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Energy Innovation Needs Assessment: Industrial Decarbonisation

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The 2025 Energy Innovation Needs Assessment: Industrial Decarbonisation was commissioned by the Department for Energy Security & Net Zero (DESNZ) and delivered by a consortium led by the Carbon Trust, including Mott MacDonald, UCL and Pengwern Associates.

Mott MacDonald was the lead technical author for the industrial decarbonisation technology theme report.

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Contents

Tables

Figures

Abbreviations

AD	Anaerobic digestion
ART	Advanced Recycling Technologies
BAU	Business as usual
BECCS	Bioenergy with carbon capture and storage
CAPEX	Capital expenditure
CBGDP	Carbon Budget Growth and Delivery Plan
CCC	Climate Change Committee
CCS	Carbon capture and storage
CCU	Carbon capture and usage
CCUS	Carbon capture, usage and storage
CHP	Combined heat and power
COMIT	Cost Optimisation Model for Industrial Technologies
DD	Deep decarbonisation
DESNZ	Department for Energy Security and Net Zero
DSR	Demand Side Response
EAF	Electric arc furnaces
EE	Energy efficiency
EINA	Energy Innovation Needs Assessment
FOAK	First-of-a-kind
GGR	Greenhouse gas removal
GVA	Gross Value Added
MBM	Meat-and-bone-meal
MVR	Mechanical vapour recompression

NZIP	Net Zero Innovation Portfolio
OEM	Original equipment manufacturers
OPEX	Operational expenditure
PCC	Post combustion capture
R&D	Research and development
REE	Resource and energy efficiency
SIC	Standard industrial classification
Tpd	Tonnes per day
TRL	Technology Readiness Level
UKCS	UK Continental Shelf

Key findings

The Energy Innovation Needs Assessments (EINAs) have been developed and updated to identify key innovation needs across the UK's energy system, to provide an evidence base for the prioritisation of investment and support for clean energy innovation. This report summarises the analysis and findings from the EINAs across the industrial decarbonisation technology theme, focusing on major industries in the UK that contribute to GHG emissions, and innovative decarbonisation options.

The EINAs analysis for the industrial sector did not include systems modelling analysis, as was undertaken for other EINA technology themes, due to the complexity and data availability. This report therefore focuses on a qualitative mapping of the decarbonisation options selected, alongside a business opportunities analysis.

In 2023, the UK industrial sector accounted for approximately 17% of GHG emissions, totalling 64.1 $MtCO_2e$. Industry was the third highest-emitting sector in 2023 with refineries, iron and steel, and chemicals sub-sectors being the greatest contributors. Approaches to decarbonisation discussed in this report are CO_2 usage, industry CO_2 capture, electrification, other fuel switching (hydrogen and biomass), and resource and energy efficiency (REE). Broadly speaking (noting some exceptions), electrification is expected to be deployed for low temperature processes, iron & steel production, and to some extent for glass production; hydrogen is expected to be deployed as an alternative fuel for ceramics and chemicals production; while carbon capture is expected to be deployed to abate process emissions e.g. lime and cement production.

Productive use of CO_2 captured from industrial facilities is a particularly important option for process emissions which cannot be removed through electrification or fuel switching. Usage options for CO_2 depends on the source that is captured, but can include mineral carbonation, synthetic fuels and carbonation of steel slag. Innovation to accelerate the deployment and scale up of CO_2 capture includes reducing the energy requirements of the conversion of CO_2 to fuels and chemicals, advanced CO_2 conversion routes (e.g. high temperature electrolysis and plasmolysis) and demonstration of CO_2 based construction materials.

Electrification of industry as a decarbonisation option will rely on a low-carbon electricity grid, supported by on-site energy production where possible. Heat for industrial processes can be produced electrically through four main approaches: heat pumps, resistive heating, electromagnetic radiation and electric arc furnaces. One of the primary applications of electrification is in steam generation, which has applications in many sub-sectors. Innovation to enable electrification of industrial sectors will include testing of the suitability of microwave heating, improved high temperature resistive heating technologies, higher-temperature industrial heat pumps and integration of heat pumps and mechanical vapour recompression (MVR), electric crackers for pyrolysis steam cracking, and scale up of electric arc calciners.

Other fuel switching in industry, for example to low carbon hydrogen or biomass, in combination with electrification, has the potential to support decarbonisation. Fuel switching to

100% hydrogen in industry will require upgrades to existing equipment as well as the construction of new infrastructure. Making existing equipment 'hydrogen-ready' will be a key focus for innovation, as well as R&D of technologies for high temperature direct firing using hydrogen in specific industrial applications. The use of biomass and liquid biofuels as alternatives to fossil fuels in industry is a potentially versatile option. Biomass could be used in boilers for steam generation, in solid fuel burners, or through gasification to produce bio-syngas for use in combined heat and power (CHP) plants. Biofuels could play a role as a transition fuel for industrial machinery and vehicles, before other low-carbon alternatives become available.

Finally, REE can be achieved through options including recycling waste heat, and supporting symbiosis of industrial sub-sectors to enable efficiencies, for example using by-products from one process as feedstock in another. Innovation in REE will include advanced manufacturing technologies to create less resource intensive materials, improving product lifespan, using Digital Twin technology to identify potential issues and inefficiencies, material substitution, and advanced separation, sorting and processing of waste.

Economic viability remains a key market barrier to the industrial decarbonisation options discussed in this report. All options detailed require significant upfront investment by prospective users, irrespective of technology maturity, primarily relating to project development and capex, with capex for First-of-a-Kind (FOAK) technologies typically higher than alternative options. Enabling infrastructure and supply chains will also need to be in place to enable these industrial decarbonisation solutions. For example, current electricity supply is insufficient to support a full transition to electrified industry. At a site level, new distribution network infrastructure and new connections may be needed or on-site solutions (e.g. storage, generation, DSR) implemented, whilst the supply of hydrogen for use in industry is currently limited.

A business opportunities calculator was developed for the EINAs industry technologies using assumptions derived from DESNZ's 2025 'Updating Evidence on Energy Efficiency (EE) Potential for UK Industry' report, which is expected to be published soon, and DESNZ's Cost Optimisation Model for Industrial Technologies (COMIT), with assessments of UK firms' potential share of these markets, informed by trade and production data. The analysis suggests the following potential business opportunities from deployment of industrial decarbonisation technologies:

- Steady Gross Value Added (GVA) growth with a compound annual growth rate (CAGR) of about 7% between 2025 and 2050 reaching approximately £1.8bn by 2050.
- By 2050, the three considered scenarios show limited variation in GVA and employment potential, with a respective 3% and 5% increase in GVA in the Higher Ambition and Max Tech scenarios compared to the BAU scenario.
- The additional GVA in the Higher Ambition and Max Technical scenarios is primarily driven by increased investment in industrial control equipment in the chemicals sector and in advanced kilns in the cement sector.

- Of the 13 technology types, industrial control equipment is the largest supporter of GVA and jobs. It accounts for approximately 26% of GVA in 2040 and 2050. Furnaces and kilns, paper making machinery and cracking are other notable technologies, accounting for a combined 38% of GVA by 2050.
- Supported total employment (direct and indirect jobs) rises from approximately 7,000 jobs in 2025 to between 29,000 and 31,000 jobs by 2050, a growth rate of approximately 6% across scenarios. These figures differ slightly from those published in the Carbon Budget Growth and Delivery Plan (CBGDP) due to different modelling inputs being used. The analysis in this report was finalised before the CBGDP scenarios were run.
- Across scenarios and across the time period, 59-63% of supported jobs are direct jobs.
- As the industrial decarbonisation technologies gain traction, CAPEX accounts for approximately half of employment in the early 2030s as new equipment is deployed across the scenarios. While total CAPEX related employment remains constant at around 10,000 from 2035 onwards, the share of total employment supported by CAPEX diminishes over time, falling to 38% in 2040 and 32% in 2050 as operation and maintenance activity becomes the main source of employment.
- An employment profile that, by 2050, is predominantly supporting high skilled science, research and engineering and technology professional occupations, as well as director/managerial jobs.

Introduction

The Energy Innovation Needs Assessments

Achieving the UK's ambitious Net Zero targets requires the accelerated scaling and deployment of innovative clean energy technologies alongside the accelerated deployment of proven clean energy technologies. The UK government has a central role to play in supporting the research, development and deployment of these innovations to achieve global and national climate objectives. The decisions made now in the prioritisation and investment of crucial clean energy technologies will be pivotal to enable progress in the coming years and decades.

The Energy Innovation Needs Assessments (EINAs) have been developed and updated to identify key innovation needs across the UK's energy system, to provide an evidence base for the prioritisation of investment and support for clean energy innovation. The 2025 publications reflect an update on the 2019 exercise, accounting for the significant changes and progress both in the clean energy sector and wider economy. To inform key decisions on clean energy innovation funding, the Department for Energy Security and Net Zero (DESNZ) require a structured evidence base, comparable across different technologies, which quantifies and assesses the role and scale of opportunities, and considers the wider factors that may impact deployment and scale up.

The methodology followed is detailed in the EINAs Technical Methodology report and is summarised below.

The EINAs technologies were decided on through a prioritisation exercise, taking into account insights from key sector experts and assessing against key criteria. An initial longlist of technologies for analysis was put together based on:

- Previously published global and national scenarios (including the 2019 EINAs)
- DESNZ priorities
- Insights from DESNZ engagement activities
- Input from technical experts

This longlist was then assessed and prioritised to inform a shortlist of EINAs technologies, which were then taken forward for analysis including:

- An assessment of each technology's innovation needs, costs and barriers to deployment.
- Modelling, using the UKTIMES and HighRES models, to assess the impact of different levels innovation in these technologies on the UK's energy system in hypothetical Net Zero scenarios, including on system cost, capacity and energy security. However, the EINAs analysis for the industrial sector did not include systems modelling analysis. This report therefore focuses on a qualitative mapping of the decarbonisation options selected, alongside a business opportunities analysis.

- Business opportunities analysis, including Gross Value Added (GVA) and employment, of the deployment of the technologies across scenarios and innovation levels.

This report summarises the findings from qualitative assessment and business opportunities analysis across the industrial decarbonisation technology theme. No systems modelling was undertaken for industrial decarbonisation due to difficulties modelling the large number of diverse decarbonisation approaches that could potentially be employed across industries.

Other reports relevant to industry include the Hydrogen, Carbon Management, Networks and Energy Storage technology theme reports.

The EINAs 2025 publications have been commissioned by DESNZ and produced by a consortium led by Carbon Trust, including Mott MacDonald, UCL and Pengwern Associates. Mott MacDonald was the Lead technical author for the industry theme report.

Scope and limitations of the EINAs:

The EINAs project is a research exercise to evaluate the potential impact of technological innovations on the UK energy system and Net Zero targets, and help inform decisions on clean energy innovation.

A number of technologies were included as part of the prioritisation but were not included in the systems modelling due to limitations of the models used for the EINAs, data availability and resource constraints. The three hypothetical scenarios developed to represent potential routes to Net Zero were selected due to their differing constraints which provide a more diverse set of outputs and insights.

The technologies and scenarios selected do not represent UK Government policy.

The industrial decarbonisation technology theme

Globally, the industrial sector accounts for around a quarter of all energy system CO_2 emissions, totalling around 9 $GtCO_2$ per year. Of this, 70% is from the steel, cement, and chemicals sub-sectors.[1]

Due to largely economic factors, UK wide industrial emissions have decreased by 60% since 1990. The reduction in the production of emission-intensive products such as steel and cement has contributed to this decrease. Nevertheless, in 2023, the UK industrial sector accounted for around 17% of greenhouse gas emissions, totalling around 64.1 $MtCO_2e$, and was the third highest emitting sector after domestic transport and buildings.[2]

The largest contributors to UK industrial emissions are the refineries (12 $MtCO_2e$), iron and steel (11.6 $MtCO_2e$) and chemicals (6.4 $MtCO_2e$) sub-sectors.[3] The main geographic sources of industrial emissions are the seven major industry clusters: Black Country, Grangemouth, Humber, Merseyside, Southampton, South Wales, and Teesside. Together, these account for around half of all industrial emissions.[4] The remainder are from dispersed industrial sites. Dispersed industrial sites are generally defined as facilities located more than 30 km way from one of the UK's seven large clusters.[5]

Emissions arise from the combustion of fossil fuels (e.g. to provide heat to the manufacturing process) or from reactions other than combustion that are intrinsic to the manufacturing process (e.g. nearly 60% of the emissions from cement production arise from the calcination of limestone).[6]

Combustion processes are required in many industrial sub-sectors to generate high and low temperature heat for manufacturing. For example, high temperatures are required for steam generation, steam cracking, in furnaces and in kilns. Low temperatures are required for drying and some separation process. Combustion of fossil fuels contribute 58 $MtCO_2e$.[7] Approaches to decarbonisation depend on the temperature of the heat required and process. Innovative technologies include:

- Electrification, such as through heat pumps, resistance heating, mechanical vapour recompression (MVR), electromagnetic radiation and arc furnaces
- Other fuel switching, such as to hydrogen and biomass
- Carbon capture and usage (CCU)
- Resource and energy efficiency (REE)

[1] IEA (2022) Achieving Net Zero Heavy Industry Sectors in G7 Members
[2] UK Government (2025) Final UK territorial greenhouse gas emissions statistics 1990-2023
[3] UK Government (2025) UK greenhouse gas emissions by Standard Industrial Classification (SIC) 1990-2023 and DESNZ.
[4] Aldersgate Group (2021) Accelerating the decarbonisation of industrial clusters and dispersed sites.
[5] UKERC. UK Energy Research Centre. [Accessed 10.02.2025]
[6] Gailini et al (2024) Assessing the potential of decarbonization options for industrial sectors
[7] UK Government (2025) Final UK territorial greenhouse gas emissions statistics 1990-2023

Emissions from reactions inherent to the manufacture of industrial products (‘process emissions’), such as in the manufacture of cement, lime, sinter, glass, and brick production, account for around 10% of industrial greenhouse gas emissions in the UK (6.1MtCO_2e).[8] These non-fuel emissions often require process-specific decarbonisation innovations that may not be easily transferrable between sub-sectors.

Large-scale investment in infrastructure and technology is essential, particularly where the required decarbonisation technologies are sub-sector specific, as is the development of clear, supportive policies and regulations to incentivise emissions reductions and innovation. Addressing these barriers is necessary for the UK to meet its net zero target and transition to a sustainable, low-carbon industrial economy.

[8] UK Government (2025) Final UK territorial greenhouse gas emissions statistics 1990-2023

Industry and the energy system

A shortlisting and prioritisation exercise was conducted to determine the industrial decarbonisation themes to be studied in this update of the EINAs. This followed a framework which considered the following factors important to DESNZ:

- **Known net zero priority:** Technologies where there is a clear government direction or expert consensus.
- **Energy security:** Technologies necessary for system resilience (grid/import shocks).
- **UK relevance:** Technologies suitable for UK specific circumstances, and where the UK is likely to have an impact.
- **Technology Readiness Level (TRL) relevance:** Technologies close to commercialisation or likely to be commercially viable by 2040.

This report focusses on four decarbonisation options for the UK industrial sector:

- Carbon Capture and Usage (CCU) as an alternative to Carbon Capture and Storage (CCS) in industrial dispersed sites
- Electrification
- Other fuel switching, such as to hydrogen and biomass
- Resource and energy efficiency

Carbon capture and storage (CCS) is covered in the Carbon Management report. Network innovation and electrical storage, both relevant for the electrification of industry, are further discussed within the Networks and Energy Storage EINA reports. Other decarbonisation approaches for industry such as on-site generation, on-site thermal storage, hybrid fuel systems and DSR can provide significant decarbonisation opportunities by enabling further electrification or reducing grid constraints. However, to maintain focus on industry specific innovation needs and shortlist criteria outlined above, these areas were not covered in detail as part of this report. Overview of industrial decarbonisation technologies

CCU as an alternative to CCS in industrial dispersed sites

CO_2 can be captured from industrial facilities, for example, from cement, steel, pulp and paper and chemicals. Carbon capture can be retrofitted onto existing plants or applied to new-build facilities. Carbon capture is particularly important for tackling process emissions which cannot be removed through electrification or fuel switching.

Carbon Capture and Storage (CCS) is the permanent storage of captured CO_2, usually in geological formations deep underground. The UK has significant geological storage capacity: the UK Continental Shelf (UKCS) has an estimated theoretical CO_2 storage capacity of 78 billion tonnes in saline aquifers or depleted oil and gas fields.[9] Outside of the identified UK CCUS clusters, CO_2 geological storage becomes a more challenging prospect due to the high costs of T&S infrastructure and difficulties sharing costs across many sites.

Additionally, smaller enterprises (e.g. in the ceramics sector), which make up a significant proportion of dispersed industrial sites, may have less capacity to develop and install relatively complex CO_2 T&S infrastructure, or access funding for this technology.

Non-Pipeline Transport (NPT) is the transportation of CO_2 using road, rail and/or shipping and will be important for capture projects outside the CCUS clusters, where a pipeline is technically and/or commercially unfeasible.

Alternatively, decarbonisation of dispersed sites may be achieved through the use of captured CO_2, through providing feedstock to local off-takers, reducing the need for extensive T&S infrastructure. Carbon Capture and Usage (CCU) is the capture and repurposing of CO_2. Usage of CO_2 minimises emissions and maximises the reuse, recycling, and removal of carbon to create a sustainable carbon cycle. Climate benefits depend on the source of the CO_2 (fossil, biogenic or air-captured), the product that is being displaced and how long the CO_2 is retained in the product, e.g. synthetic fuels using CO_2 can displace fossil fuels, but CO_2 is still released to the atmosphere during their combustion.

Worldwide, CO_2 is already being used in several industries with the majority being used for urea/fertiliser production and enhanced oil recovery. Other industries include food processing, carbonated drinks, chemicals production, metals and agriculture.

The opportunity for end usage of CO_2 is dependent on the source that is captured, due to the inherent impurities contained within the CO_2 stream in some cases.

Examples of usage opportunities in industrial sub-sectors include:

- Mineral carbonisation: The process of sequestering CO_2 within raw materials that contain calcium and magnesium. These materials can then be used in construction. Companies such as Carbon8 (UK, aggregate), OCO technologies (UK, aggregate), and CarbonCure (Canada, concrete) have demonstrated this usage process at a several kilo-tonne CO_2 per annum level.
- Synthetic fuels: CO_2 is captured through the gas-shift reaction and is then utilised in the production of fuels such as methanol, alongside hydrogen. These fuels can then be used to help decarbonise the transport sector. The Reuze project at Dunkirk, France plans to convert more than 300,000tpa of CO_2, captured from ArcelorMittal's steel plant, into e-fuels for shipping and aviation.[10]
- Carbonation of steel slag: Steel slag is a byproduct from the blast furnace steel making processes that is often used in other construction materials.[11] It also possesses the

[9] Oil and Gas Authority (2020) UKCS Energy Integration: Annex 2 Carbon Capture and Storage
[10] CCU Projects Database [Date accessed: 11.02.2025]
[11] DiGiovanni et al., 2024, Carbon dioxide sequestration through steel slag carbonation: Review of mechanisms, process parameters, and cleaner upcycling pathways, Journal of CO2 Utilization.

ability to store CO_2 through carbonation of the calcium and magnesium oxides. This process occurs naturally in an atmospheric environment; however accelerated carbonisation can be achieved through either direct or indirect (via an agent solution) reactions.[12]

The TRL of these CO_2 usage technologies varies, but is up to TRL 9 for some mineral carbonisation methods.[13] Notable CO_2 utilisation projects from carbon capture in the UK include the UK's first Post Combustion Capture (PCC) facility installed on a gas turbine at Tata Chemicals Europe facility near Northwich. This is designed to capture up to 40ktpa of CO_2, which is then dehydrated and purified into food grade CO_2 for the production of pharmaceutical grade bicarbonate of soda.[14]

Electrification

The Climate Change Committee (CCC) forecasts electrification to contribute 57% of emissions reductions in industry by 2040, in its 7th Carbon Budget Balanced Pathway.[15] This also relies on the reduction in carbon intensity of the electricity grid, which is the objective of the government's Clean Power 2030 mission.

Heat for processes can be electrified through four main technologies:[16]

- Heat pumps
- Resistive heating[i]
- Electromagnetic radiation
- Electric arc furnaces

Heat pumps are well-known for domestic applications in space heating up to 50 °C; however, High Temperature Heat Pumps (HTHPs) are capable of outputting above 200 °C. Industries such as paper milling produce significant waste heat through the exhaust air of the dryer process, which can be recovered through heat pumps to deliver heating to process water. The TRLs of HTHPs vary from 4 to 9 depending on the application, temperature and size of the heat pump.[17]

One of the most fundamental applications of electrification is in steam generation. Steam production has applications in many sub-sectors, and the use of resistive heating in boilers is a long-standing technology in the industry, capable of producing high pressure saturated steam.

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[12] Zhang et al., 2024, Use of steel slag as carbonation material: A review of carbonation methods and evaluation, environmental factors and carbon conversion process, Journal of CO2 Utilization
[13] Monterio et al., 2022, Novel Carbon Capture and Utilisation Technologies (CCU): Research and Climate Aspects, Journal of CO2 Utilization
[14] Tata Chemicals Europe (Accessed: 2025) Carbon capture and utilisation
[15] Climate Change Committee (February 2025) The Seventh Carbon Budget
[16] ERM (Nov 2023) Future Opportunities for Electrification to Decarbonise UK Industry
[17] IEA HPT (2024) Annex 58 High-Temperature Heat Pumps Final Report

Electromagnetic radiation, through a variety of wavelengths, can be used in heat production applications.[18] Radio, microwave, and infrared have all been demonstrated to be capable of creating temperatures over 2,000 °C, although the wavelength used is dependent on the type of source product (volume, thickness, material). Induction heating has been used in industry for almost a century for processes such as melting and hardening. This method is restricted to ferrous materials due to the magnetic properties required.

Electric arc furnaces (EAF) are an established technology which can be used in the metallurgy industry. A high voltage is passed through electrodes creating electric arcs, which radiate heat towards the subject material. In the direct-EAF variant, heat is also generated in the metal through the electrode. Tata Steel is developing a £1.25bn electric arc furnace project at its Port Talbot site which will reduce CO_2 emissions by 90%[18], supported by £500m of government funding.[19]

Electric arc technologies can also be used in cement manufacturing in the calcination and sintering processes. Pilot projects such as SaltX Electric Calciner Research Centre in Sweden have demonstrated a 1.4 MW electric arc, with CO_2 separation of 17 tonnes per day (tpd).[20]

Due to the wide reach of the grid, electrification can reach dispersed industrial sites mentioned above, as other options which require new infrastructure may not be economically viable in these locations and at the scale required. However, an increase in electrification will require new connections to the electricity network, which is currently oversubscribed, and potentially new distribution network infrastructure to be rolled out in parallel. [21]

Fuel switching to hydrogen and biomass

The combustion of fossil fuels, particularly natural gas, account for around 83% of industrial emissions. Where electrification is not a viable substitute or difficult to implement due to particular barriers (e.g. inadequate grid connection), fuel switching to low carbon hydrogen or sustainable biomass has the potential for substantial decarbonisation.

Opportunities for fuel switching in industry are being accelerated by UK government support, such as the Net Zero Innovation Portfolio (NZIP) Industrial Fuel Switching Competition[22], which allocated around £50m to support feasibility studies and demonstration projects. The first phase delivered feasibility studies and the second phase then supported demonstration projects, showcasing applications in hydrogen, biofuels and electrification.

[18] Tata Steel (Accessed: 2025) Green steel future
[19] UK Government (2024) Tata Steel / Port Talbot steelworks Q&A
[20] SaltX Technology. [Date accessed 11.02.2025]
[21] NESO (Accessed: 2025) Clean Power 2030
[22] Department for Energy Security and Net Zero (2022) Industrial Fuel Switching Competition Phase 2: demonstration projects (closed to applications)

Fuel switching to hydrogen

Fuel switching to 100% hydrogen requires upgrades to existing equipment on site and the construction of new infrastructure, e.g. control systems, pipelines, valves, pressure skids, hydrogen buffer storage and hydrogen burners.

With respect to burners, Original Equipment Manufacturers (OEMs) are currently demonstrating viable hydrogen firing equipment. When switching to a blend of natural gas and limited hydrogen by volume, only limited modifications to equipment may be needed. For example, Forterra has demonstrated 20% hydrogen blends across its brick ranges with no impact on brick quality and using existing kiln equipment.[23]

Hydrogen firing generally increases NOx emissions (compared to natural gas) due to the higher flame temperature. The HyNet industrial fuel switching project suggested there may be a 20 – 30% increase in NOx emissions, through observation of a demonstration glass furnace project.[24] This may therefore require further investment in additional or upgraded NOx abatement systems.

Deployment of this decarbonisation option will depend on the supply of sufficient hydrogen in the UK, along with the required infrastructure to deliver it to industrial sites. Production of hydrogen is covered in the EINAs Hydrogen technology theme report.

The CCC's 7th Carbon Budget Balance Pathway suggests that hydrogen will play an important role in decarbonisation of ceramics and chemical production, where electrification is not currently a suitable alternative.[15] Electrified technologies in these subsectors such as electric kilns (TRL 6) and electrical cracking (TRL 3-4) have a low TRL and may not prove commercially viable in the short term.[25]

Demonstration projects, such as those by Hanson UK in Ribblesdale, which has operated on a 100% climate-neutral mix of 39% hydrogen, 12% meat-and-bone meal (MBM), and 49% glycerine; have shown that fuel switching is a feasible pathway to decarbonisation.[26] This project received funding through the UK government's Industrial Fuel Switching competition.

In the steelmaking industry, there has been investment into the feasibility of hydrogen furnaces by parties such as British Steel. [27]

The UK government's Autumn Budget in October 2024 confirmed plans to support 11 green hydrogen projects with £2.3 billion of funding, once operational, as part of the first Hydrogen

[23] Forterra (Accessed: 2025) Paving the highway to hydrogen
[24] HyNet Industrial Fuel Switching. May 2022.
[25] DESNZ. (July 2023) Enabling Industrial Electrification
[26] Heidelberg Materials. HeidelbergCement produces cement with climate-neutral fuel mix using hydrogen technology. [Date accessed 11.02.2025]
[27] British Steel (November 2022.) Net Zero Innovation Portfolio Industrial Fuel Switching. Desktop Feasibility Study: Green Hydrogen in Steel Manufacture.

Allocation Round.[28] These projects have targeted local hydrogen offtake for industrial processes, including manufacturing, mining, and whiskey distilleries.

Fuel switching to biomass

The use of biomass and liquid biofuels as alternatives to fossil fuels in industry has also been examined. Biomass is a versatile fuel switching option. For instance, it can be used in a boiler for steam generation, as a fuel switch for solid fuel burners, or through gasification to produce a bio-syngas for use in combined heat and power (CHP) plants.

Anaerobic digestion (AD) is another technology which uses biogenic wastes to produce bio-methane, which can then be used as a fuel in CHP plants. This technology is utilised in several distilleries in Scotland, where waste barely and malt is used as a digestate for AD.[29]

In the cement industry, there is the potential for replacement of 20 – 30% of fossil fuels with solid biomass and refuse derived fuels (part biomass), without requiring significant investment.[30]

Biofuels could assist decarbonisation through use as a transition fuel for industrial machinery and vehicles, before hydrogen and electric alternatives become commercially available.

Earlier studies estimated that the demand of biomass for industrial processes could reach 53 TWh by 2030[31], if all opportunities for fuel switching occurred. This compares to total UK solid biomass use of 95 TWh in 2022. [32] However, in the CCC's 7th Carbon Budget, fuel switching to hydrogen is prioritised over fuel switching to biomass. Due to its finite supply, biomass prioritised for sectors that deploy CCS (i.e. Bioenergy with Carbon Capture and Storage) and can contribute to negative emissions. Additionally, in order for biomass to be considered a low carbon fuel it must be sustainably sourced, therefore adding further supply constraints.[32]

Resource and energy efficiency

Resource and energy efficiency (REE) refers to reductions in both raw materials and energy consumption in industrial processes.

Overall industrial energy consumption can be reduced through the use of waste-derived fuels, development of energy efficient equipment (advanced reactor design) and optimising process control. One example is the recycling waste heat, which can allow for an increased output from input materials, or in some industries enables lower temperatures to be utilised in production. These technologies and interventions aim to create the same end product, with less energy than legacy technologies.

[28] UK Government (2024) Autumn Budget 2024
[29] Andrews, E. Et al,. (January 2025) Whisky decarbonisation potential using bio-waste. Fuel Volume 380
[30] Kusuma, R.T et al,. 2022. Sustainable transition towards biomass-based cement industry: A review. Renewable and Sustainable Energy Reviews
[31] BEIS (December 2018) Industrial Fuel Switching Market Engagement Study. Element Energy & Jacobs.
[32] DESNZ (2023) Biomass Strategy

Resource efficiency encompasses strategies to design-out waste, encourage re-use, increase recycling and remanufacture, and the use of lower-carbon/secondary materials. This is vital in the transition to a circular economy where economic activity is decoupled from new resource extraction using a systemic approach across the full material and product lifecycle to maintain the value of our resources for as long as possible.

Resource efficiency interventions exist across the full material and product lifecycle from design and manufacturing, sale and use, and end of life that aim to maintain the value of our materials and products for as long as possible:

The design stage is a key opportunity to advance RE, whether designing to reduce embodied carbon (e.g. using WLC assessments and circular economy statements in construction planning) or designing to enable repair and recycling at EOL.

At the manufacturing stage RE interventions including the use alternative feedstocks, low carbon materials and recycled inputs inherently produce fewer emissions in the process (such as the use of cullet as a replacement for sodium carbonate in glass making). The reuse of materials can advance RE, for example refurbishing existing building stock or reusing key construction materials such as steel and concrete structures can reduce overall material consumption and embodied carbon in the infrastructure sector.[33] Industrial symbiosis of sub-sectors has potential to contribute to improved REE, through utilising by-products from one process as a feedstock in another. For example, fly ash from combustion processes can be used as cementitious material.[34]

A change in how products are used (e.g. rental models, lifetime extension etc.) can reduce the demand for a new products and raw materials, which can be induced through changing business models or cultural change. Life extension (repair, retrofit or refurbishment) leads to resource efficiency, where consumption of a new product is avoided or delayed. Reuse, remanufacturing, and recycling are processes which can allow raw materials to continue useful life through ‘new’ products.[35]

Advanced Recycling Technologies (ART) chemically and physically transform waste into feedstocks for new products, such as plastics and synthetic fuels, using methods like pyrolysis, gasification, and dissolution. ART is expected to account for 4–8% of global polymer production by 2030, rising to 6–10% by 2040.[35] In the UK, firms like Mura Technology have built facilities processing up to 20 ktpa of plastic waste, with plans to expand to 80 ktpa.[36] The impact of ART varies by sector, and government can influence uptake through permit requirements such as mandating recycled content in industrial products.

[33] UK Green Building Council (November 2021) Net zero whole life carbon roadmap. A Pathway to Net Zero for the UK Built Environment.
[34] UK Government (November 2023) Unlocking Resource Efficiency. Phase 1 Executive Summary
[35] Peng, Z. 2022. Advanced recycling: Opportunities for growth. McKinsey & Co. [Accessed: 19.02.2025]
[36] The Chemical Engineer (November 2023) Mura Technology’s flagship advanced plastics recycling plant opens in Teesside [Accessed 25.02.25]

Future deployment of industrial decarbonisation technologies

Industrial decarbonisation technologies cover a range of maturities and potential applications. The following sections look at the projected deployment of the EINAs technologies, based on their current state.

In the CCC’s 7th Carbon Budget report, industry emissions in the UK are shown to fall 78% (40.8 $MtCO_2e$) by 2040 (relative to 2023) in its Balanced Scenario, based on a similar level of industrial output. This is achieved by:

- Electrification which accounts for 57% of emission reductions as an alternative to fossil fuel heating, particularly electric boiler, electric ovens, electric furnaces, heat pumps for low temperature heat and electric arc furnaces in the iron and steel sub-sector.
- CCS accounts for 17% of emissions reductions, focussed in industrial sub-sectors with a high level of process emissions, e.g. in chemicals, cement and lime.
- Fuel switching to hydrogen accounts for 7% of emissions reductions, e.g. in chemicals, glass.
- Resource and energy efficiency together account for 13% of emissions reductions, playing a small role in all sub-sectors.

At the global level, the IEA has studied a feasible pathway to net zero for the global energy sector in its Net Zero by 2050 roadmap. In this, global industrial CO_2 emissions reduce by nearly 95% by 2050.[5] Material and energy efficiency accounts for around 25% of emission reductions. The rest is achieved through electrification, CCUS and fuel switching to hydrogen; the IEA estimates that today’s prototype and demonstration stage technologies will account for 60% of reductions.

Industrial decarbonisation energy innovation opportunities

This section provides a high-level review of decarbonisation innovation opportunities within the focus technology areas as outlined above. The analysis is inherently limited for the industrial sector given the heterogeneity across sectors, processes, technologies and locations. However, this section aims to provide an overview and introduction to key areas for innovation within the sector.

Opportunities for cost savings

Electrification has the potential to reduce certain operational costs within industry. In comparison to combustion equipment, electric alternatives: reduce pollution (e.g. NOX and SOX from combustion processes) and have limited residues and byproducts; comprise fewer moving parts, which can lead to reduced maintenance and spare parts costs; can be more energy efficient as heat is not lost within flue gases; and can provide more controlled and precise heating through digitalisation, which can improve product quality as well as achieve cost savings.

Utilising electrified processes can also allow industrial sites to benefit from flexible tariffs, through Demand Side Response (DSR) initiatives, which could reduce opex for industrial sites and reduce curtailment, particularly if combined with electrical or thermal energy storage, or the storage of physical products (intermediary or end products). These technologies are discussed further in the Energy Networks and Energy Storage reports.

Resource efficiency has immediate cost savings potential, through the reduction of the raw materials consumed which can be achieved by novel design and manufacture techniques. For example, automotive manufacture is a resource intensive process where reduction in resource use can lead to substantial cost savings.[36] Similarly, energy efficiency can reduce costs immediately through reduced heating and power requirements. This can be achieved through upgrading equipment which has no impact on the final product but requires less energy input. Investment in improved control systems, using big-data analytics or artificial intelligence, can reduce energy consumption required for industrial processes, as well as optimise maintenance, through predictive and preventative measures.[37]

High-level innovation needs for decarbonisation of major industry[38]

This table details key components and areas of technology innovation required to reduce cost and accelerate the deployment of the industrial decarbonisation opportunities assessed in this

[37] UK Government (December 2023) Energy efficiency in the manufacturing sector
[38] Sources for Table: Mott MacDonald, ERM Future Opportunities for Electrification to Decarbonise UK Industry, Stockholm Environment Institute Hydrogen steelmaking for a low-carbon economy, HyNet Industrial Fuel Switching, Imperial College London Assessing the potential of CO2 Utilisation in the UK, US Department of

report. The table details the direct technology impacts of innovations, as well as the other EINAs priority technologies that could benefit from innovation in these areas. Each innovation is assessed according to its likely impact on cost reduction and deployment for the relevant technology, with a qualitatively assessed 1(very low) – 5 (very high) impact rating. Column descriptors within the table are defined as following:

- Technology: technologies where the innovation is applicable.
- Other impacts: other technology families that are indirectly impacted by this innovation.
- Cost reduction: how the innovation opportunity can reduce the overall costs of the technology, rated from 1 (low) to 5 (high).
- Barrier reduction: how the innovation opportunity can contribute to reducing barriers to deployment, rated from 1 (low) to 5 (high).
- Time frame: period over which the innovation could feasibly start to be adopted and have material implications for the UK energy system and Net Zero

Energy (DOE) Industrial Decarbonisation Liftoff https://liftoff.energy.gov/industrial-decarbonization/, HM Government UK Net Zero Research and Innovation Framework (2021), Unlocking Resource Efficiency (https://www.gov.uk/government/publications/unlocking-resource-efficiency)

Table 1: Innovation needs for decarbonising industry: CO_2 usage, electrification, other fuel switching, and resource and energy efficiency

Decarbonisation option	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
All	Construction of mid-scale demonstration facilities; sustained reliable operation to remove uncertainties	All industry		3 – Can facilitate scaling up, and capex and opex reduction	4- Can reduce financing risks once technology considered proven	From 2025
CO_2 Usage	Solutions to reduce energy requirements during the conversion of CO_2 to fuels and chemicals (e.g. reverse water gas shift)	CO_2 use for synthetic fuels, chemicals production, CO_2 mineralisation	Can be applied to other CCUS technology families such as BECCS and DACCS	4- Potentially reduced energy consumption, which is a key contributor to lifecycle costs (fuel costs)	3 - Reduction in costs can contribute to greater market uptake	2030s
CO_2 Usage	Advanced CO_2 conversion routes (e.g. high temperature electrolysis and plasmolysis)	CO_2 use for synthetic fuels, chemicals production, CO_2 mineralisation	Can be applied to other CCUS technology families such as BECCS and DACCS	4- Potentially reduced energy consumption	3 - Reduction in costs can contribute to greater market uptake	2030s

Decarbonisation option	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
CO_2 Usage	Demonstration of the reliability of CO_2 based construction materials, e.g. through long term trials	CO_2 mineralisation	Can be applied to other CCUS technology families such as BECCS and DACCS	1 – Potentially limited impact on cost reduction	4 – Improve confidence in materials which can contribute to greater market uptake	2025-2030
Electrification	R&D into the suitability of microwave heating to understand impact on product quality	Food and drink manufacturing processes, ceramics production	Limited	1 – Potentially limited impact on cost reduction	4 – Improve confidence in materials which can contribute to greater market uptake	2025-2030
Electrification	R&D and demonstration of improved high temperature resistive heating technologies, e.g. resistance furnaces, longer lifetimes of heating elements, refractory materials	Ceramics production, automotive manufacturing, oil refining, glass production	Process heating applications	1 – Potentially limited impact on cost reduction	4 – Allows decarbonisation of further sub-sectors	2030s

Decarbonisation option	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
Electrification	R&D and demonstration of higher temperature industrial heat pumps, and integration of heat pumps and MVR to elevate temperatures provided by heat pumps	Paper manufacturing processes	Other industrial sub-sectors with demand for heat, CCUS (as capture plant could be electrified)	2- Potentially reduced energy consumption, which is a key contributor to lifecycle costs (fuel costs); potentially reduced opex compared to maintenance required for combustions systems	4 – Allows decarbonisation of further sub-sectors	2030s
Electrification	R&D and demonstration of electric cracker for pyrolysis steam cracking, including testing of product yield and quality	Chemicals production	Limited	2- Potentially reduced energy consumption, opex	4 – Allows decarbonisation of further sub-sectors	2030s
Electrification	R&D and scale up of electric arc calciners	Cement and lime production	Iron and steel	2- Potentially reduced energy consumption, opex	4 – Allows decarbonisation of further sub-sectors	2030s

Decarbonisation option	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
Fuel switching	R&D to make existing gas equipment 'hydrogen-ready', e.g. hydrogen supply to burners, new burners, refractory, NOX abatement	E.g. chemicals production, glass, iron and steel	Hydrogen for power	1 – Potentially limited impact on cost reduction	3 – Reduces impact of future transition to decarbonisation	2025-2030
Fuel switching	R&D and demonstration of technologies for high temperature direct firing using hydrogen in specific industrial applications, e.g. hydrogen flame stability, NOX emissions, impact on existing equipment, impact on product quality	E.g. primary steel production, glass, ceramics, chemicals	Limited	2 – Potential reduction in opex	4 – Allows decarbonisation of further sub-sectors	2030s

Decarbonisation option	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
REE	Advanced manufacturing technologies, such as near net shaped and additive manufacturing (or 3D printing) to create lighter, cheaper and less resource intensive materials, reduce lead times	All	All	4 – Reduction in cost of raw materials; potential reductions in energy costs	3 - Reduction in costs can contribute to greater market uptake	2025-2030
REE	Improving product lifespan, e.g. increased product reuse, improved product repairability	In all sectors (excluding potentially cement and concrete as lifespan is generally longer than that of the building)	All	4 – Cost of new product is avoided or delayed	1 – Potentially limited impact	2025-2030
REE	Digital Twin technology to identify potential issues and inefficiencies and improve the cost effectiveness, efficiency and flexibility of production	All	All, including electrification and fuel switching	4 – Reduction in cost of raw materials; potential reductions in energy costs	3 - Reduction in costs can contribute to greater market uptake	2025-2030

Decarbonisation option	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
REE	Light weighting through material substitution or lean design to reduce the weight of material inputs into a product	All	All	4 – Reduction in cost of raw materials; potential reductions in energy costs	3 - Reduction in costs can contribute to greater market uptake	2025-2030
REE	Advanced separation, sorting and processing of waste that enables more and higher quality recycling	All	All	2 – Potential reductions in cost of raw materials; potential reductions in waste disposal costs	2 - Reduction in costs can contribute to greater market uptake	2025-2030

Market innovation barriers and enablers

Economic viability

The economic viability of industrial decarbonisation is currently a key non-innovation barrier to deployment.

The decarbonisation options detailed in this report all require upfront investment by prospective users, irrespective of technology maturity. This can reduce the initial uptake of new technologies, particularly where the existing asset or equipment being replaced has many years of remaining life ('sunk cost').

Upfront costs relate to project development and capex. Capex for First-Of-A-Kind (FOAK) technologies are typically high compared to alternative options. Capex is also required for site modifications.

Market uncertainty may deter investment into decarbonisation in sectors where there is uncertainty in the future demand for products. High levels of competition from other suppliers may also reduce appetite for new technologies with high upfront costs.

The price ratio between industrial electricity and gas prices could impact the economic viability of electrification processes. Additionally, the exposure of electrified technologies to fluctuating wholesale prices could deter investment, although fossil fuels are also subject to this uncertainty. This uncertainty could be managed through commercial arrangement with energy suppliers, such as power purchase agreements (PPA).

In addition, in some cases where the technology is commercially available, infrastructure may not be in place to facilitate the transition. For example, CO_2 usage is only viable if an off-taker is close to the capture plant or CO_2 transportation infrastructure is available.

The UK Emissions Trading Scheme is expected to play a significant role in incentivising decarbonisation approaches by making it more expensive to use fossil fuels without abatement.[39]

The UK government is developing an Industrial Carbon Capture business model to provide support to industrial CCS projects participating in the CCUS Cluster Sequencing process. As part of the CCUS Cluster Sequencing process, the Padeswood Cement Works CCS project was selected by DESNZ to proceed to negotiations for support through the Industrial Carbon Capture business model.[40]

A forthcoming Industrial Decarbonisation Strategy, as well as the Invest 2035 industrial strategy, the revision of the hydrogen strategy, the development of a low-carbon flexibility roadmap, progression of the hydrogen to power business models, and clarity around the

[39] DESNZ (December 2024) Traded carbon values used for modelling purposes, 2024
[40] DESNZ (2023) Cluster sequencing Phase-2: Track-1 project negotiation list, March 2023

subsequent processes of the Hydrogen Allocation Rounds, are all likely to reduce uncertainty in this space and boost the innovation and deployment environment across industry.

Enabling infrastructure and supply chains

Enabling infrastructure required for these technologies could be a barrier to industrial decarbonisation.

Supply of electricity, through renewable or fossil fuel source, is insufficient at present for full transition to an electrified industry. In its Clean Power 2030 Action Plan, DESNZ sets out ambitions to increase installed capacity from around 110 GW currently to over 200 GW by 2030[41]. Further to this, the National Grid infrastructure will need to be expanded to be capable of transmitting the increased electricity supply to the demand sites. National Grid is planning to invest £35 billion between 2026 and 2031, which will improve grid capacity and increase the reach of the transmission network.[42] At the site level, new distribution network infrastructure and new connections may be needed to be rolled out in parallel but are often subject to queues.[43]

Supply of readily available low carbon hydrogen for fuel switching is currently limited and therefore a significant barrier to uptake in the chemicals, glass, and iron and steel sectors.

At present, many of the technologies outlined in this report are at the small or pilot study scale. The deployment of commercially available products is reliant on a small number of manufacturers. Building up a supply chain from a small base will require significant global expansion. Whereas some components are already manufactured for other industries, other components may be bespoke and supply chains at scale do not exist yet. Supply chains will therefore need to scale up significantly to meet global targets. These constraints present an opportunity for UK supply chains to develop and capture a significant global share of the industrial decarbonisation sector.

[41] DESNZ (2024) Clean Power 2030 Action Plan
[42] National Grid (December 2024) RIIO-T3 Business Plan.
[43] NESO (Accessed: 2025) Clean Power 2030

Business opportunities in industrial decarbonisation technologies

Introduction

The purpose of this section is to explore the potential scale of the business opportunities for the UK associated with the national development of the industrial decarbonisation technologies (as defined elsewhere in this report as alternatives to CCS in industrial dispersed sites, electrification, fuel switching and resource and energy efficiency technologies). Innovation will be a key driver in supporting the growth of this sector in the UK and realising these business opportunities, and therefore an important element to capture as part of this innovation assessment.

It summarises the key findings from the development of a series of 'business opportunities calculators'. These calculators utilise information about the potential domestic deployment of the industrial decarbonisation technologies from DESNZ's 2025 'Updating Evidence on Energy Efficiency (EE) Potential for UK Industry' report, which is expected to be published soon, and DESNZ's Cost Optimisation Model for Industrial Technologies (COMIT), with assessments of UK firms' potential share of these markets, informed by trade and production data.[44] They combine this understanding of potential deployment with assumptions around the cost structure and employment intensity of the different activities required for the manufacturing, deployment, and operation of each technology to generate an understanding of the potential business opportunities in terms of:

- Gross Value Added (GVA) – a measure of the value generated by the production of goods and services. GVA can be thought of as broadly equivalent to the contribution of that sector/activity to Gross Domestic Product.
- Employment – Employment is measured in terms of jobs and includes both direct employment – the jobs associated with the construction and operation of the assets – and indirect employment – the jobs associated with the production of the goods and services needed by the workers with direct jobs i.e. jobs associated with the supply chain needed to construct, operate and, as necessary, decommission the assets.

All results are illustrative of potential business opportunities, generated using a particular set of modelling outputs and other assumptions to help inform UK Government decision making. They do not reflect UK government policy targets/ambitions regarding either deployment or the business opportunities that might be realised. The results reflect the GVA and employment

[44] DESNZ's 2025 Updating Evidence on Energy Efficiency Potential for UK Industry' report provided investment forecasts for 258 energy efficiency technologies. DESNZ's Cost Optimisation Model for Industrial Technologies (COMIT) providing investment forecasts for 131 deep decarbonisation technologies. In COMIT, deep decarbonisation technologies are defined as CCUS, electrification and fuel switching. The two technology lists were grouped into 13 technology types for the purposes of this analysis: furnaces and kilns; steam production and distribution; waste recovery and/or re-use; bioprocessing and catalysts; food processing machinery; industrial control equipment; machinery for processing stones, ceramics, cement; paper-making machinery; pumps, compressors, motors; drying; cracking; miscellaneous and; hydrogen production.

impacts associated with the deployment of specific industrial decarbonisation technologies that are the focus of the report and are not a comprehensive assessment across the sector. For example, any jobs related to industrial resource efficiency are not considered here, though the 2023 Unlocking Resource Efficiency research published by DESNZ has identified significant potential for innovative technologies and materials to drive industrial resource efficiency in the UK.

There is uncertainty around how industry is going to meet Net Zero by 2050. In particular, many industrial deep decarbonisation technologies are in their nascency. It is therefore highly likely that the actual levels of deployment will not reflect the deployment profiles used in this analysis.

All monetary values in this section refer to 2022 GBP unless otherwise specified. The methodologies for the calculators, along with key caveats and assumptions, are available in the EINAs Technical Methodology reports.

Industrial decarbonisation business opportunity analysis

The deployment assumptions underpinning the calculator uses one scenario for deep decarbonisation technologies: a central scenario from COMIT model from Spring 2025. The scenario provides a Net Zero consistent pathway for the UK manufacturing & refinery sector and presents similar industrial decarbonisation routes to those published in the Climate Change Committee 7th Carbon Budget report.[45] It uses three scenarios for energy efficiency: BAU, Higher Ambition and Max Technical, defined in the EE roadmap as follows:

- Business as usual: A pathway where existing trends in energy efficiency and decarbonisation continue. This provides a 20-40% reduction pathway.
- Higher Ambition: The Higher Ambition scenario is set as a mid-point between the BAU and Max Tech emission saving scenarios, representing a realistic yet ambitious level of emission savings for industrial EE.
- Max Technical: A pathway where all potentially technically feasible options are deployed when they become available without cost being a limitation.

In the results displayed below, the one deep decarbonisation scenario is combined with each of energy efficiency scenarios to generate outcomes at the sectoral level for three different deployment scenarios. Important to note that compared to other EINA reports, this report does not consider potential GVA or supported jobs from export opportunities. This was due to analysis limitations, as the highly heterogeneous technology mix for industrial decarbonisation meant that robust global technology projections or potential UK market share capture estimates could not be identified.

[45] The Seventh Carbon Budget - Climate Change Committee

Gross Value Added (GVA)

The business opportunities calculators suggest that GVA associated with the manufacture and supply of these technologies will grow strongly between 2025 and 2050 across all scenarios. Figure 1 shows that sectoral GVA in real terms grows from between £0.3 and £0.4bn in 2025 to between £1.8 and £1.9bn in 2050, depending on the EE scenario. This represents a compound annual growth rate (CAGR) of 6.8% to 7.2%. By 2050, meeting the Higher Ambition scenario targets would lead to an additional £45m in GVA per year relative to the BAU scenario, increasing to an additional £94m in the Max Technical scenario. The majority of the additional GVA in these more ambitious scenarios is expected to be driven by additional investment in two technology types: increased adoption of advanced furnaces and kilns in each of the cement and ceramics sectors, alongside new food processing machinery in the food and drink sector.

Energy efficiency technologies initially account for the majority of the GVA in all scenarios but, from 2035 onwards, deep decarbonisation is the larger contributor to GVA. In the datasets which underly this analysis, there is a rapid increase in the rate of deployment of deep decarbonisation technologies between 2025 and 2035 and then again between 2045 and 2050 whereas the deployment rate of energy efficiency technologies is relatively consistent across the period. As a result, by 2035, deep decarbonisation technologies grow in importance to account for 54-58% of GVA, depending on the EE scenario. By 2050 this has risen further to 62-66% of total GVA, depending on the EE scenario.

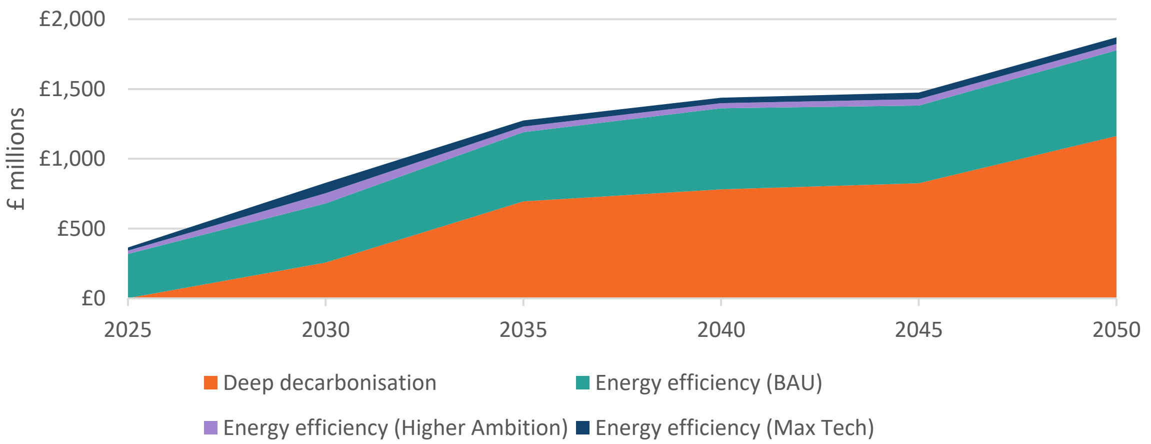

Figure 1: GVA by Deep Decarbonisation vs Energy Efficiency by EE scenario[46]

Figure 2 looks at the breakdown of GVA across technologies in two particular years: 2040 and 2050. Industrial control equipment accounts for approximately 26% of GVA in both 2040 and 2050, regardless of EE scenario. In 2040, furnaces and kilns (23% of GVA) and paper-making machinery (16% of GVA) are the second and third largest contributors to GVA respectively. By 2050, paper-making machinery becomes the second largest contributor to GVA (15% of GVA) and the third largest contributor is cracking (12% of GVA).

[46] The GVA from Energy Efficiency (Higher ambition) is the additional GVA in this scenario relative to the BAU scenario. Similarly, the GVA from Energy Efficiency (Max Tech) is the additional GVA in this scenario relative to the Higher ambition scenario.

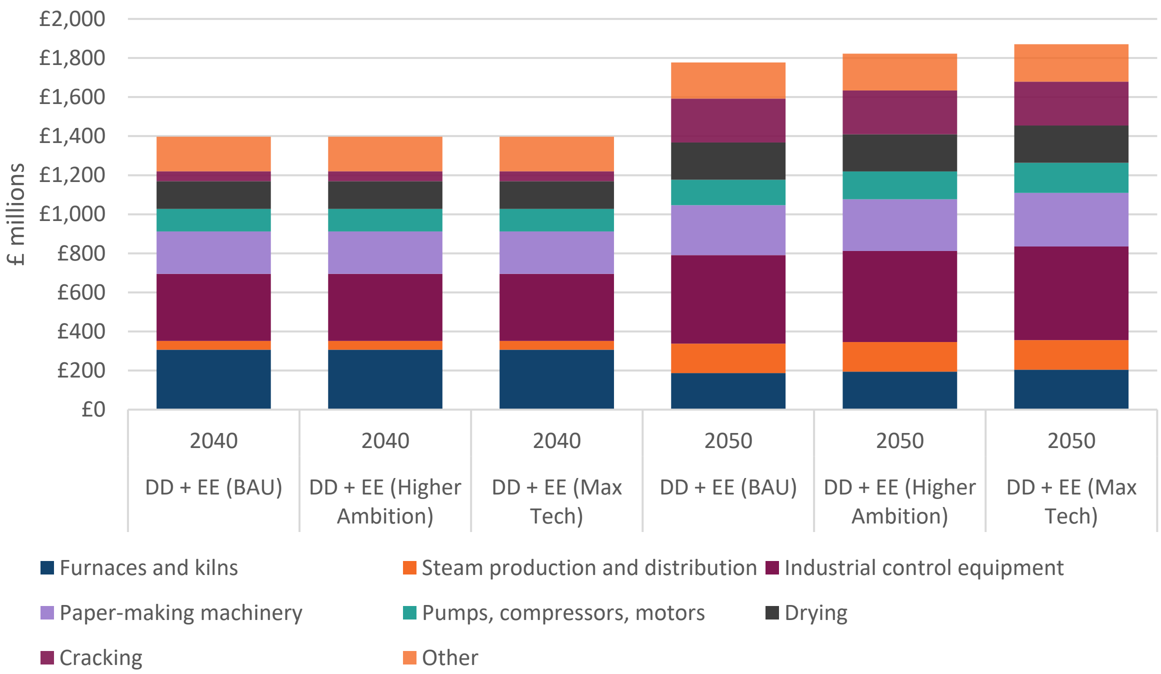

Figure 2: GVA by EE scenario by technology type[47]

Direct and indirect jobs[48]

Supported employment (direct and indirect jobs[49]) follows the stable growth in GVA. Supported employment rises from approximately 6,000 to 7,000 jobs in 2025 to between 29,000 and 31,000 jobs in 2050, depending on the EE scenario. This represents a CAGR of around 6% across the period. Throughout the period, and in all three EE scenarios, around 59-63% of these jobs are direct jobs, implying that the employment intensity of the supply chain activities of the technologies within the sector is relatively consistent over time and between EE scenarios (see also Figure 6 below). By 2050, there are 2.5% more total jobs supported (approximately 700 extra jobs) if Higher Ambition targets are achieved relative to BAU and 5.3% more total jobs supported (approximately 1,500 extra jobs) under maximum technical deployment relative to BAU. As for GVA, these extra jobs relative to BAU are expected to be principally driven by incremental investment in advanced furnaces and kilns in the cement and ceramics sectors and food processing machinery in the food and drink sector.

[47] The 6 technology types aggregated under 'other' are: waste recovery and/or re-use; bioprocessing and catalysts; food processing machinery; machinery for processing stones, ceramics, cement; miscellaneous and; hydrogen production.
[48] Jobs figures in this report may differ from other publications due to earlier versions of the COMIT and EE Roadmaps models being used.
[49] A direct job is employment associated with the stated activity. An indirect job is a job that exists to produce the goods and services needed by the workers with direct jobs i.e. those jobs associated with supply chain activities. The estimate of indirect jobs is based on the application of Type 1 multipliers to the different cost categories (activities) within the sector.

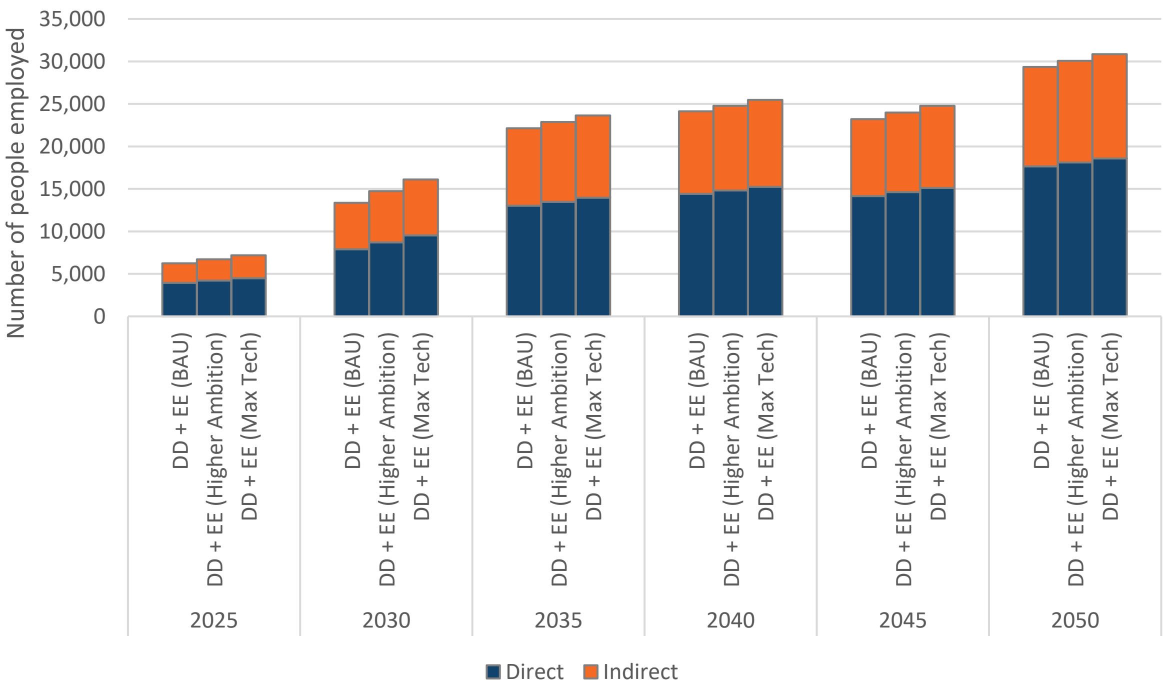

Figure 3: Total jobs supported by EE scenario by direct vs indirect

Figure 4 and Figure 5 show the breakdown of employment across different technology types and different cost categories i.e. construction and operation & maintenance, respectively.

As is the case for GVA, there is no one technology type which dominates the job picture in 2040 or 2050. In 2040, the primary drivers of employment in the sector are projected to be industrial control equipment and furnaces and kilns. The modelling suggests that, in combination, these two technology types account for approximately 48% (11,300-12,100 jobs) of jobs supported in 2040. In 2050, industrial control equipment continues to be the largest supporter of jobs (7,100-7,500 jobs) but paper-making machinery (4,200-4,500 jobs) replaces furnaces and kilns as the second most prominent technology type. The decrease in the relative importance of furnaces and kilns between 2040 and 2050 reflects the projections that capital investment in this technology type will be concentrated at the beginning of the period. By 2050, there are very few CAPEX-driven jobs associated with this technology type and this decline is only partially offset by the growth in OPEX-related jobs.

The relationship between CAPEX and OPEX jobs follows the expected trend with OPEX-related jobs becoming increasingly dominant by 2050 as the stock of assets increases. Between 2040 and 2050, the number of jobs supported by CAPEX is more or less constant at around 10,000 jobs but it gradually becomes a lower share of the total (45-46% in 2035, 38-39% in 2040 and falling to 32% in 2050). The number of OPEX jobs grows by 61-67% over the period from 12-13,000 in 2035 to 20-21,000 in 2050.

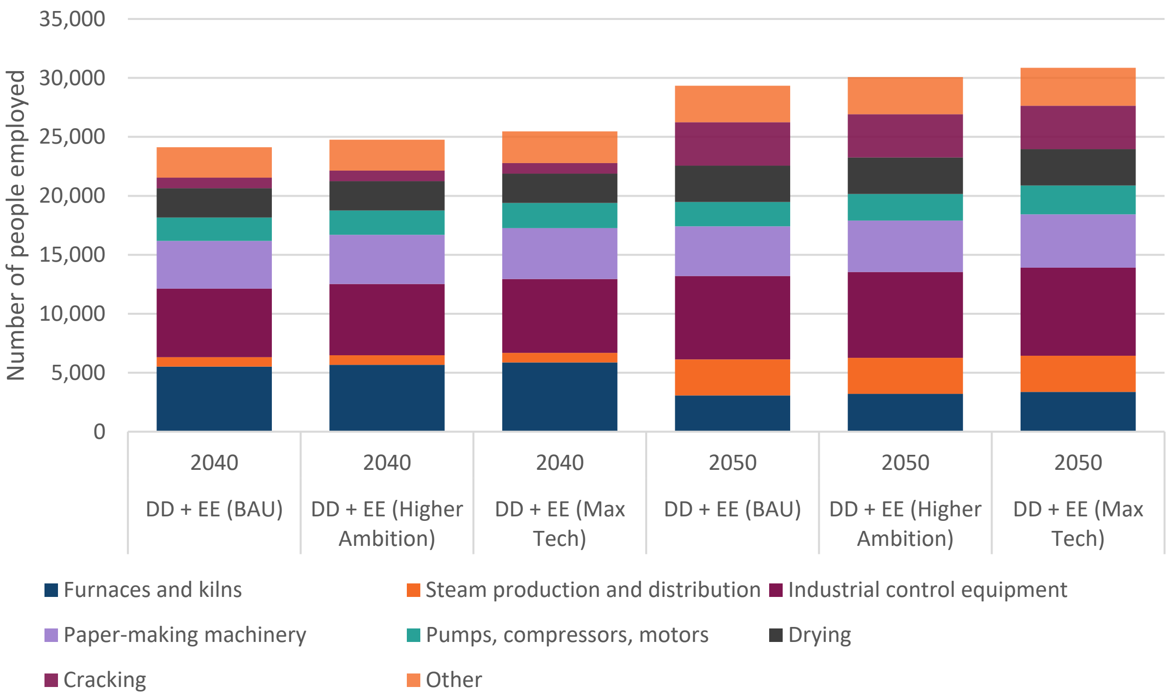

Figure 4: Total jobs supported (direct + indirect) by EE scenario by technology type[50]

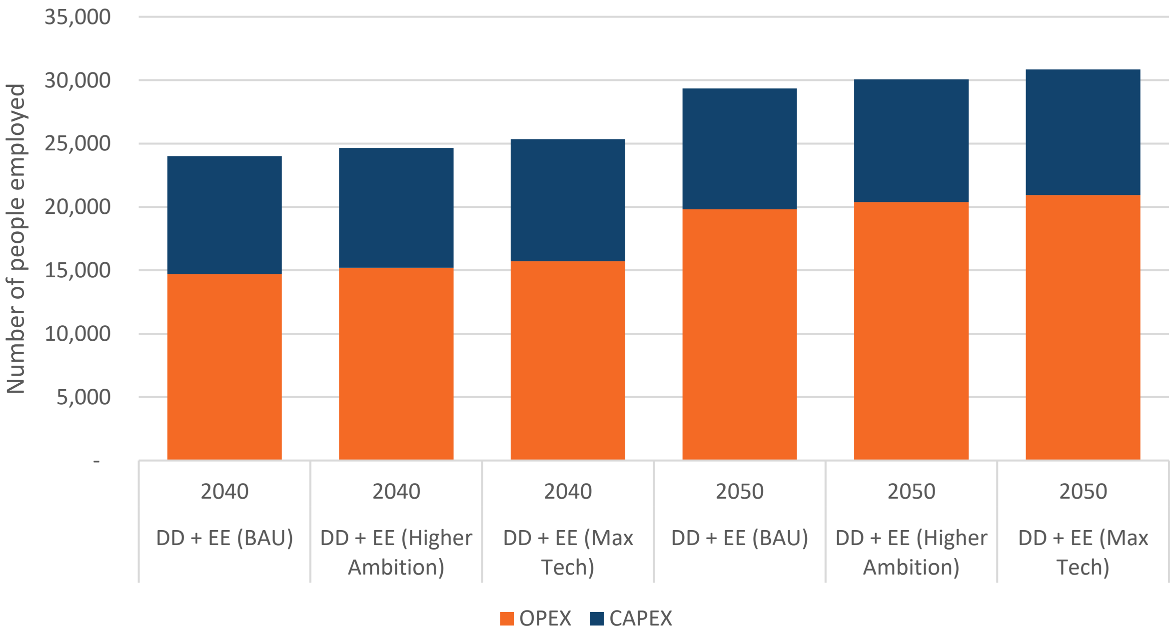

Figure 5: Total jobs supported (direct + indirect) by EE scenario by cost category

Finally, Figure 6 shows that most of the direct jobs supported by the sector in 2050 are expected to be in high-skilled professional occupations. The occupations that account for the largest number of jobs supported are professionals in science, research, engineering and technology (between 6,000 and 6,300 direct jobs, 34% of the total), followed by other

[50] The 6 technology types aggregated under 'other' in this report include: waste recovery and/or re-use; bioprocessing and catalysts; food processing machinery; machinery for processing stones, ceramics, cement; miscellaneous and hydrogen production.

professional occupations (between 2,200 and 2,300 direct jobs, 12% of the total) and managers, directors and senior officials (between 2,200 and 2,300 direct jobs, 12% of the total). The sector is also expected to support around 2,300 to 2,400 jobs in skilled trade jobs by this date.

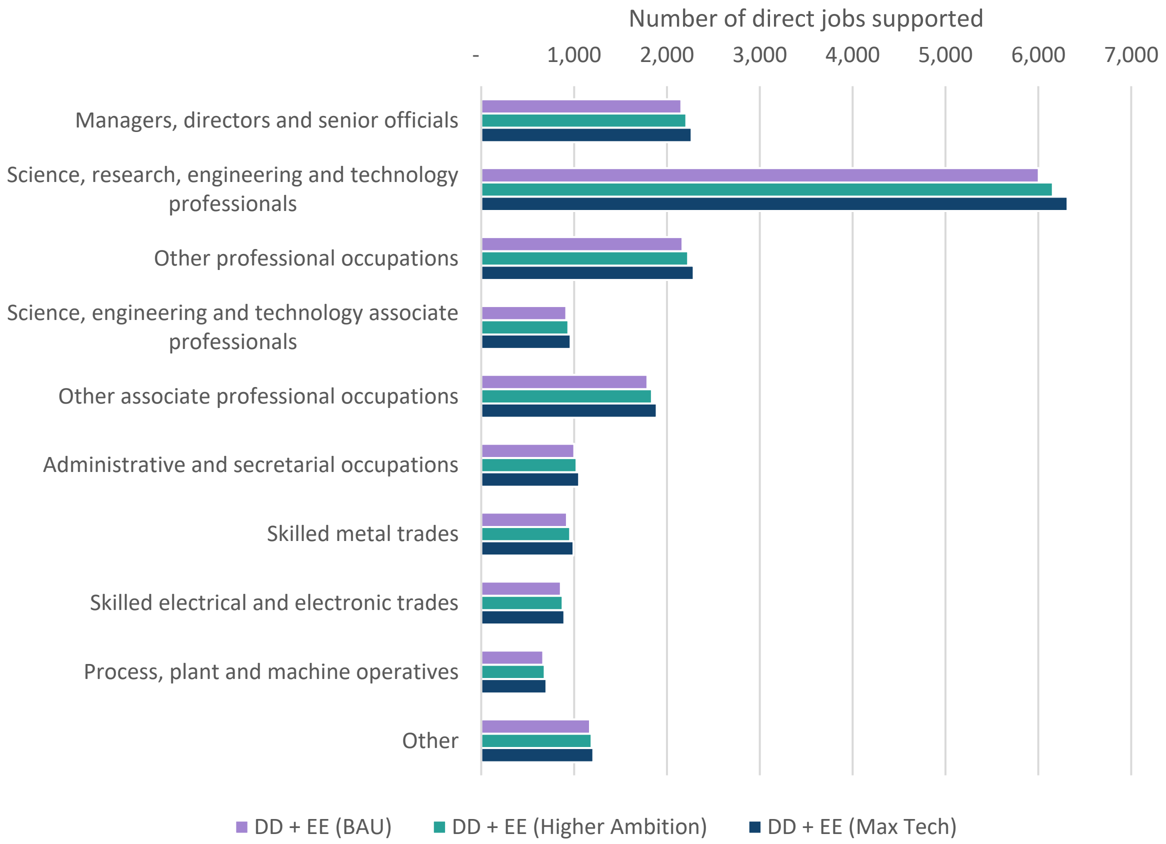

Figure 6: Direct jobs supported by EE scenario by occupation type in 2050

Note: For the purposes of this analysis, the 412 4-digit SOC codes have been aggregated to 15 SOC groupings. See the EINAs Technical Methodology report for more details on this aggregation. In Figure 6 the heading 'other' covers the following six SOC groupings: elementary occupations; transport and mobile machine drivers and operatives; other skilled trade occupations; skilled construction and buildings trades; sales and customer service occupations and; caring, leisure and other service occupations.

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