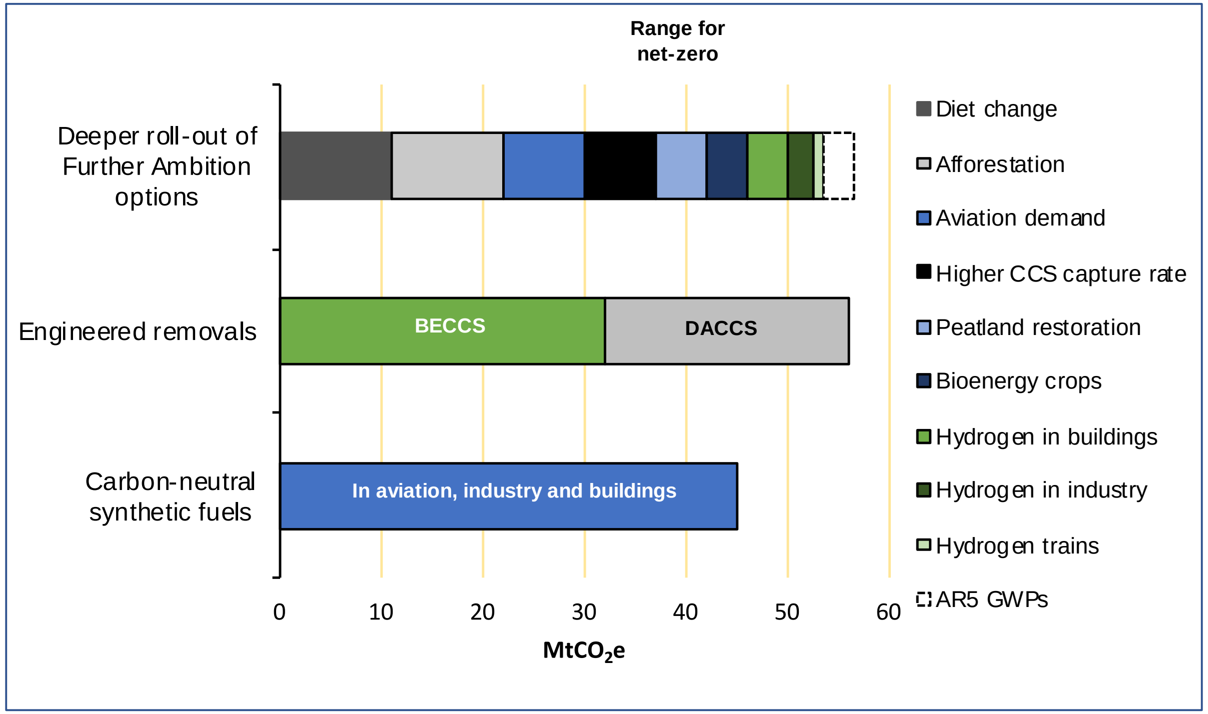
Note. The dotted line shows net emissions in 2050, taking into account negative emissions.

- The **Further Ambition** options include more challenging additional measures to reach a 96% GHG reduction by 2050 compared to 1990 levels. These include:
  - development of a significant low-carbon hydrogen economy to support further decarbonisation of industry, heavy goods vehicles and shipping
  - major changes in land use and farming
  - a greater role for CCUS at scale and in combination with biomass (BECCS)

The CCC Net-Zero scenarios – Speculative options

To close the gap from 96% to 100% GHG reduction by 2050, further Speculative options are required.

Additional abatement potential from Speculative options in 2050



Source: CCC Net-Zero Report

Note. The shaded area reflects the range for additional emissions reductions required beyond the CCC Further Ambition options to get to Net-Zero emissions in 2050 (i.e. 33-45 MtCO2e). The AR5 GWPs area shows the higher emissions and emissions savings associated with higher global warming potential factors for GHGs, consistent with the upper end of the Net-Zero shaded area.

- The **Speculative** options include:
  - further changes in demand (aviation) and consumer behaviour (diets)
  - more radical shifts in land use
  - extensive implementation of CCUS, including direct air carbon capture and storage (DACCS) and biomass carbon capture and storage (BECCS)
  - development of a major supply of low-carbon liquid fuels produced from algae and captured CO_2 using renewable power

Net-Zero and the role of hydrogen

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- The CCC Net-Zero scenarios identify a crucial role for hydrogen in decarbonising domestic and industrial heat, shipping and surface transport (mainly buses and trains).

- The CCC Net-Zero Technical report states:

  - Producing 225 TWh of hydrogen via advanced gas reforming could require up to 30 GW of hydrogen production capacity, equivalent to 30-60 hydrogen production plants.
  - Production of 44 TWh of hydrogen via electrolysis could require between 2-7GW of electrolyser capacity, depending on load factors. This implies 200-700 units of 10 MW scale, although modular units could be co-located.
  - Current hydrogen production is around 26.9 TWh (683 kt/year)[1] the majority of which is produced via SMR or POX across 15 sites. Over 50% of this is produced and used in the 6 UK refineries.

1. Taken from the Energy Research Partnership "Potential role of hydrogen in the UK energy system", 2016.
2. UKPIA Estimate.

Low-carbon hydrogen production and use – Gigastack

Two low-carbon hydrogen production and use projects are being progressed, centred on UK refineries.

The first, the Gigastack Zero Carbon Hydrogen Plant, uses renewable electricity to generate hydrogen via electrolysis.

Gigastack Zero Carbon Hydrogen Plant

Source: Phillips 66

- ITM Power, in collaboration with Ørsted, Phillips 66, and Element Energy, are now progressing the Gigastack project[1, 2], which seeks to demonstrate:
  - Scale up and cost reduction in the development of ITM Power's polymer electrolyte membrane (PEM) electrolyser technology from 5 MW to 100 MW.
  - Development of a cluster-based approach using renewable electricity supplied from the Ørsted Hornsea Two offshore wind farm to generate hydrogen via electrolysis.
  - Use of green hydrogen to reduce refinery CO_2 emissions, although there is also potential to use oxygen co-generated with the hydrogen to further reduce refinery CO_2 and NO_x emissions[3].
- The ITM Power technology has already been demonstrated successfully in the 10MW Refhyne project at the Shell Rhineland Refinery in Wesseling, Germany.

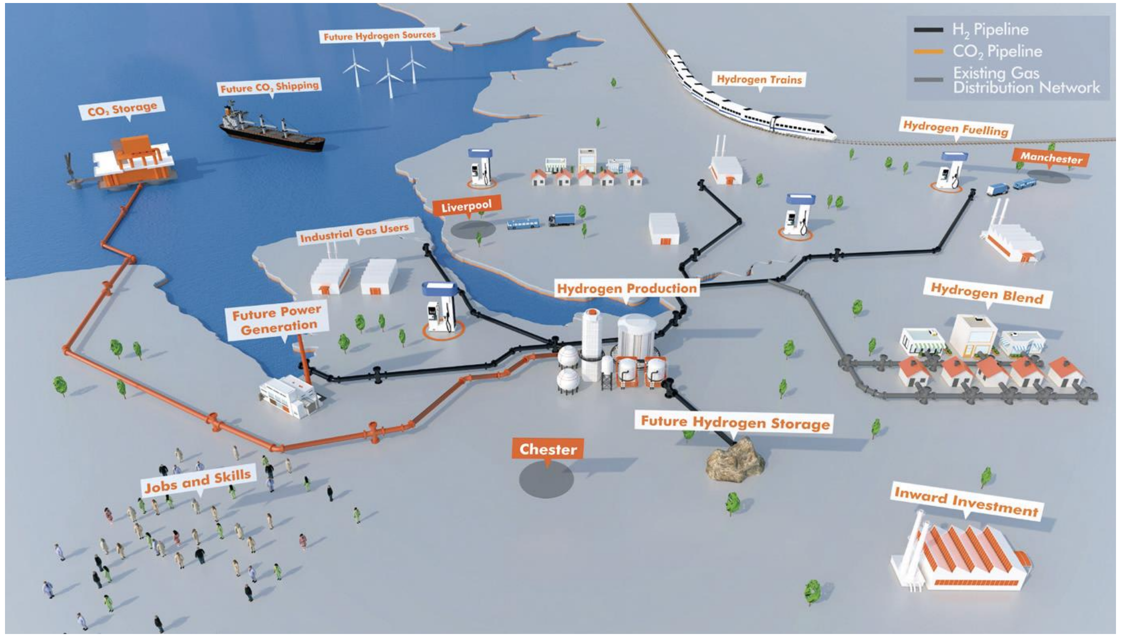
Until recently, hydrogen production via electrolysis had not been considered scalable for refinery and other large-scale applications. Although smaller-scale production had been considered for refinery application, it had been viewed only as a late-development option for refinery hydrogen production.

1. Gigastack - Demonstrating renewable hydrogen for a net zero future.
2. Gigastack: Bulk Supply of Renewable Hydrogen.
3. de Mello, L. F. *et al.* A technical and economical evaluation of CO_2 capture from FCC units. *Energy Procedia* 1, 117–124 (2009).

Low-carbon hydrogen production and use – HyNet

The second, the HyNet Low Carbon Hydrogen Project, involves the development and deployment of a 100 kNm^3/hr hydrogen production and supply facility, using gas reforming with CCUS.

HyNet Low Carbon Hydrogen Plant



Source: Cadent

Essar Stanlow Refinery

Source: Essar

- The HyNet hydrogen production units will be located at the Essar Stanlow refinery and use Johnson Matthey's LCH™ technology, which includes carbon capture. Capex has been estimated at around £253.9m for the first phase.
- The plant will use refinery fuel gas (RFG) as a feedstock to produce up to 3000 GWh/yr of hydrogen, with the capability to expand production by up to six times. The HyNet CCUS infrastructure is envisaged to have an initial capacity of 10 $MtCO_2$/yr, with potential to double capacity.
- The hydrogen produced is intended to sustitute RFG, with a hydrogen-fired combined heat and power (CHP) plant also under consideration[1].

1. See Progressive Energy HyNet industrial fuel switching feasibility study (2020).

Industrial clusters and carbon capture and storage

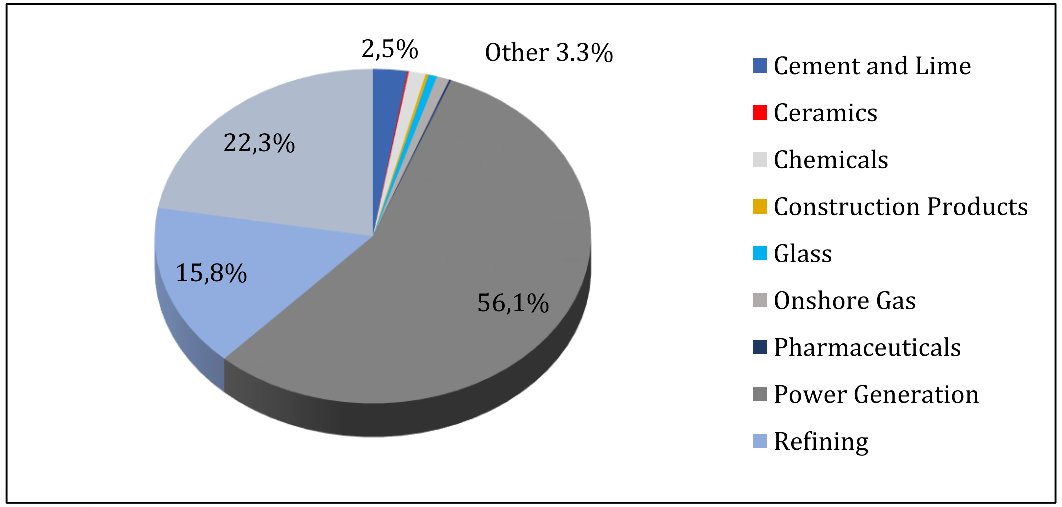
The UK Government has set out an ambitious challenge to establish the world's first net-zero carbon industrial cluster by 2040 and at least one low-carbon cluster by 2030.

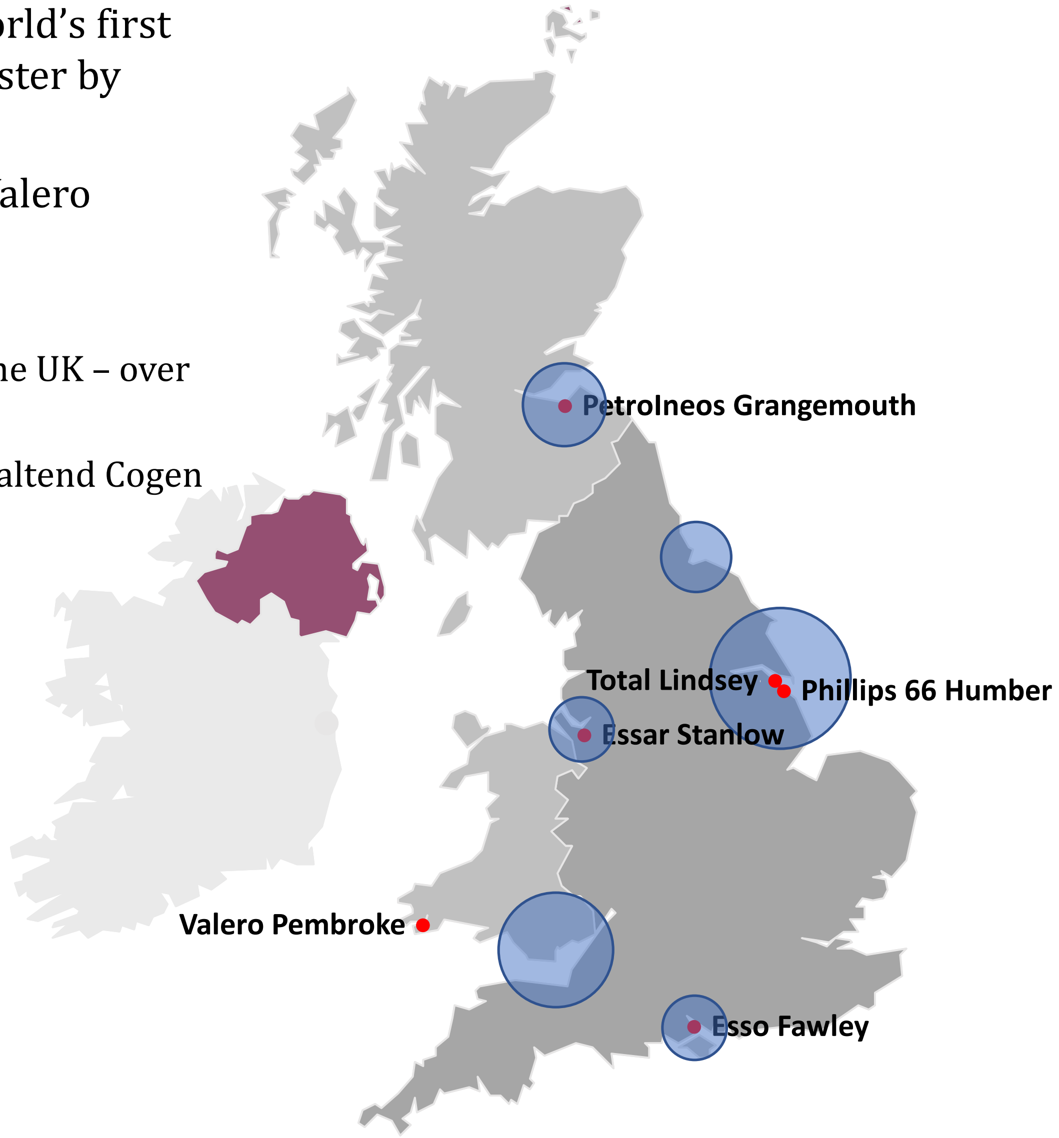
Five of the six UK refineries are located within the six clusters identified; Valero Pembroke has joined discussions within the South Wales cluster.

The Humber cluster

- The Humber cluster currently has the highest concentration of CO_2 emissions in the UK – over 18 $MtCO_2e$.
- Existing emissions are dominated by power generation – Drax, VPI Immingham, Saltend Cogen and smaller CHP units, some included within other sectors (e.g. refining).

Humber cluster EU ETS emissions - sector breakdown





Humber cluster projects – Zero Carbon Humber

Three major projects have been proposed for the Humber cluster – Zero Carbon Humber, Humber Zero and Gigastack – with a number of smaller projects, such as the Altalto Immingham waste-to-liquids sustainable aviation fuels plant and increased refinery use of renewable and waste-derived feedstocks.

Zero Carbon Humber – linked projects

- Hydrogen to Humber (H2H) Saltend, an SMR plant with carbon capture at the PX Group Saltend Chemicals Park, led by Equinor.
- A pipeline network developed by National Grid Ventures, connecting energy-intensive industrial sites and offering options to switch to low-carbon hydrogen and CO_2 capture.
- CO_2 compression at the Centrica Storage Easington site.
- CO_2 storage under the southern North Sea using offshore infrastructure shared with the Teesside industrial cluster.
- Potential for:
  - Bioenergy carbon capture and storage (BECCS) at the Drax Power Station.
  - CCS implementation at the SSE Thermal Keadby 3 gas-fired power station
  - Hydrogen production at the Uniper Killingholme site.

Source: Zero Carbon Humber

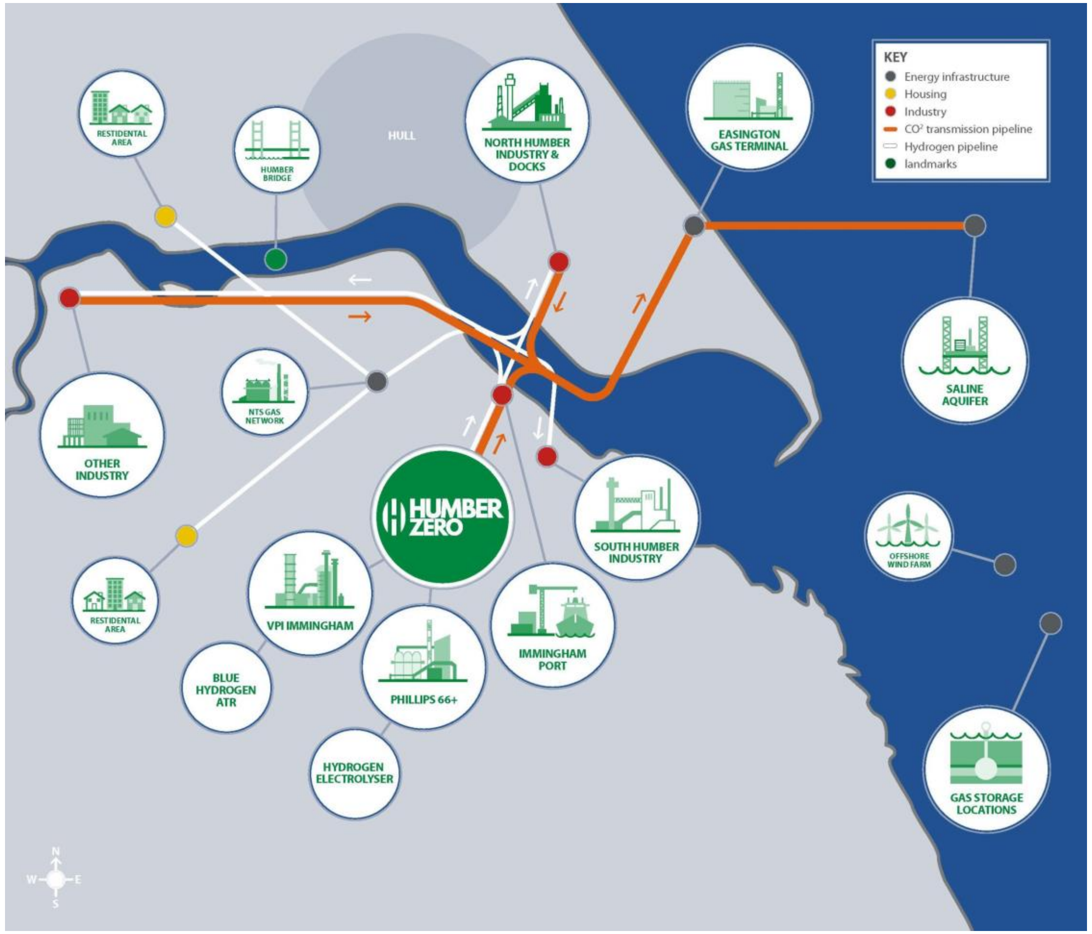
Humber cluster projects – Humber Zero

UKPIA

Phillips 66, Uniper and VPI Immingham have entered into a memorandum-of-understanding to co-develop Humber Zero, a large scale decarbonisation project.

- Initially, Humber Zero will capture around 8 mt/year of CO_2, with the potential to target 30 MtCO_2e from the wider Humber Cluster to the west of Immingham. It is intended to be operational by the mid-2020s.
- Post combustion capture on two of the three existing generators at VPI Immingham and selected processing units at the Phillips 66 Humber and Total[1] Lindsay refineries.
- The CCS project will be combined with the development of a hydrogen hub producing green and blue hydrogen to serve the third VPI Immingham generator and local industry, with the potential also to supply 1000 MWth hydrogen via the gas network to over 1m local homes.

Schematic for Humber Zero project



1. Prax Group take ownership from 1st January 2021.

Crude substitution by renewable and waste-derived feedstocks

Lipid hydrotreatment

Lipid hydrotreatment for the production of low-carbon liquid fuels (LCLFs) is well-established outside the UK, with a number of purpose-built plants with throughputs of up to 1mt/yr[1].

Three European refineries (ENI Venice, ENI Gela and Total La Mède), have also been converted to operate as biorefineries.

Lipid hydrotreaters have also been integrated with existing refinery operations at a number of locations to take advantage of shared hydrogen supply, utilities and logistics.

In the UK, the [Phillips 66 Humber] refinery has recently increased its capacity for processing used cooking oil (UCO).

The Phillips 66 Humber UCO processing unit

Source: Phillips 66

1. Examples include Neste Rotterdam, Neste Singapore and Diamond Green Diesel in in Norco, Louisiana.

Sustainable aviation fuel from waste-derived feedstocks

Gasification and Fischer-Tropsch synthesis

The gasification and Fischer-Tropsch (FT) synthesis route provides access to a wider range of LCLFs and chemical feedstocks such as naphtha and microcrystalline waxes, along with chemicals such as methanol, ethanol and higher alcohols, aromatics (via methanol), hydrogen, ammonia (via hydrogen) and CO-derived chemicals such as acetic acid and oxo-alcohols.

These pathways build on technologies already commercialised at scale for production of gasoline, diesel, jet fuel and lubricant base fluids from natural gas (GtL) and coal (CtL).

Altalto Immingham waste-to-liquids plant

Source: Altalto

Planning approval has recently been granted for a waste-to-liquids (WtL) plant in Immingham, North East Lincolnshire.

The Altalto plant is a cooperative venture between British Airways, Shell and Velocys, which will take 500 kt/yr of municipal waste and convert this into around 50 kt/yr of LCLFs, leading to an estimated net CO_2 saving of over 80 kt/yr.

Government policies to deliver Net-Zero

UKPIA

Current Government policies are unlikely to deliver Net-Zero, as they don't offer any reward for decarbonising at scale. UKPIA believe that the following measures, if implemented early, could deliver the necessary incentives to business to move to Net-Zero while delivering a "just transition".

Policies to decarbonise the downstream oil sector:

1. Stimulate early demand for LCLFs and hydrogen for transport
2. Ensure consumers are informed on the role of LCLFs in decarbonisation
3. Revise CO_2 standards and emissions labels for vehicles to show lifecycle emissions
4. Industries and Government to develop sector-specific plans to decarbonise sectors with limited decarbonisation options (e.g. aviation)
5. Deliver a hydrogen strategy that sets out policy, regulatory and preferred business frameworks and gives clarity about how supply and demand can be grown together
6. Develop a business environment that encourages investment in decarbonisation, but allows companies to compete globally
7. Continue to promote industrial clusters with the downstream oil sector at their centre
8. Prepare the workforce to deliver Net-Zero in a "just transition"
9. Ensure Government support for research, development and deployment of all manufacturing and transport decarbonisation technologies aligns with company needs
10. Deliver a regulatory framework that allows for innovation.

UKPIA

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