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Decarbonise Now: Securing A Greener, Cleaner, Better Industrial Future

The Industrial Mission Zero Network Report

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This Report

PREFACE

It is clear that we will not achieve net zero without placing industrial decarbonisation at the heart of the pathway to reduce carbon dioxide emissions. 8% of business and industry is responsible for 80% of the UK's gas use. If we are to meet our 2035 commitments to decarbonise our emissions by 78% on 1990 levels, then we will need to reduce those industrial emissions by two thirds. The importance of acting now to deliver what is needed to achieve this cannot be overstated. Without industrial decarbonisation, net zero will not be delivered.

The Net Zero Review, Mission Zero, was equally clear that tackling industrial emissions must be a priority for the UK in order to deliver on its climate commitments. The Review proposed that one of its ten missions be established for Energy Intensives and Industry, ensuring that a clear and stable pathway towards decarbonising our industries be set out for the long term. While other countries such as the US and Germany are providing long term support for industry to map out their own emissions reductions into the 2030s, for the UK, both the current plans for the Net Zero Industrial Hubs, the UK's CCUS and hydrogen strategies, and the wider detailed pathway for the Emissions Trading Scheme do not extend beyond 2030. For heavy industry and energy intensives that need to take long term, multi-decadal decisions on their future, to invest into disruptive technologies and create new cross industry partnerships, this certainty and clarity is becoming ever more imperative.

The Industrial Mission Zero Network was set up as part of the Mission Zero Coalition, and established to provide further detail on how to deliver on the policy recommendations of the Net Zero Review, and its industrial mission. The Network has met for several roundtable discussions to highlight both the challenges but also the opportunities that industrial decarbonisation can bring. The Network includes AVEVA, Carbon Clean, Carbon Tracker, SSE Thermal, High Value Manufacturing Catapult (HVMC) and Industrial Decarbonisation Research and Innovation Centre (IDRIC). This report is the product of the discussions of the Network, and is intended to highlight the need for why industrial decarbonisation not only matters, but is essential for delivering net zero not only by 2050, but the UK's National Determined Contribution of 68% emissions reduction by 2030.

In response to the recommendations of the Net Zero Review, the government has set out its intention to provide a long term direction for industrial decarbonisation. This is welcome, and the Introduction to this report sets out in further detail what recent developments have taken place following the publication of the Mission Zero report. This report is intended to build on the broader recommendations in the report, and to provide further detail on how a longer term industrial decarbonisation mission for both industry and energy intensives might not only ensure that the UK can achieve its carbon budgets, but also seize the opportunity that industrial decarbonisation can present to the UK. The Net Zero Review was clear that to delay measures that are needed will cost more: not only in terms of extra investment and finance needed, as prices rise and demand increases, but also in terms of the human cost for not transitioning high carbon industries and energy intensives to low carbon technologies before it is too late. Chapter One of this report sets out the opportunity for industrial decarbonisation within this important international context. Low carbon industries and materials present a vast opportunity for the UK not only to lead, but to benefit economically from the additional inward investment and export opportunities that these products can bring. However other countries are increasingly aware of these opportunities also: the UK needs to act now, if it is to realise the potential investment and trade benefits, that may not come again.

Chapter Two of this report highlights what is the current situation and policy landscape within industrial decarbonisation in the UK. In doing so,

it highlights the existing challenges and barriers that industry and business faces in being able to effectively decarbonise at scale. Identifying these barriers is essential if we are to make further progress, as well as listening to the voice of business and industry as to the challenges they are facing that makes deployment of low carbon industrial processes difficult.

Chapter Three then looks at what the policy frameworks and solutions could be that would help remove these barriers, and accelerate deployment for the future. In particular, the focus of this report is on what can not only be delivered to provide long term certainty for industrial decarbonisation, but also what are the solutions and technologies that can and should be deployed today, in the present, in order to bend the emissions curve downwards as fast as possible. Energy efficiency and electrification, digitisation, reuse of heat and the microgeneration of power and energy are key opportunities for industrial decarbonisation that can be deployed in parallel with the development of CCUS and hydrogen technology. While these are key innovations that will be essential for net zero, this report highlights how we need to take a 'twin track' approach to industrial decarbonisation by first decarbonising all industries we can now, with the tools and technologies that we can deploy with the correct policy support, and second, by providing the longer term, more expansive plan for disruptive technologies and industrial CCUS decarbonisation for all industrial sites that will need this technology and also the wider deployment of hydrogen, through industrial pipeline networks.

Finally, Chapter 4 sets out the wider context in which industrial decarbonisation in the UK needs to take place, but also how the UK's progress in industrial decarbonisation can act as an international example for how to provide future climate policy leadership. As new international frameworks based on carbon are developed, including CBAM mechanisms, as well as the wider Breakthrough Agenda that seeks to decarbonise heavy and high emitting industries, there is a vital role to play in the international agenda on industrial decarbonisation. This report is being launched at COP28, where the Global Stocktake has the potential to highlight the importance of decarbonising industry. The report makes further recommendations on how new international policy frameworks can help to encourage new forms of international collaboration and cooperation to deliver the decarbonisation of industry, and its greater use of energy efficiency and electrification and digital technologies in order for all countries to meet their climate targets.

Industrial decarbonisation is not simply about reducing our emissions, however, essential though that challenge is for meeting our climate commitments. Industry and our energy intensive, foundation businesses represent not only an essential component of modern society, responsible for producing the materials, chemicals, products and the fuels that allow our economy to function. If we are able to decarbonise our industries, we are also able to help every business and organisation in turn help to reduce their carbon emissions. And in doing so, we can deliver a new model of economic opportunity that recognises that the industries of the future that will deliver growth are those that prioritise decarbonisation as an investment and not a cost, and an opportunity, before others do. This report is clear that decarbonisation must and will not lead to deindustrialisation. Indeed, the opposite is the case: if we do not act now, and act fast, to position the UK as the leader in low carbon industrial processes of the future, the jobs of the future and the investments of the future will go elsewhere, resulting in 'low carbon leakage'. It is a price we cannot afford to pay.

Rt Hon Chris Skidmore OBE
Chair, Mission Zero Coalition

Introduction

If we do not succeed in decarbonising our industries, net zero will not succeed. Industry, which includes ores and minerals mining, manufacturing, construction and waste management, accounted for approximately 24% of total net anthropogenic GHG emissions in 2019, this total can be increased up to around 34% if emissions from electricity and heat production are attributed to their use in the sector. A key message from the IPCC's 2022 report on the mitigation of climate change stated:[1]

"Net zero CO2 emissions from the industrial sector are challenging but possible. Reducing industry emissions will entail coordinated action throughout value chains to promote all mitigation options, including demand management, energy and materials efficiency, circular material flows, as well as abatement technologies and transformational changes in production processes. Progressing towards net zero GHG emissions from industry will be enabled by the adoption of new production processes using low- and zero-GHG electricity, hydrogen, fuels, and carbon management."

Further, industrial clusters account for 15%-20% of global CO2 emissions.[2] Therefore, it is evident that governments need to develop robust industrial decarbonisation strategies and accelerate the speed of implementation. This report follows the Independent Net Zero Review, focusing on the Energy Intensives and Industry Mission.

The Independent Net Zero Review was one of the largest engagement exercises on net zero ever conducted. As part of the review process, its chair Chris Skidmore held 52 evidence roundtables, speaking directly to nearly a thousand businesses and organizations. These demonstrated the importance of a stable policy environment for business, especially industry that requires long term certainty of decision making.

The 2022 Non-domestic National Energy Efficiency Data-Framework (ND-NEED) found that in England and Wales the highest 6% of electricity consumers are responsible for 80% of electricity consumption, while the highest 4% of gas consumers are responsible for 80% of gas consumption.[3] As such, industrial decarbonisation is a crucial area for the UK government to focus on if they are to reach their Net Zero by 2050 target. However, current measures need to go further and new, innovative, methods to accelerate decarbonisation must emerge. The Coalition convened experts from different areas of industry, including CCUS, hydrogen, renewable energy and software providers to discuss the current pathway to decarbonisation set out by the government, its gaps and potential solutions moving forward. The report will also look wider to the international landscape for examples of best practice, forward-thinking policies and to provide recommendations for a globally decarbonised industrial sector.

UK INDUSTRIAL DECARBONISATION STRATEGY 2021

In March 2021, the Department for Business, Energy and Industrial Strategy (DBEIS), now Department for Energy Security and Net Zero (DESNZ), launched the UK's Industrial Decarbonisation Strategy, laid out in Figure 1. The Strategy considered both clustered and dispersed sites, which are responsible for 37.6 MtCO2e and 33.6 MtCO2e, respectively. The 2050 framework sets out three pillars with varying options:

- Primary sector decarbonisation incentive
  - Carbon pricing
  - Product standards
- Carbon leakage mitigation mechanisms
  - Climate diplomacy
  - Improving productivity
  - Treatment of imports
- Wider supporting policy framework
  - Skills transition
  - Energy/ resource efficiency regulation
  - Targeted assistance for innovation and complex sites

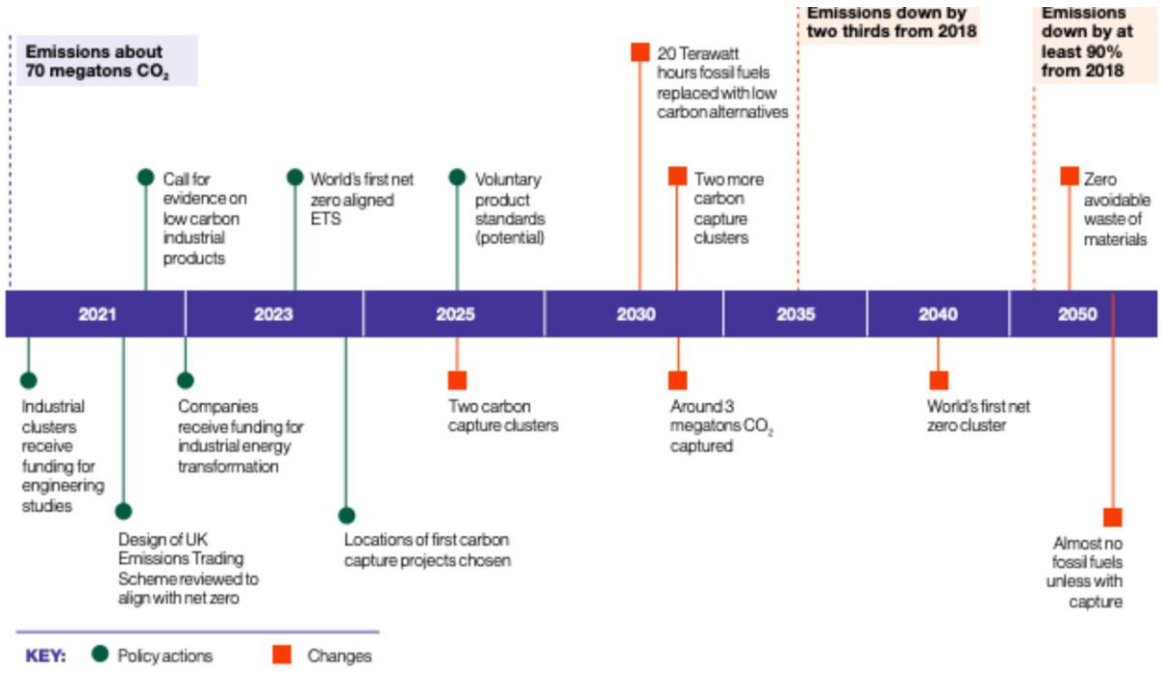


Figure 1. Indicative roadmap to net zero UK industry

Additionally, the strategy notes three key levers for unlocking investment in the technologies needed to decarbonise industry: a UK Emissions Trading Scheme (UK ETS) cap, funding mechanisms to overcome barriers to securing private sector investment, and policy reforms to mitigate the risk of carbon leakage for specific sectors. The strategy also stated that by the mid 2020s the first two clusters for CCUS will be connected, supported by CCUS business models and the £1bn CCUS Infrastructure Fund, with another two connected within the five years after that. The technology strategy for the following three decades covers three key areas: efficiency, CCUS and fuel switching, shown in Figure 2. Development of industrial digital technologies and the building of CCUS network infrastructure in the first two clusters were expected in strategy to occur by the mid-2020s. Finally, the Strategy expresses the vision for the UK to be a global leader in industrial decarbonisation and manufacturing of low carbon industrial products. However, since its publication the UK has fallen behind other countries highlighting the need for improved and reformed measures. The Independent Net Zero Review made a number of recommendations for action around industrial decarbonisation, presented in figure 2.[4]

MISSION ZERO

As a result of consultations with a diverse range of stakeholders, the Independent Review of Net Zero established the Energy Intensives and Industry Mission, discerned core challenges to the decarbonisation of industry and laid out recommendations to support it. Key issues heard by the review and the corresponding recommendations are laid out in Table 1.

Mission: Setting a clear plan for industry decarbonisation built around long-term investment in CCUS and hydrogen networks and technologies. Energy intensive industries such as steel and cement will need to use emerging technologies like CCUS and hydrogen in order to decarbonise. CCUS will also play a role in balancing remaining emissions from the use of oil and gas as transition fuels.

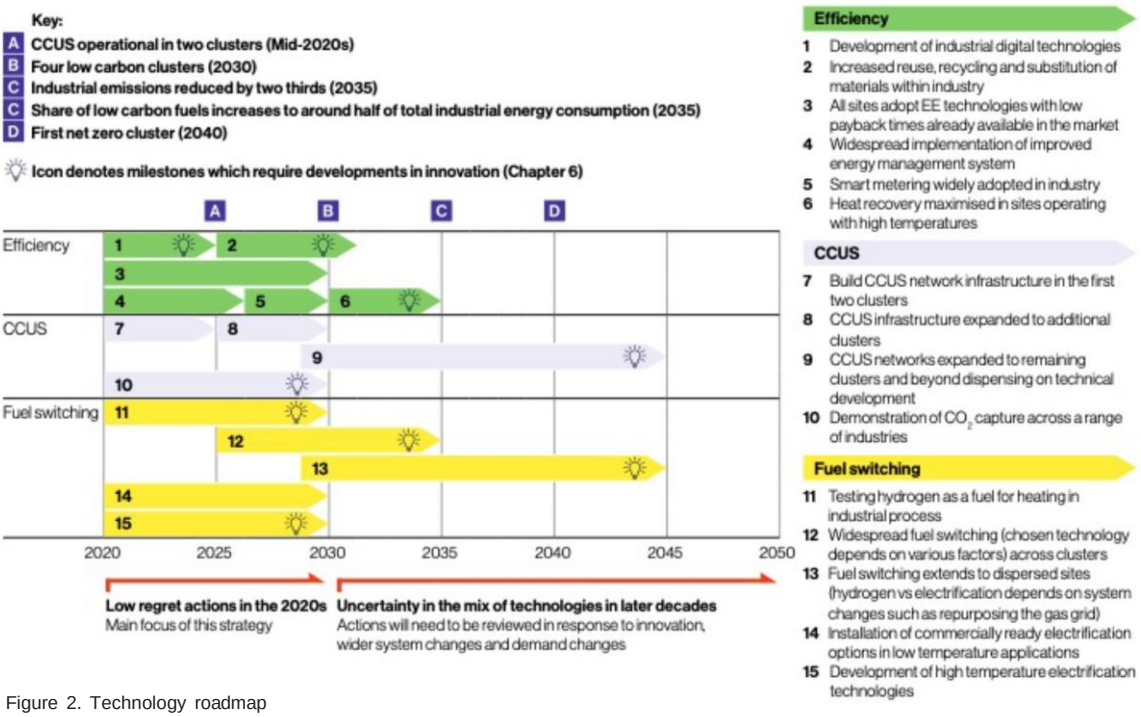


Figure 2. Technology roadmap

Table 1. Issues heard by the review and recommended actions

ISSUE HEARD BY THE REVIEW	ACTION RECOMMENDED
Lack of clarity on the plan for cluster selection beyond Track 1; industry needs greater certainty on the process and timeline for cluster selection to incentivise investment and kick start deployment	In 2023, government must act quickly to re-envisage and implement a clear CCUS roadmap, showing the plan beyond 2030. As part of the roadmap, government should take a pragmatic approach to cluster selection. This means allowing the most advanced clusters to progress more quickly. The roadmap should include: a. Approach to confirming the pipeline of capture projects, at least up to 2030, that will receive future funding, not limited to Track-1 cluster locations. In doing so, it should set out the process and timeline for Track-2 cluster selection b. Greater clarity on planned investment for CO2 transport and storage, including a streamlined route to market for future CO2 storage sites and a plan for making economic licenses more readily available to those that have safety licenses for CCUS acreage already. c. The plan for ensuring our supply chains and skills can meet demand.

Lack of long-term funding certainty for CCUS and hydrogen projects, exacerbated by the recent temporary pause of the Energy Bill, which will be essential for the delivery of business models.	As soon as legislation allows, government must finalise and legislate for hydrogen and CCUS business models and regulatory frameworks across the value chain. This will enable the UK to start awarding contracts and building capacity as soon as possible. In 2023 HMT should set out the funding envelope available to support Track-1 clusters.
Dispersed sites face specific barriers to decarbonisation, and risk being left behind due to their lack of access to established industrial clusters which are being prioritised for early deployment of CCUS and hydrogen.	By 2024, government must develop a strategy for dispersed sites and mini clusters to connect to the CCS network and set out what support should be offered for doing so. This should include non-pipeline transport. For hydrogen, we recommend that government delivers the transport and storage business models as soon as feasibly possible
In the short-term, we will still need oil and gas as transition fuels towards 2050. Where their use cannot be eliminated, CCUS and greenhouse gas removal methods will be needed.	Government should consider setting a 10% storage obligation target to fossil fuel producers operating domestically, to restore carbon dioxide to the geosphere by at least 2035, separate to any investment on nature-based solutions. Government should also recognise the importance of 'geological net zero' and work to align international ambitions toward geo zero by 2050, in line with net zero.

The Net Zero Review made several other recommendations to deliver on its Industry Mission, shown in Table 2.

#	AREA	OWNER	TIMING	RECOMMENDATION
13	Clarify UK's competitive advantage and green industrial policy	BEIS/ DIT	-	Carry out competitiveness analysis for clean technologies setting out the UK's export and import strategies and where it intends to develop leadership - and utilise this to clarify for investors and industry the UK's current green industrial policy
39	Hydrogen	BEIS	2023	By the end of 2023, the government should develop and implement an ambitious and pragmatic '10 year' delivery roadmap for the scaling up of hydrogen production. This roadmap should include detail on the plan for Track-2 decisions and should also include clear indication of how much capacity government hopes to procure through each future allocation round, including for electrolytic hydrogen, and how the UK will support growth of the electrolyser supply chain.

40	Hydrogen	BEIS	2023	Government should deliver transport and storage business models as soon as feasibly possible and take a pragmatic approach to support key 'no regrets' transport and storage projects.
41	Hydrogen	BEIS	-	Future System Operator (FSO) should take forward a role in setting out a system plan for hydrogen, considering the interactions between hydrogen storage and balancing renewables for the decarbonised grid. Government, with advice from the FSO, takes decisive leadership on naming priority areas for minimum viable pipeline and storage infrastructure, providing strategic direction that shows how we will link up demand and supply. We need early identification of strategic assets that are critical enablers of other infrastructure and therefore require at risk investment.
42	Hydrogen	BEIS	2023	Government should continue the hydrogen heating community trials, to inform decisions on the role hydrogen can play in heating. Additionally, by the end of 2023, government should update its analysis of the whole system costs of the mass roll out of hydrogen for heating, in order to ensure that the case for economic optimality and
57	GGRs	BEIS	2023	Government should announce, as soon as is possible, its intentions for engineered GGR business models including timings and eligibility. This announcement must clearly outline what standards these business models are expected to require.
70	Manufacturing	BEIS	2024	Government should develop a policy proposal to incentivise on-site generation in Manufacturing by Q2 2024, with options to consult on the funding formula required by the public and private sector to reach the tipping point of adoption.
71	Manufacturing	BEIS	2023	Government should progress its consultation on carbon leakage measures, including a carbon border adjustment mechanism (CBAM) and mandatory product standards by 2023. This will enable Government to implement effective carbon leakage mitigations from 2026.

124	Carbon Leakage	BEIS/ HMT	2026	Government should progress with the consultation on carbon leakage measures and speed up decision-making to enable Government to implement effective carbon leakage mitigations from 2026.
125	Carbon Markets	BEIS/ HMT	2024	By 2024, Government should work within the UK ETS Authority to develop a pathway for the UK ETS until 2040. This pathway should: a) Set out a vision on the future design and operation of the ETS b) Set out a timeline for expanding the coverage to the rest of the UK economy, as well as sectors consulted on including maritime and waste. c) Address inclusion of GGRs to incentivise early investment in new technologies and potentially nature based solutions. d) Provide reassurance to businesses around how the Government will mitigate the risk of carbon leakage as a result of expanding the ETS.
126	Carbon Markets	BEIS	2024	Government should endorse international VCM standards as soon as possible and consult on formally adopting regulated standards for VCMs and setting up a regulator for carbon credits and offsets by 2024.
127	Carbon Markets	BEUS	2024	Government should set up a programme for offsets and carbon credits, providing guidance to businesses looking to invest in carbon credits and offsets, for businesses looking to provide carbon credits and offsets, and explore the opportunities to create a market in the UK for offsets through energy efficiency measures.

GOVERNMENT RESPONSE

The Government formally responded to the Net Zero Review on 30 March 2023.[5] Specifically, on decarbonisation of Industry, the government's response is presented below:

On carrying out a competitiveness analysis for clean technologies: The government states that it has set out a clear and consistent set of strategic objectives and a long-term policy framework. Net Zero Strategy (2021), British Energy Security Strategy (2022), Net Zero Growth Plan (2023) and Powering Up Britain: Energy Security (2023) are intended to provide longer-term clarity and certainty to businesses and investors. £30 billion of domestic investment was committed for the green industrial revolution at the Spending Review 2021, £6 billion for energy efficiency at the Autumn Statement 2022 and up to £20 billion for CCUS announced at Spring Budget 2023. Support for low carbon technologies to deliver net zero and economic goals

is being continuously assessed, as is the impact of international policies on the UK's competitiveness to secure investment in net zero.

On developing a delivery strategy roadmap for scaling up hydrogen production: Progress has been made in the government's ambitions to have up to 2GW of low carbon hydrogen production capacity in operation or construction by 2025, and up to 10GW production capacity by 2030. The successful candidates for the first two strands of the Net Zero Hydrogen Fund (NZHF) were announced with the publication of Powering Up Britain: Energy Security. Contracts totalling up to 250MW of capacity from the first electrolytic hydrogen allocation round are planned to be awarded later in 2023. A second electrolytic hydrogen allocation round in Q4 2023, and the government aims to award contracts to up to 750MW of capacity in early 2025, A shortlist of projects to progress to the next stage of due diligence for this round were published alongside Powering Up Britain: Energy Security.

The government will fund projects prior to the hydrogen levy being operationalised. On 15 March 2023 the Chancellor announced a £20 billion investment in the early development of CCUS to help meet the government's climate commitments. Alongside Powering Up Britain: Energy Security, the Track-1 project negotiation list was announced, including industrial capture and hydrogen projects. Track-2 of the CCUS cluster sequencing process to establish 2 further CCUS clusters was also launched. A hydrogen production delivery roadmap by the end of the year, which would provide greater clarity to investors and developers on scaling up hydrogen production and supply chain growth across the decade.

On delivering transport and storage business models: The 'British Energy Security Strategy' made a commitment to design new business models for hydrogen transport and storage infrastructure by 2025. The government recently consulted on the need and potential approaches for T&S infrastructure strategic planning. The government response to the consultation is planned to be published by the end of June 2023, with any further details on strategic planning to align with the production roadmap. To bring forward hydrogen T&S business models, the government is aiming to introduce legislative measures, which will be crucial to designing these new business models by 2025.

On establishing the Future System Operator (FSO) role: The government agrees that cross-cutting strategic planning for hydrogen infrastructure could be beneficial to ensure whole energy system benefits are realised. The response to the consultation on hydrogen T&S infrastructure was to be published in Q2 2023, setting out the government's approach to strategic planning for hydrogen T&S infrastructure. The response stated that further time is required to consider the potential role and responsibilities of government, regulators such as Ofgem and other bodies such as the FSO in system planning for hydrogen transport and storage infrastructure.

On hydrogen community trials and analysis of whole system costs: The government is working with industry and the HSE to develop evidence on the feasibility, costs and benefits of converting gas networks to hydrogen to inform decisions on the role of hydrogen in heating by 2026, including supporting industry to organise community trials. It will continue to assess new evidence on hydrogen heating as it becomes available and keep the costs, benefits and whole system impacts under review.

On deployment of CCUS, including a clear roadmap and the funding envelope to support Track-1 clusters: As well as the confirmed £20 billion funding for CCUS, the government will also kick-start the delivery of subsequent phases of this new sustainable

industry in the UK, taking advantage of the country's natural comparative advantage in CCUS.

Through the cluster sequencing process, the government states it has made significant progress in making CCUS a reality in the UK. With the announcement of the negotiating list for the Track 1 clusters and a process to bring forward 2 more clusters through Track 2, it also stated its intention to commence a process to expand the Track 1 clusters. As announced on the 30th March, the Track-1 project negotiation list includes:[6]

East Coast Cluster

- Net Zero Teesside Power
- bpH2Teesside
- Teesside Hydrogen CO2 Capture
- HyNet Cluster

Hanson Padeswood Cement Works Carbon Capture and Storage Project

- Viridor Runcorn Industrial CCS
- Protos Energy Recovery Facility
- Buxton Lime Net Zero
- HyNet Hydrogen Production Plant 1 (HPP1)

The response stated the government will launch a process to expand those clusters allowing further capture projects in Hynet, Teesside and Humber later in 2023. It also said it was launching its process for selecting the next CCUS clusters and, that Acorn (in Scotland) and Viking (in The Humber) were expected to be best placed to meet the government's objectives.

The response also communicated that the government and industry continue to engage with all aspects of the supply chain, through the CCUS Council Supply Chain working group chaired by Lord Hutton. This group has the objective to ensure the supply chain capacity and capability can meet the UK demand, as well as assist other countries in the plans to decarbonise using CCUS.

On strategies for non-pipeline transport and dispersed sites for CCUS: the government said it was continuing to explore the development of pipeline and non-pipeline options for sites outside the CCUS Cluster Sequencing Track 1 locations and potential interactions with business model support. They are providing £5 million for local clusters to develop strategic, area-based plans to decarbonise, which is technology agnostic and could facilitate strategic thinking on dispersed CCUS networks in different locations around the UK as well as other technologies. A vision for the UK CCUS sector in 2023 is said to be set out this year to raise confidence and improve visibility for investors.

On GGR business models: In the Net Zero Strategy, the government committed to developing incentives for investment in GGRs by consulting on our preferred business models in GGRs. In 2022, it published a consultation on both power BECCS and GGR business models. The response stated the government will publish the power BECCS response imminently and intend to provide a response to the GGR consultation and set out the next steps this year. The consultations asked for opinions on factors such as net negativity and permanence to help define legitimacy in carbon removals, as well as committing to reviewing the existing landscape of standards and initiatives relating to engineered GGR MRV (monitoring, reporting, and verification). BECCS projects will be required to demonstrate compliance with strict biomass sustainability criteria. In January this year, the government held the first GGR Business Model Expert Group. This group of experts from industry will advise on the design of the GGR business model, alongside our wider stakeholder engagement.

On incentives for investment in decarbonisation: The government stated it recognises the importance of incentivising investment in decarbonisation, to support businesses with their transition to net zero and to meet its legally binding carbon budgets. From

April 2023, the Annual Investment Allowance will be permanently increased to £1 million, which will amount to full expensing for a significant portion of investment, covering 99% of businesses.

The government has also announced an economy-wide policy of full expensing, allowing companies to write off the full cost of qualifying main rate plant and machinery in the year of investment, with a 50% first year allowance for special rate plant and machinery investments. The tax system is being kept under continuous review. The response communicates that the government will engage with industry and carefully consider how best to incentivise businesses to invest in green technology. This is intended to help the government to consider whether there is a case for doing more through the tax system or whether other levers are more appropriate.

On development of a policy proposal to incentivise on-site generation in Manufacturing: The government response expressed that it understands how energy costs impact the competitiveness of UK manufacturing and agrees that on- site generation is one measure that can help manufacturers, including energy intensive industries, to manage their energy use and related costs. New policies to incentivise on-site generation adoption will require a high level of consultation and co-development from across several government departments. This includes the Department for Business and Trade that works closely with manufacturers from across sectors, Defra which leads relationship with food and drink manufacturers, Department for Energy Security and Net Zero that has the lead for energy efficiency and Department for Leveling Up, Housing and Communities that leads planning, working with local authorities, These departments will need to consider approach and timing of any potential proposals, while working together with expert stakeholders from industry, local government and the National Grid.

On implementing carbon leakage mitigations from 2026: The government responses stated that the UK is committed to ensuring that efforts to decarbonise industry are not undermined by carbon leakage, and currently does so through free allocation under the UK ETS. It is currently reviewing its approach to free allocations, looking at ways to better target support for those most at risk of carbon leakage to ensure they are fairly distributed. The government has published a consultation on a range of domestic carbon leakage mitigation policies that could potentially mitigate future carbon leakage risk and ensure UK industry has the optimal policy environment to decarbonise. These include product standards, a carbon border adjustment mechanism (CBAM) and policies which would help grow the market for low emission industrial products, as well as any emissions reporting requirement which might be needed to underpin new policies. While the best solutions to carbon leakage are international, options for domestic action must be considered in parallel to support efforts to decarbonise the UK economy and reduce UK and global emissions. Government is clear that any policy or suite of policies will need to balance a range of priorities as well as meet existing commitments, both domestically and internationally. These include its commitment to free and open trade; respecting international climate change obligations, appreciating countries' differing levels of development, particularly for least developed and low-income countries, as well as minimising burdens on businesses and consumers and enabling consumer choice. Alongside changes to free allocation policy, consulting on these measures will inform the best approach to carbon leakage measures that support efforts to decarbonise UK industry, with the aim of ensuring that carbon leakage risks are mitigated at all stages of the UK's net zero transition.

On developing a pathway for the UK ETS by 2040: The government responded that it will work within the ETS Authority to publish one this

year. This pathway will set out its intention to legislate to continue the ETS beyond 2030 until at least 2050. It will remain aligned with the UK net zero target, giving businesses the certainty they need to invest in decarbonisation. The government will explore expanding the scheme to more sectors of the economy, including high emitting sectors. It consulted last year on expanding the scheme to cover energy from waste/waste incineration and domestic maritime emissions and on incorporating greenhouse gas removals. It will also explore the potential role of emissions trading in decarbonising heat, alongside possible options for rebalancing energy costs away from electricity, and to develop a harmonised approach for measuring carbon emissions from farms.

It also communicated that throughout, it will ensure effective carbon leakage mitigations are in place to ensure the UK's efforts in decarbonisation lead to a true reduction in global emissions.

On voluntary carbon markets (VCMs) and carbon credits and offsets: The response articulates that the UK government recognises the potential role that voluntary carbon markets could play in the delivery of domestic and international net zero and the role carbon markets can play in enabling businesses to transition to net zero. It notes that market integrity concerns need to be addressed to maximise this opportunity.

The government supports work to improve the integrity of VCMs, including that of the Integrity Council on Voluntary Carbon Markets (IC-VCM) and Voluntary Carbon Markets Initiative (VCMI), both launched under the UK's COP26 Presidency to develop international best practice. It will consult on the specific steps and interventions needed to support the growth of high integrity voluntary markets and protect against greenwashing. This will position the UK to serve as a global hub for voluntary carbon trading.

The government's work with the British Standards Institution will also develop nature market standards for investment in carbon and other ecosystem services, building on the international best practice such as the work of IC-VCM and VCMI, as well as the experience of the UK's Peatland and Woodland Carbon Codes.
Finally, the response states that it is important that credits do not come at the expense of direct action by businesses; reflect genuinely additional removal and reduction in GHG emissions; and align with a credible science-based pathway to net zero. Forthcoming reports of VCMI and IC-VCM will also provide recommendations to business.

The Review's recommendations and actions taken in response are also addressed in the Powering up Britain papers. The Net Zero Growth Plan confirmed that the Government is partly or full acting upon 23 out of 25 of the recommendations for 2025.[7] The Energy Security Plan states:[8]

- In line with the recommendations from the Independent Review of Net Zero, we are exploring policy options for increasing the deployment of on-site electricity generation at manufacturing facilities, to encourage manufacturers to produce their own energy. This will help decarbonise business and reduce dependence on imported energy.
- We are delivering policies to support deployment of new low carbon hydrogen production, reduce upfront infrastructure costs, and provide greater clarity and certainty around future demand and revenue streams, through our £240 million Net Zero Hydrogen Fund (NZHF) and our Hydrogen Production and Transport and Storage Business Models. Building on this progress, the Government will take forward the Net Zero Review recommendation to develop a delivery roadmap in 2023 to show how hydrogen production can be scaled up over the coming decade.
- The Government recognises the importance of providing further certainty for industry beyond our 2030 ambitions. We will therefore

continue to work with stakeholders to set out a vision for the UK CCUS sector, which will provide clarification on the future of CCUS, how it will support our net zero ambitions, and crucially provide the confidence and certainty developers, investors, and other stakeholders are looking for in the long run.
- We are committed to deploying CCUS in 2 industrial clusters by the mid-2020s and 4 clusters by 2030, with the aim of capturing and storing 20-30 million tonnes of CO2 per year by 2030. Including to capture and store up to 6 million tonnes of CO2 a year from industrial sectors.

Additionally, the Net Zero Growth Plan[9] states:

- With respect to recommendations from the CCC and the Independent Review of Net Zero to deliver hydrogen T&S business models as soon as possible while supporting 'no regrets' projects, and plans for distribution and storage outside our industrial clusters, we aim to respond to our consultation on hydrogen T&S infrastructure in Q2 2023, with any further details on strategic planning to align with the production. To bring forward hydrogen T&S business models, we are aiming to introduce legislative measures when parliamentary time allows, which will be crucial to designing these new business models by 2025. Our consultation response will provide detail on institutional arrangements for hydrogen system planning, noting the Independent Review of Net Zero recommendation that the Future System Operator take a hydrogen system planning role.
- We will work with industry to progress development of non-pipeline transport in a timeframe consistent with our Track-2 objectives, supporting decarbonisation of sites away from CO2 stores or industrial clusters suggested in the Independent Review of Net Zero.
- We will set out a vision for the UK CCUS sector to raise confidence and improve visibility for investors as suggested in the Independent Review of Net Zero.
- Both the CCC and the Independent Review of Net Zero make recommendations concerning policy development of the UK Emissions Trading Scheme (ETS). These have, in part, been addressed in our recent consultation on Developing the ETS, on which the ETS Authority will be publishing a response in due course.
- Set out our ambitions for hydrogen (in the 'Fuel Supply and Hydrogen' chapter of this report). Our upcoming call for evidence on industrial electrification will address recommendations regarding the barriers to this decarbonisation technology.

On the 30th March, the Government also published its Carbon Budget Delivery Plan (CBDP).[10] Finally, the government published its UK Net Zero Research and Innovation Framework: Delivery Plan 2022-2025 on the 30th March. Two of the research areas particularly relevant to decarbonising the industrial sector are industry and low carbon hydrogen supply and CCUS and GGR:

- **Industry and low-carbon hydrogen supply**
  - Improving resource and energy efficiency
  - Switching to low and zero-carbon fuels
  - Capturing and storing industrial emissions
  - Efficient, cost-effective production of low carbon hydrogen at scale
  - Demonstrating effective, low-cost methods of bulk hydrogen transportation and storage
  - Power generation
  - Effective use of hydrogen at the system level
  - Understanding how hydrogen at the system level
  - Understanding how hydrogen will impact the environment and society

- **Carbon capture, utilisation and storage & greenhouse gas removal**
  - Capturing CO2 from point sources, efficiently and at low cost
  - Removing GHGs directly from the air and sea, efficiently and at low cost
  - Reducing energy demand from engineered removal technologies
  - Exploring routes to deploy bioenergy with carbon capture and storage (BECCS)
  - CO2 transport and storage infrastructure
  - Developing economic ways to utilise captured CO2 in products or processes
  - Creating the conditions for future scale-up and deployment/ commercialisation
  - Monitoring, reporting and verification
  - Managing environmental impacts and co-benefits

The Plan states that publicly funded research and innovation is needed where market failures or barriers preclude private sector investment. De-risking investment is crucial for economic growth based on net-zero, government investment in early stage technology is a step towards this.[11]

FURTHER UPDATES

Since March 2023, the government has released further plans and information on industrial decarbonisation pathways.

April 2023

- The Department for Energy Security & Net Zero published Hydrogen investment roadmap: Leading the way to net zero, laying out a 2035 delivery plan.[12]
- Round Two of the Net Zero Hydrogen Fund opened in April. Strand 1 provides development expenditure for front and engineering design and post-design activities. Strand 2 provides capital expenditure support for hydrogen production projects that do not require revenue support through the Hydrogen Business Model.[13]
- The second version of the UK Low Carbon Hydrogen Standard was published that defines what constitutes 'low carbon hydrogen' at the point of production.[14]
- The CCUS Net Zero Investment Map was published, summarising joint government and industry commitments to the deployment of CCUS in the UK.[15]

June 2023

- Under Low Carbon Hydrogen Supply 2 competition - Stream 1 Phase 2, five projects were awarded almost a combined £19 million with the aim of supporting physical demonstration of innovative hydrogen supply solutions.[16]
- On 28th June 2023, the successful projects of the Carbon Capture, Usage and Storage (CCUS) Innovation 2.0 competition were announced.[17] The competition aims to accelerate the deployment of next generation carbon capture, usage and storage (CCUS) technology in the UK to be deployed at scale by 2030.[18]
- The DESNZ published its response to the consultation on a GGR Business Model and aims to publish its next steps later this year.[19]
- The Local Industrial Decarbonisation Plans competition opened for applications. The competition is run by government in partnership with Innovate UK, offering £5 million to support dispersed industrial manufacturers not located in the UK's existing industrial clusters to decarbonise, reduce their emissions and avoid carbon leakage.[20]
- A joint response of the UK Government, the Scottish Government, the Welsh Government and the Department of Agriculture, Environment and Rural Affairs for Northern Ireland was published in June 2023 on developing the UK emissions trading scheme.[21] The key decisions made were:

- Setting the UK ETS cap to be consistent with net zero and doing this at the top of the net zero consistent range, smoothing the transition to the net zero cap
- Setting the Industry Cap at 40% of the overall cap
- Providing long term market resilience
- Free allocation technical changes
- Phasing-out of aviation free allocation
- Expanding the scope of the scheme
- Incorporating Greenhouse Gas Removal (GGR) technologies

July 2023

- On the 5th July 2023, the DESNZ published a summary of a study of 7 industrial sites to understand the safety, feasibility, cost and impacts for these sites to switch from natural gas to 100% hydrogen for heat.[22]
- DESNZ put out a call for evidence on fuel-switching to electricity for enabling industrial electrification, which closed on 20th October 2023.[23]
- The UK ETS Authority announced the net zero consistent cap, the cap for 2021-2030 will be 936 allowances, 30% lower than the previously legislated allowances, which will be reached through a smooth condition. The industry cap will be reset in 2024 to align with the introduction of the net zero consistent cap, set at 40% of the overall cap.[24]
- DESNZ launched the 'Enabling Industrial Electrification Call for Evidence' on the 19th July, aiming to understand how to enable industry to switch away from fossil fuels to electricity. The Call for Evidence closed on 20th October.[25]

August 2023

- The minded government position on hydrogen transport and storage infrastructure published on 1st August 2023 stated "subject to the timings of the Energy Bill and other factors, the FSO is anticipated to become operational in 2024. We anticipate that the FSO's day one role for hydrogen would be limited to those considerations necessary to allow it to perform its other day one system planning roles for natural gas and electricity".[26]
- On the 15th August 2023 the UK Government announced £3.75 million in government funding for green AI innovations as new artificial intelligence (AI) solutions will accelerate industrial decarbonisation across the country. First of all, 12 green AI initiatives will receive a share of £1million. The schemes range from solar energy improvements to the decarbonisation of dairy farming.[27]
- On 16th August 2023 the government released the shortlisted projects for the 2022 electrolytic hydrogen allocation round, expected to total up to 250MW capacity, aiming to be awarded in Q4 2023.[28]
- In August 2023 the government responded to the consultation on hydrogen transport and storage infrastructure. In addition to the response here, the government said it will look to publish a 'hydrogen networks pathway'.[29]
- The government published a response to the Call for evidence on the future policy framework for the delivery of power with Carbon Capture, Usage and Storage.[30]

September 2023

- DESNZ is supporting industry to begin a neighbourhood trial, located in Fife, by 2024, and a large village trial by 2025.[31] H100 Fife is aiming to be the world's first 100% hydrogen-to-homes heating network.[32]

October 2023

- DESNZ published an update on Industrial Carbon Capture Business Models, setting out further details on the government's current proposals on the potential business models for industrial facilities (including waste management facilities) with carbon capture usage and storage (CCUS).[33]
- The Energy Act 2023 received Royal Assent on 26th October 2023. The Act pertains to industrial decarbonisation by introducing a

licensing framework for CO2 transport and storage, supporting up to 50,000 jobs by 2030 and facilitating the first large village hydrogen heating trial.[34]
- On October 30th the Department for Business and Trade published its National Digital Twin Programme (NDTP), which is being tested in real-world situations through the demonstrator programme.[35]

November 2023
- The King's Speech on the 7th November did not refer to industrial decarbonisation as a part of the programme of legislation the government intends to pursue.

WIDER POLICY LANDSCAPE

The CCC's Progress Report 2023[36] lays out further recommendations:
- Further details and a delivery timeline for the hydrogen levy are required. The levy should support low-carbon hydrogen production while not biasing towards hydrogen and away from electrification, where electrification is an option
- Develop policies for industrial electrification that address general barriers such as investment constraints, as well as specific barriers for different industrial sub-sectors.
- Publish a strategy and timeline for the decarbonisation of the iron and steel industry in line with the Carbon Budget Delivery Plan.
- Set out a long-term pathway for the UK ETS cap beyond 2030.
- Undertake and publish research on trends and drivers of increased bioenergy use in industry over the past 15 years, to inform the Government's strategy on biomass use and the policy levers to incentivise best use.
- Develop policies for decarbonising smaller industrial facilities, focused on those not covered by the UK ETS and/or not in an industrial cluster.
- Introduce specific funding for research and development in industrial electrification.
- Provide greater levels of funding for industrial electrification consistent with the support available for hydrogen and CCS. Funding should support the additional operational and capital costs of electrification in manufacturing.
- Set out the Government's approach to ensuring electricity networks have the capacity to meet increased demand from industry.
- Take action to reduce the electricity costs of industrial users. This should start with greater exemptions for policy costs and network charges, but further measures will be needed to bring the electricity price closer to the gas price.
- Develop an indicator to track energy efficiency in industry. This might be done by measuring the energy-intensity of a fixed 'basket' of industrial products in a similar way to inflation indices.
- Publish a strategy that sets out how the UK Government will achieve the abatement from industrial energy efficiency committed to in the Carbon Budget Delivery Plan.
- Publish details of the £20 billion spending commitment for CCUS, including what it is to be spent on and how much is earmarked for different types of CCUS.
- Develop alternative plans for meeting the 2030 NDC in case of delays to abatement and removals that rely on CCS. These plans should outline measures that can achieve emissions reductions in three years or less and include conditions for progress on CCS that will be used to determine whether these contingency measures are progressed.
- Continue to work with the UK Government on industrial decarbonisation in Wales, formally requesting some specific support measures, including for the adoption of CCUS and hydrogen in the South Wales Industrial Cluster.

The UK Government responded to the CCC's 2023 Annual Progress Report to Parliament in October 2023, those relevant to industrial decarbonisation are presented in Table 3.

Table 3. Government response to CCC's recommendations on industrial decarbonisation

RECOMMENDATION	OWNER	RESPONSE
Create clear incentives for manufacturing facilities notcurrently covered by the UK ETS to decarbonise.	DESNZ	The UK Emissions Trading Scheme (ETS) currently includes regulated activities in industrial facilities which result ingreenhouse gas emissions, including combustion of fuels on a site where combustion units with a total rated thermal inputexceeding 20MW are operated. As noted in Powering UpBritain, the Government will explore expanding the UK ETS tomore sectors of the economy, including high-emitting sectors.Subject to agreement within the UK ETS Authority, we will setout a long-term pathway for the UK ETS and aim to do so thisyear. The Powering Up Britain announcement also includedplans for a dedicated energy advice service for SMEs andplans for a pilot offering subsidised energy assessments andgrants for energy efficiency measures. Government has a range of policies to incentivise thedecarbonisation of manufacturing and industrial sectors,including manufacturing facilities not currently covered by the UK ETS. • Manufacturing sites can apply for grant funding towards thecosts of decarbonisation projects. The Industrial Energy Transformation Fund (IETF) targets existing industrialprocesses, helping industry to cut energy bills by investing inmore efficient technologies and reduce emissions by bringingdown the costs and risks associated with investing in deepdecarbonisation technologies. The fund is open to a broadrange of industrial sectors of all sizes and will support applicants, both within and outside of the ETS. • The Government published the 2023 Enabling Industrial Electrification: a call for evidence with the aim of designing an optimal policy framework to enable industrial sites to switch away from fossil fuels to electricity. Alongside this, the Government has committed to outlining a clear approach to gas and electricity price rebalancing by the end of 2023/2024 and to make significant progress towards affecting relative prices by the end of 2024. We are working to develop our approach to rebalancing to meet these commitments and will provide further information in the coming year. In particular, for smaller emitters, we expect that energy efficiency will be an important first step towards decarbonisation, so it is important to highlight ongoing policy development arising from initiatives such as the pilot Business Energy Advice Service and the consultation on a potential future Climate Change Agreements Scheme. Insights are also expected from the Local Industrial Decarbonisation Plans to address decarbonisation opportunities for dispersed sites.

RECOMMENDATION	OWNER	RESPONSE
Develop policies for industrial electrification that addressgeneral barriers such as investment constraints, as wellas specific barriers for different industrial sub-sectors.	DESNZ	The Net Zero Growth Plan reiterated the ambition to replace 50 TWh of fossil fuels per year by 2035 with low carbon alternatives, such as hydrogen, electricity and biomass. In March 2023, analysis in the Net Zero Growth Plan highlighted that fuel switching to electricity has the potential to reduce annual industrial emissions by between 7 and 19 MtCO2e by 2050, contributing between 15% and 40% of the (necessary) carbon abatement in industry by 2050. Currently, the Government provides support for fuel switching (including electrification) through the Industrial Energy Transformation Fund (IETF) and the Scottish IETF, which provides grants to help with the upfront costs of installing or retrofitting industrial equipment associated with electrifying industrial processes, and the Industrial Fuel Switching Competition (IFSC), which is innovation funding for electrification and enabling technologies. The Government recognises that there are several barriers to fuel switching to electricity. For example, electricity is currently significantly more expensive than natural gas. In July 2023, the Government published a Call for Evidence on fuel switching to electrification. The responses will be used to build a greater understanding of the role of electrification in industry, the challenges industry faces when considering electrification options and to test early-stage policy thinking. This will then enable government to design an optimal policy framework to overcome barriers and manage interactions with the wider system, such as the review of electricity market arrangements (REMA) and future electricity networks.
Publish a strategy and timeline for the decarbonisation of the iron and steel industry in line with the Carbon Budget Delivery Plan.	DBT	We continue to work with the sector to support its decarbonisation options. The appropriate decarbonisation pathway for individual sites will be based on multiple factors and is a commercial decision for individual companies. The Government is working closely with companies as they make commercial decisions on the optimum decarbonisation route for their sites. As part of this, on 15th September 2023 HMG and Tata Steel announced a proposed joint investment package for an Electric Arc Furnace for greener steel production at Port Talbot. This proposed investment could reduce direct carbon emissions from the site by 5 million tonnes each year by 2030. This represents a 7% reduction in UK business sector and industrial process emissions. Tata Steel is now discussing these proposed arrangements with their trade union partners, ahead of formal consultation processes.

RECOMMENDATION	OWNER	RESPONSE
Review, invest in, and initiate reform of industrial decarbonisation data collection and annual reporting to enable effective monitoring and evaluation, and policy implementation. This will require additional data collection and reporting to allow for effective tracking of energy efficiency, material efficiency, fuel switching, CCS, including progress developing these measures, and more holistic measurement on a product or whole lifecycle carbon basis. This reform should also be used as an opportunity to remove overlaps in reporting between existing schemes, which place an unnecessary burden on industry.	DESNZ	The Government is conscious that organisations report data on industrial decarbonisation through a variety of policies and programmes and recognises that costs for businesses should be proportionate. We will continue to look at options to streamline reporting and data collection - for example in developing new IT systems or in project reports and applications under grant programmes. This will build on the recent consultations on non-financial reporting, carbon leakage and the Climate Change Agreements Scheme. Government is also exploring how we can use existing administrative data (principally the UK Emissions Trading Scheme and Climate Change Agreement data) to improve final energy consumption statistics. In addition, the Department for Energy Security and Net Zero is exploring how to leverage additional data on energy expenditure from existing Office of National Statistics surveys, and introducing hydrogen production reporting which we hope to extend to an understanding of hydrogen consumption in industry and other sectors.
Resolve the distortive disincentive against electrification of sites within the UK ETS caused by the design of Climate Change Agreement targets.	DESNZ	The Government do not agree that the design of the Climate Change Agreements scheme causes a distortive disincentive against electrification of sites within the UK Emissions Trading Scheme (UK ETS). We recognise that sectors are involved in both schemes to varying degrees and will continue to engage with organisations from different sectors who take part in both schemes. We also note that for some organisations, only electricity is included in their Climate Change Agreements as their heat is covered by UK ETS, which will have an impact on how they interact with the schemes. The impact of the fuel split across different schemes can also be considered as part of target setting negotiations for both the Climate Change Agreements scheme extension and any potential future scheme.

RECOMMENDATION	OWNER	RESPONSE
Continue to support innovation and demonstration of fuel switching and CCS technologies for end-use in manufacturing and construction, for example through grant funding and government-backed business models.	DESNZ	The £1 billion Net Zero Innovation Portfolio currently funds industrial fuel switching and Carbon Capture, Usage and Storage (CCUS) grant funding programmes. There are three programmes demonstrating fuel switching to low carbon energy sources in industrial settings, including manufacturing and construction end uses; the Industrial Fuel Switching programme, and sector-specific Red Diesel Replacement and Green Distilleries programmes. There are two CCUS programmes supported; the CCUS Innovation programme, which promotes the development of next generation technologies for the treatment of industrial flue gases, and the international Accelerating CCUS Technologies programme which investigates early stage emerging technologies which may be constituents of future development programmes. Any further programmes will be subject to future spending reviews.
Design industrial decarbonisation policies in a way that supports and creates jobs,	DESNZ	The Industrial Decarbonisation Strategy (2021) committed to both "unlock new job opportunities through deployment of low carbon infrastructure in industrial areas" and "support the skills transition so that the current and future workforce benefit from the creation of new jobs". In March 2021, the Government awarded £171 million pounds of the Industrial Decarbonisation Challenge (IDC) to nine projects located in the five industrial clusters to fund early stage design work to deploy technologies and infrastructure that will significantly reduce emissions in these industrial areas. Based on developer estimates, the successful deployment of these projects within industrial clusters not only advances government ambitions in achieving net zero but could create around 60,000 future jobs over the next 30 years for a low-carbon future. These projects are in progress and on track to complete in 2024.

RECOMMENDATION	OWNER	RESPONSE
Finalise the Industrial Carbon Capture (ICC) business model and deliver the first industrial carbon capture contracts to enable final investment decisions on the first ICC projects in H1 2023, consistent with the Government's ambition to deploy carbon capture in at least two clusters by the mid-2020s	DESNZ	The Government intends to publish an updated version of the Industrial Carbon Capture (ICC) and Waste ICC Contracts later this year, this version will be the Basis for Negotiating upon with the three industrial and two waste projects who were shortlisted on the Track-1 Project Negotiation List to proceed to the negotiations phase of the Cluster Sequencing Process. This is a significant step towards the UK's first operational Carbon Capture, Usage and Storage (CCUS) networks, delivering first of a kind carbon capture projects in the UK and underlining the Government's commitment to delivering on net zero ambitions. The Government will work to identify projects that could be potential alternatives to any of the initial Track-1 projects, if any are unable to agree contracts within the criteria and timelines required. The Government will continuously monitor the value for money offered by the Track-1 Project Negotiation List, to ensure only the best and most cost-effective capture projects reach final investment decisions.
Finalise and deliver the Transport and Storage Regulatory Investment business model in 2022, consistent with the Government's ambition to establish at least two CCS transport and storage clusters in the mid2020s. This will require promptly beginning the process of awarding permits and construction of the necessary infrastructure, to ensure that it is ready in time for deployment.	DESNZ	The version of the Transport and Storage Regulatory Investment (TRI) model set to be published prior to Track-1 Final Investment Decisions (FIDs) is expected to be delivered in the second half of 2024. The TRI Update v1.1 is set to be published in the second half of 2023.

RECOMMENDATION	OWNER	RESPONSE
Publish a plan for distribution and storage of hydrogen outside clusters.	DESNZ	Dispersed industrial sites account for approximately half of the UK's industrial emissions and hydrogen can be important in helping to decarbonise industrial sites which are harder or more expensive to electrify, including those outside large industrial clusters. In August 2023 the Government response to the hydrogen transport and storage infrastructure consultation set out our minded-to position that some form of strategic planning, potentially combined with elements of market-led development, is likely necessary to enable the efficient, cost effective and timely roll-out of Transport and Storage (T&S) infrastructure. Strategic planning can also give clarity and confidence to off-takers for whom hydrogen is a viable decarbonisation pathway. We intend to publish a hydrogen networks pathway, to set out the next steps in our vision for the development of hydrogen T&S infrastructure across the UK. This aims to set out in more detail the considerations necessary to assess the T&S needs across the future hydrogen economy, both within and beyond industrial clusters.
Publish a plan for CO2 transport from dispersed sites before the end of 2022.	DESNZ	The Government is committed to further development of Carbon Capture, Usage and Storage (CCUS), and continues to explore the development of pipeline and non-pipeline options for sites outside the CCUS Cluster Sequencing Track-1 locations and potential interactions with business model support. The Track-2 process will establish 2 new CCUS clusters. Government has concluded that Acorn and Viking Transport and Storage (T&S) systems, due to their maturity, remain best placed to deliver our objectives for Track-2, at this stage, subject to final decisions, due diligence, consenting, subsidy control, affordability, and value for money assessments. The Government has been clear that Acorn and Viking T&S systems must credibly demonstrate the potential to receive and store CO2 through non-pipeline transport (NPT) in a timeframe consistent with Track-2 objectives. Though the initial projects will connect to the store via pipeline, the Government will progress development of its NPT policy in due course to facilitate the connection of projects and clusters reliant on NPT, subject to factors including due diligence and value for money assessment. We will set out a vision for the UK CCUS sector later in 2023 to raise confidence and improve visibility for investors. Additionally, government is providing up to £5 million for dispersed sites to develop strategic, area based plans to decarbonise, which is technology agnostic and could facilitate strategic thinking on dispersed CCUS networks in different locations.

RECOMMENDATION	OWNER	RESPONSE
Continue to work with the UK Government on industrial decarbonisation in Wales, formally requesting some specific support measures, including for the adoption of CCUS and hydrogen in the South Wales Industrial Cluster.	Welsh Government	In June, the CCC published a progress report on reducing emissions in Wales that contained many recommendations for the Welsh Government, including those listed in the UK progress report. The Welsh Government will prepare a response to the points raised by the report and lay it in the Senedd later this year.
Take action to reduce the electricity costs of industrial users. This should start with greater exemptions for policy costs and network charges, but further measures will be needed to bring the electricity price closer to the gas price.	DESNZ	In the Powering Up Britain publication of March 2023, the government accepted the recommendation from the Independent Review of Net Zero in committing to outline a clear approach to gas and electricity price rebalancing by the end of 2023/24 and make significant progress affecting relative prices by the end of 2024. We are working to develop our approach to rebalancing and will provide further information in the coming year. We recognise that UK industrial electricity prices are high and are committed to supporting Energy Intensive Industries (EII) who face the highest costs. Since 2013 we have provided over £2 billion to EIIs to make electricity costs more competitive. In February 2023 we announced the British Industry Supercharger, reducing energy costs for key UK industries. The measures consist of a full exemption for renewable electricity policy costs and capacity market costs and support for network changes, aiming to be introduced in 2024-25.

RECOMMENDATION	OWNER	RESPONSE
Set out the Government's approach to ensuring electricity networks have the capacity to meet increased demand from industry.	DESNZ	Government published the Electricity Networks Strategic Framework in August 2022 setting out plans to transform the network. Government is working with Ofgem and network companies to ensure there is enough capacity to meet increased industry demand. Ofgem's Accelerating Strategic Transmission Investment decision accelerates £20 billion worth of transmission projects to ensure there is adequate capacity. For distribution networks, Ofgem has allocated £22.2 billion to expand capacity, including £3.1 billion for strategic network upgrades to anticipate new demand. Through their Future Systems and Network Regulation and Future of Local Energy Governance consultations, Ofgem will ensure the network is strategically upgraded in anticipation of new demand. They also propose a Regional System Planner that would oversee cross-vector energy planning to ensure the network is expanded in the right places. Nick Winser, the Electricity Networks Commissioner, delivered recommendations to government in July to halve transmission network delivery timescales. Government will respond with an action plan this year.
Introduce specific funding for research and development in industrial electrification.	DESNZ	Innovation in electrification is currently supported through the £1 billion Net Zero Innovation Portfolio Industrial Fuel Switching programme. Any further funding for electrification is subject to future spending reviews. The Government recognises that there are several barriers to fuel switching to electricity, including a requirement for further technology innovation and demonstration. A Call for Evidence seeking evidence on these barriers and possible solutions was launched in July 2023. This seeks views on how potential market failures can be addressed, including through additional investment. Subject to business case approval, we will extend the Industrial Energy Transformation Fund (IETF) to 2028, providing up to £185 million in grant funding in Phase 3 to help industry identify and deploy decarbonisation technologies within their industrial processes. IETF support can help offset the upfront costs of electrifying industrial equipment and accelerate the commercialisation of novel technologies by supporting studies and permanent deployment of technologies which may have only previously been proven at lab scale.

RECOMMENDATION	OWNER	RESPONSE
Provide greater levels of funding for industrial electrification consistent with the support available for hydrogen and CCS. Funding should support the additional operational and capital costs of electrification in manufacturing.	DESNZ	The Government recognises that there are economic barriers to fuel switching to electricity. In July 2023, Government published a Call for Evidence on fuel switching to electrification, which includes questions on these barriers and possible policy solutions. On capital costs, the Government provides support for fuel switching (including electrification) through the Industrial Energy Transformation Fund (IETF) and the Scottish IETF, which provide grants to help with the capital costs of installing or retrofitting industrial equipment associated with electrifying industrial processes. On operational costs, the Government has committed to outlining a clear approach to gas and electricity price rebalancing by the end of 2023/2024, and aims to consult in Autumn 2023 on reforms to the (non-retail) electricity market as part of the Review of Electricity Market Arrangements (REMA) programme. These policies could change the economics of electrification for industry, and any impacts will need to be considered when designing future electrification policy. Any further funding for electrification is subject to future spending reviews.
Publish details of the £20 billion spending commitment for CCUS, including what it is to be spent on and how much is earmarked for different types of CCUS.	DESNZ	Our objective is to leverage the unprecedented £20 billion of funding to store as much carbon and create as many jobs as possible through Track-1 and beyond. The allocation of funding to different projects and sectors is subject to the outcome of negotiations. We expect it to crowd-in billions of pounds of additional private capital as our private partners also commit to the programme, creating jobs and bringing investment to our industrial heartlands.
Publish a strategy that sets out how the UK Government will achieve the abatement from industrial energy efficiency committed to in the Carbon Budget Delivery Plan.	DESNZ	The UK Government intends to publish a strategy for industrial energy efficiency in due course. In the meantime, schemes such as the Industrial Energy Transformation Fund (IETF) and the Business Energy Advice Service Pilot will provide support for energy efficiency measures. We consulted in Summer 2023 on the future of the IETF, collecting views on how government could most effectively target barriers to energy efficiency investment. Responses to the IETF consultation will feed into future strategy development.

RECOMMENDATION	OWNER	RESPONSE
Develop policies for decarbonising smaller industrial facilities, focused on those not covered by the UK ETS and/or not in an industrial cluster.	DESNZ	The UK Emission Trading Scheme (ETS) covers dispersed industrial facilities who exceed a 20MW threshold, incentivising their emissions reduction through a 'cap and trade principle' whereby a cap sets the total amount of carbon that can be emitted and, as it decreases over time, will make a significant contribution to how we meet our Net Zero 2050 target. Dispersed sites have received capex funding for energy efficiency and deep decarbonisation projects under the Industrial Energy Transformation Fund (IETF): 70% of successful IETF applications came from dispersed sites, equating to around £130 million in grant funding. In terms of roll-out of decarbonisation network infrastructure to dispersed sites, the government has committed to setting out a vision for the Carbon Capture Utilisation & Storage sector later in 2023 that will support our net zero ambitions and raise investor confidence. The Powering Up Britain announcement included plans for a dedicated energy advice service for SMEs and plans for a pilot offering subsidised energy assessments and grants for energy efficiency measures. The Local Industrial Decarbonisation Plans competition will provide up to £5 million support for dispersed industrial manufacturers to start their journey towards a low-carbon future.
Set out a long-term pathway for the UK ETS cap beyond 2030.	HMT	The UK Emissions Trading Scheme (ETS) Authority has confirmed the UK ETS cap will be aligned to net zero from 2024 going forwards. It is a long-term policy that aligns with the Government's long-term goals.
Publish a detailed timeline specifying each stage of the process of CCS development for Tracks 1 and 2 of the CCUS Cluster Sequencing Programme from now through to first capture and storage of CO2 in each cluster and sector, including completion of engineering design, contracts and permitting, construction and commissioning, and publish a plan of how the Government will ensure this timeline aligns with their planned first capture dates for each cluster and sector.	DESNZ	To avoid any risks of jeopardising ongoing Track-1 negotiations before contract signing, and in consideration of the imperative to uphold commercial confidentiality, Track-1 deems it inadvisable to publish the timeline and plan, as per the recommendation. Given the early stage of development of Track-2 and the uncertainties regarding its full scope, as well the need to retain commercial confidence of detail it does possess, it is highly probable that Track 2 will not be able to satisfy the recommendation put forward as well.

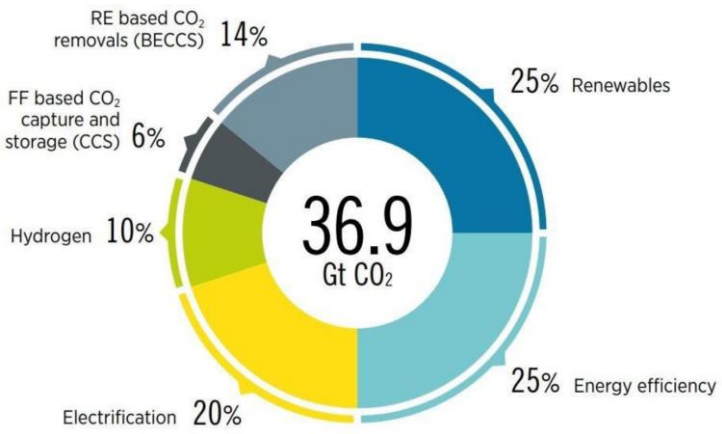
RECOMMENDATION	OWNER	RESPONSE
Finalise funding mechanisms and allocate funding to support the development of 10 GW of low-carbon hydrogen production by 2030, ensuring these are designed to limit residual and upstream emissions, but also reflect hydrogen costs in a way that does not bias towards hydrogen where electrification is competitive.	DESNZ	We are working at pace to finalise funding mechanisms and allocate funding to support our up to 10GW hydrogen production capacity ambition. In August 2023, we published the Hydrogen Production Business Model (HPBM) contract – the Low Carbon Hydrogen Agreement (LCHA). We aim to announce successful projects that will be offered HPBM contracts and Net Zero Hydrogen Fund grants through the first electrolytic hydrogen allocation round in Q4 2023, and through the cluster sequencing process for CCUS-enabled projects from 2024, subject to matters such as due diligence and negotiations.
Accelerate the development of new business models for hydrogen transportation and storage infrastructure, with a view to keeping options open for larger scale hydrogen use by 2030.	DESNZ	The British Energy Security Strategy made a commitment to design new business models for hydrogen transport and storage (H2 T&S) infrastructure by 2025, an already ambitious timeline. Government has published a consultation on these business models, and recently responded to this consultation setting out its minded-to position for their high-level designs. A further update on the design of these business models is expected by the end of this year. Government has taken on board previous stakeholder feedback about accelerating development of these business models and has already introduced provisions in the Energy Bill intended to support the design of these new business models by 2025. The H2 T&S business models are being designed with a view to encouraging the development of hydrogen T&S infrastructure that can support a range of end-uses, including increasing use in industry, power, transport and potentially heat.

RECOMMENDATION	OWNER	RESPONSE
Government should clarify its 2030 10 GW hydrogen production commitment in TWh/ year and review whether this target is sufficient to meet future demands. Pending the outcome of this, strategic decisions may be needed around the scale of hydrogen use across sectors, or to adjust the level of the target.	DESNZ	We will be setting out more details on the future development of UK low carbon hydrogen production later this year in response to the recommendation made in the Independent Net Zero Review, led by Chris Skidmore MP, to publish a ten-year hydrogen production delivery roadmap. This roadmap will incorporate the period of our 2030 up to 10GW hydrogen production capacity ambition and reflect the various levels of hydrogen demand we could see beyond this date.

Further, the Carbon Capture and Storage Association launched a supply chain strategy in July 2023 which called for coordinated action from UK Government and industry to create a domestic industry, whilst securing existing jobs in energy-intensive industries and create new ones.[37]

Overall, it is clear the pace at which planning around Net Zero is occurring is accelerating. However, the government should be held to account that these plans come to fruition. This report emphasises that tackling the cause of emissions should be the focus of industrial decarbonisation. Whilst CCUS and hydrogen will play an important role in the long-run journey to net-zero, they are not the answer. IRENA's 2022 World Energy Transition Outlook placed electrification and energy efficiency as key drivers of the energy transition. With electrification accounting for 20% of emissions reductions, and energy efficiency for 25%. In contrast hydrogen and CCS are estimated to reduce 10% and 6% of emissions, respectively. Figure 3 shows IRENA's outlook for reducing emissions by 2050.[38]

Figure 3. Reducing emissions by 2050 through six technological avenues



Chapter One

THE OPPORTUNITY

Too often, industrial decarbonisation is viewed as a cost and burden to industry, with capital costs and expenditure that will lead to 'carbon leakage', with the production of manufactured goods being offshored elsewhere. Evidence for actual carbon leakage causing companies directly to either close or relocate has been limited.[39] In contrast, the opportunity to lead the establishment of new forms of low carbon materials, standards, and products, will potentially not only safeguard future British manufacturing jobs, it can lead to an increase in jobs and investment in the UK. This point has been well understood by local leaders, such as Tees Valley Mayor Ben Houchen, who published the Tees Valley Net Zero Strategy in December 2022, setting out how:

"Net Zero is too often framed in terms of what we have to sacrifice – not what we have to gain. Achieving Net Zero will require changes to the way we work, travel and power our lives. For a lot of our businesses this will mean transforming the way they operate. Achieving Net Zero presents the industry in the Tees Valley with a stark choice, either invest in innovative technologies and growth or close. There is no status quo. This effectively means there is no choice for our region, we must support our industrial companies to transition to Net Zero and ensure it anchors their ongoing operations in the region. This transition also opens up new opportunities for new green investments and continued regeneration of our industrial base. Net Zero needs innovative products and services to make zero emission products and services affordable and appealing. We need new technologies to power our industry and to move people and goods around our region. We need businesses to step up to take advantage of the supply chain opportunities as Tees Valley leads the way in green energy production."[40]

The total value of UK low carbon and renewable exports was £6.1 billion in 2020, which is equivalent to around 1% of total UK exports (£609.9 billion). Low carbon goods and services exports are expected to be worth £1 trillion-£1.8 trillion globally in 2030.[41] The UK should be positioning itself to lead this market, by developing the supply of low carbon manufacturing and industrial goods, rather than find that it will simply be forced to respond to an international market and its changing demands, which as Ben Houchen notes, will be inevitable. There is a choice to be made: to not act is to deny this choice, with all the cost it will bring to leaving industries as stranded assets.

We are now in a global net zero race, with those countries that can provide the greater certainty and clarity in long-term policy support able to increasingly attract inward investment. As the CCC stated in their 2023 Progress Report, "companies investing in industrial decarbonisation overlook the UK in favour of countries providing greater policy support. This risk is growing due to measures such as the United States' Inflation Reduction Act and the EU's proposed Green Deal Industrial Plan. The UK must carefully design industrial policy to minimise carbon leakage and incentivise investment in the UK."[42]

The IPCC's sixth synthesis report highlights that reducing industry emissions will require coordinated action throughout value chains. Additionally, it notes that actions taken to reduce industry sector emissions may change the location of energy-intensive industries, the organisation of value chains and will potentially have distributional effects on employment and economic structures.[43]

Industry remains the UK's third highest emitting sector,[44] Its decarbonisation not only largely reduces environmental impact, but also presents benefits for the economy and energy security. For example, the iron and steel industries make up 14% of industrial emissions in the UK. Significantly reducing steel industry emissions is required if the UK is to meet its net zero targets.[45]

A core message of this report is that industrial decarbonisation does not equal de-industrialisation. It is an economic opportunity that, in parallel, creates a strong pathway towards the UK's net zero targets. Within the evidence sessions, Reckitt supported this, stating that their work aims to communicate that the cost of living crisis in the UK is not in conflict with the case for net zero, they can complement each other. Industry contributes over £150bn GVA to the economy, through direct, indirect and induced ways.[46] Furthermore, the Industrial Decarbonisation Research and Innovation Centre (IDRIC) draws attention to the ability of industrial decarbonisation to create positive spillover effects for decarbonisation across the economy, most importantly construction, energy production and transportation, as a result of developing low-carbon materials and generating know-how. Therefore, fostering the UK's industrial sector whilst simultaneously improving the understanding of the opportunities of net zero is crucial.

Russ Hall from the High Value Manufacturing Catapult underlined the need to think of the problem as a system, "the opportunities are there and if we view it as a system, then we will find a way to support UK industry in the journey to net zero and, potentially, enable it to be self-fulfilling, enabling growth as well as decarbonisation."

The current conversation on industrial decarbonisation surrounds industrial clusters, CCUS and hydrogen. However, whilst these are important areas of focus and should be consistently pushed forward, the full infrastructure and operational capacity needed may not be developed for at least another decade. There are other routes to decarbonisation which allow for reduction emissions starting in the near term. Enhanced industrial performance should be buckled down on, improving both economic and environmental performance.[47] Enhanced efficiency, electrification and digitalisation are interconnected routes to reducing emissions. The development of low-carbon technologies and infrastructure also increases industry competitiveness by driving investment and cost-savings. and contributes to the UK's clean growth.[48] From the other perspective, there is a risk of negative pressure on investor sentiment from lack of compliance with ESG standards/ green taxonomy. This chapter will look at the opportunities offered by each element of industrial decarbonisation as well as the risk of reducing competitiveness and carbon leakage.

JOB CREATION AND GROWTH

Industrial decarbonisation presents an opportunity to build supply chains, rebuild jobs and foster growth that is sustainable and resilient to future needs for emissions reductions. If the UK is able to be a first mover and create green industries that provide a variety of stable careers, worry around the effect of climate change mitigation can transform into opportunity. It is a chance for the UK to become an industrial centre. David Parkin, Director of HyNet made this clear, "HyNet is there to break that link between carbon dioxide emission from industry to allow all of these companies you see on the screen today to continue to operate in 2050 and beyond, but in a low carbon way."

Moreover, researchers from the Centre for Climate Change Economics and Policy, Grantham Research Institute on Climate Change and the Environment and Centre for Economic Performance, London School of Economics and Political Science discern that "seizing opportunities from the CCUS value chain can be part of an economy-wide, net-zero-aligned growth path in the UK."[49] It is an opportunity to create net-zero aligned jobs, unlock export opportunities from the supply chain and align industrial growth with the net zero trajectory and, crucially, deliver negative emissions.

The CCUS value chain is comprised of four segments, capture, transportation, storage and use. Each includes a variety of supply chain activities which requires a range of jobs and skill sets.[50]

- **Capture**
  - Plant design and engineering
  - Major plant fabrication
  - Equipment design and manufacture
  - Construction and commissioning

- **Transport**
  - Pipework onshore and offshore supply and installation
  - Marine transport of CO2
  - Marine loading and offloading

- **Storage**
  - Wells, subsurface and reservoir design and engineering
  - Marine and subsea contractors

- **Usage**
  - Transformation of CO2 through chemical and biological processes[51]
  - CCUS consultancy and R&D

According to a recent study by the University of Chester and MACE, funded by IDRIC, the decarbonisation of the UK industrial clusters is estimated to require £515 billion of new infrastructure by 2050. To support this, an estimated 350,000 workers will be required across all levels. Both technical and professional roles are required, with the split expected to be approximately 72% technical and 28% professional. While these demand estimates include many generalist skills in areas such as accounting, marketing, and administration, most skills will be required in design, engineering, manufacturing, and construction.[52] Industrial Cluster Decarbonisation plans have been set out by six clusters across the UK, with the common goal to achieve decarbonisation by 2040. Table 4 shows the number of jobs anticipated by each cluster's plan, indicating whether they are all directly related to the cluster.[53]

Table 4. UK Cluster Job Projections

CLUSTER	NO. OF JOBS ANTICIPATED	DETAILS
Humber Industrial Cluster	20,000	Direct jobs[54]
Net Zero North West Cluster	34,500	All jobs associated with the cluster.[55]
Repowering the Black Country	50-500+ per hub	Up to 60 hubs are expected to be required.[56]
Scottish Net Zero Roadmap	5000 average per year	Associated, between 2023-2045.[57]
South Wales Industrial Cluster	113,000	Retained industrial and manufacturing jobs in the region.[58]
Tees Valley Net Zero	30,000	Associated.[59]

The South Wales Industrial Cluster's (SWIC) estimates shown in Figure 4 show the impact on jobs in the region without supportive policies for decarbonisation. The pathway of the green line estimates job increases from the construction of infrastructure developments for hydrogen, CCUS and electricity and installation of technologies at each site, as well as the job losses from increased productivity.[60] Indirect effects of CCUS include safeguarding and extending employment in existing energy intensive industries which would become unviable due to carbon legislation and supporting the development of existing or new carbon intensive industry facilities that depend on CCUS.

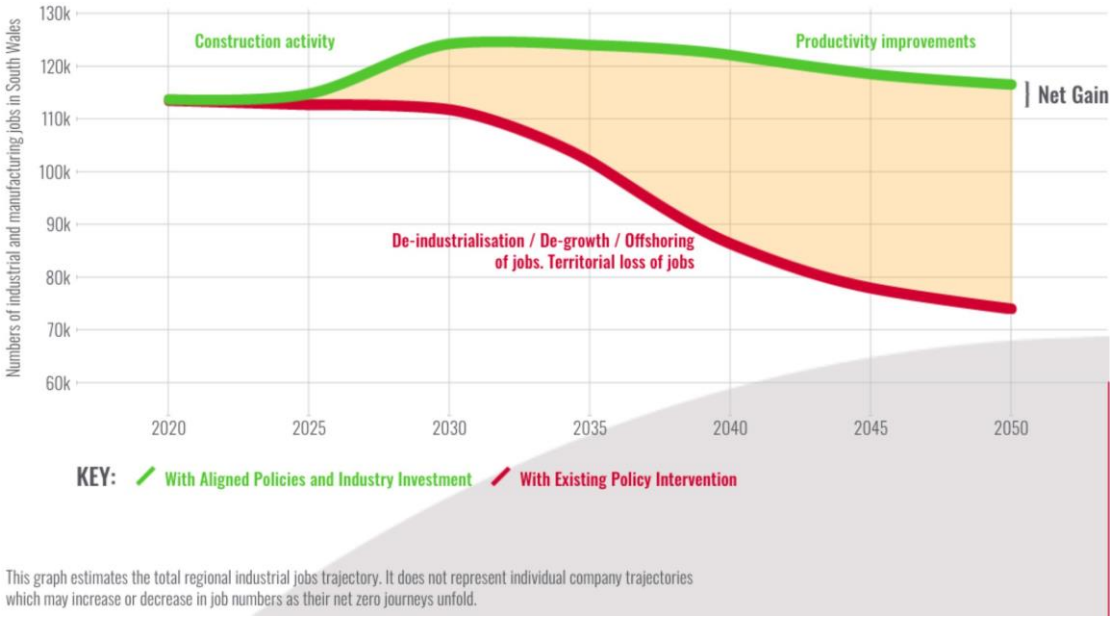
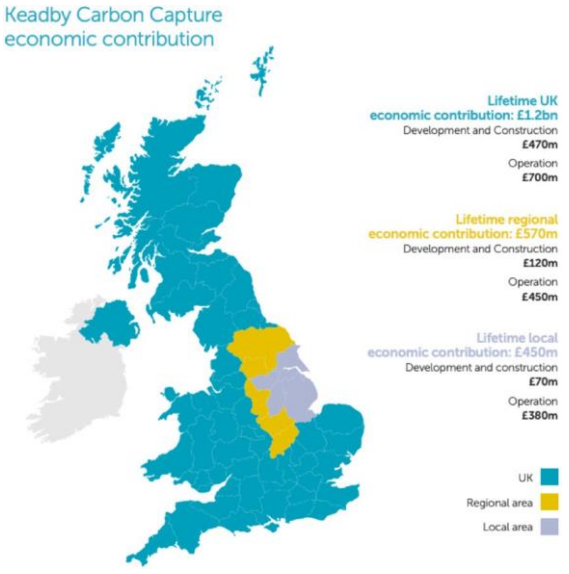


Figure 4. Potential impact on SWIC jobs through decarbonisation

Hull and Humber is the UK's largest emitting industrial cluster, with 12 million tonnes of CO2 emissions per year, making it also the second largest emitting industrial cluster in Europe, behind the Ruhr Valley in Germany. Additionally, in Hull, as well as other industrial areas, such as Merseyside, Grangemouth, Teesside and South Wales the economic challenges are evident. Industrial decarbonisation presents an avenue for creating a prosperous regional economy. Reckitt's case study of Oh Yes! Net Zero Hull shows the potential of decarbonisation as international investors and companies are increasingly attracted to the Humber, with Humber 2030 Vision stating over £15 billion of private investment is to be unleashed in the region. Further, 1 in 10 regional jobs will be safeguarded and thousands more created by decarbonising the Humber.[61]

It is estimated that an average year of the first 25 years of operation of Keadby Carbon Capture Power Station has the potential to generate £28 million GVA and 250 jobs in the local area, £34 million GVA and 320 jobs in the region, and £53 million GVA and 560 jobs in the UK. The potential total economic contribution of the project over its development, construction and first 25 years of operation is estimated by BiGGAR Economics to be £450 million GVA in the local area; £570m GVA in the region, and £1.2 billion GVA in the UK.[62]



Further, the integration of digital solutions and AI, in support of industrial decarbonisation and the development of CCUS and hydrogen production, will require additional digital and data management skills in the design and operation of these industrial assets, which, therefore, presents an opportunity for skills creation.

BENEFITS OF ELECTRIFICATION AND EFFICIENCY

The need and demand for low-carbon products and services is increasing; for example, demand for low-carbon steel is expected to hit 200 million tonnes by 2030, up from 84 million tonnes in 2021,[63] and the global low-carbon fuels market is expected to be between $40-50 billion by 2030.[64] By meeting enhanced customer demand, and regulatory standards, companies gain opportunities for improved profitability and strengthen competitiveness. By participating in decarbonisation efforts and projects, companies can gain access to a huge investment market. According to the IEA, $4.2 trillion is required in global clean energy investment to meet 2030 climate targets.[65] Briefly communicated, "overlooking most of the energy efficiency potential gravely understates the scope for profitable climate solutions: it makes climate protection look harder and costlier than it actually is, diverting and inflating attention to costlier and riskier options."[66] As Andrew Large from the Confederation of Paper Industries highlighted during the evidence sessions, "we need to show that you can operate in a low carbon way inside the United Kingdom and do so in a competitive and viable way."

The government is currently gathering evidence on how to support industry to move away from fossil fuel reliance, the benefits of electrification, must be stressed in the meantime. Electrification is also an area that the industrial sector should be focusing on. It is the replacement of technologies or processes that use fossil fuels with electrically-powered equivalents. Fuel switching to electrification is expected to play a significant role in industrial emissions reduction, with the CCC's balanced pathway seeing emissions savings on par with hydrogen (both 14MtCO2e per year) by 2045.[67] Benefits of these replacements include higher efficiency, reduced energy demand, and the increasing impact on emissions as electricity generation is decarbonised.[68] Electrification also presents a large cost-saving opportunity, renewable-based electricity is now the cheapest power option in

The High Value Manufacturing Catapult's Manufacturing Energy Toolkit (MET) has shown how simple interventions around energy measurements can have a big impact on industrial energy efficiency and emissions reduction.

MET was trialled by Warwick Manufacturing Group with SMEs and saw an average energy cost saving of 21%, this cost saving frees up operational expenditure that can be redirected to further equipment investment or efficiency savings. For high energy consuming businesses MET has been able to give significant emission reductions, with emissions savings of over 20 tCO2pa for foundries and enamellers, as well as the complete removal of reliance on natural gas.

MET is available from HVMC nationally to SMEs, the impact of schemes like MET are clear to see, significant energy and emission savings for very little cost. Scale up of this sort of programme across industry would lead to significant reductions in industrial emissions.

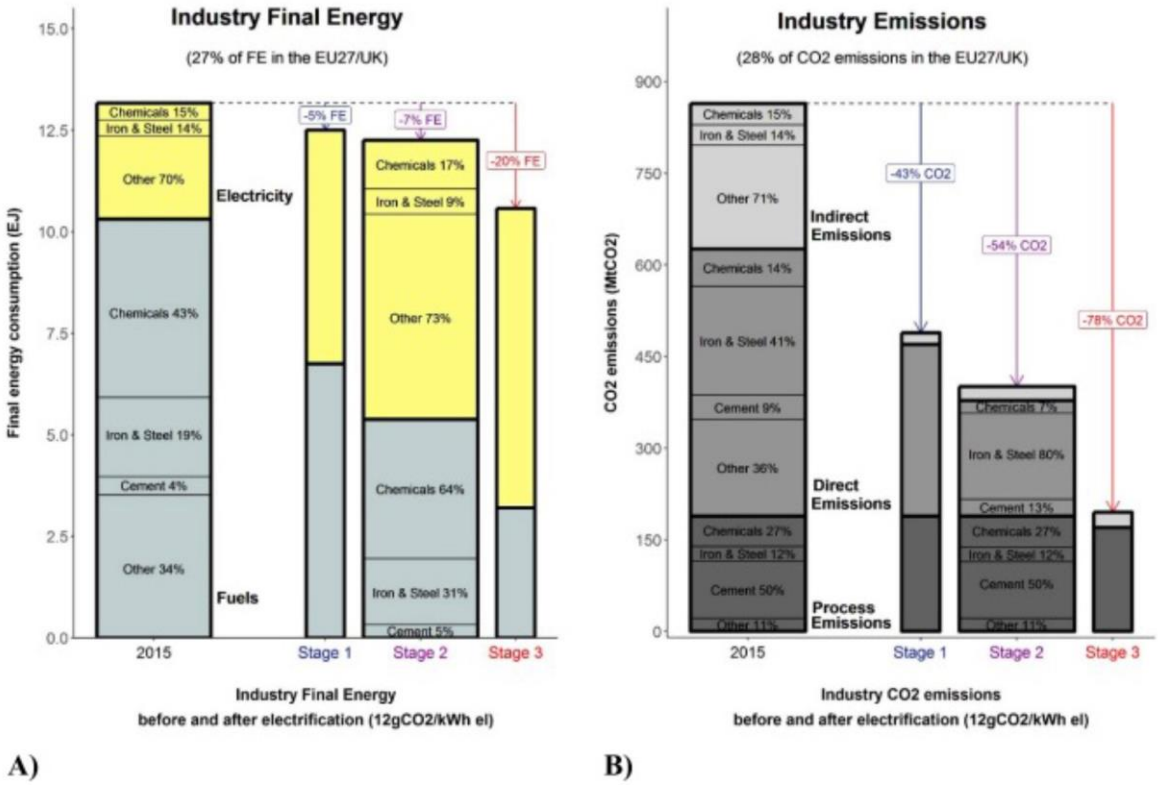


Figure 5. Industry FE consumption (A) and CO2 emissions (B) before and after electrification[73]

most regions, according to IRENA's 2022 world outlook, however its utilisation in industrial processes is still lagging.[69]

The IEA states that "policies implemented so far do not approach electrification in a comprehensive manner."[70]

In the UK, the proportion of electricity generated by renewables was 42% in 2022.[71] Figure 5 shows the estimated final energy consumption at each stage of electrification: stage 1 being entry points for industry electrification with mature technologies, stage 2 the more technologically advanced phase of industry electrification and stage 3 the maximum potential of industry electrification with high technological uncertainty.[72] Therefore, if the UK can support in delivering these key technologies, it will improve the efficiency and simultaneously accelerate the UK's industrial sector to net zero. There is a chance to set a precedent and be at the forefront of the drive towards electrification and, potentially, create innovative technologies for export to support other countries meet their industrial decarbonisation targets.

Another benefit of increased electrification is its importance for dispersed sites who are not connected to CCUS and hydrogen networks. Increased industrial electrification will also have knock-on effects on the increase of grid capacity and renewable generation capacity, which will be focused on in the forthcoming Power Network Report. They stated "the time has arrived for industrial companies, supported by policy makers and utilities, to plan for the adoption of electric technologies for their current fuel use."[74]

Furthermore, combined heat and power (CHP) captures and utilises the heat produced during the electricity generation process. It is a highly efficient process, not only reducing carbon emissions by up to 30% compared to conventional generation, but also resulting in cost-savings of up to 20% for operators. In 2022, 17% of fuel input to CHP was from renewable fuels, which was the highest to date. However, CHP output accounted for only 7% of total electricity generation, similar to the previous 5 years.[75]

BENEFITS OF DIGITALISATION

Digitalisation is likely to bring myriad opportunities and benefits to the decarbonisation of industry. Digital technologies have the potential to accelerate decarbonization in a 'Connected Industrial Economy' by ensuring seamless data exchange and integration between various energy systems and industrial processes, providing insights for optimising energy consumption and reducing carbon emissions, and enhancing transparency needed to gain market confidence for new commodities (such as green hydrogen or biogenic CO2). The regulatory environment around decarbonisation is evolving. For example. there is now a global community established to look at the carbon footprint of generating Hydrogen, Open Hydrogen Initiative (OHI), that could be used to provide input to measurement mechanisms.[76]

AVEVA presented five key areas for opportunities engendered from digitalisation:

- **Efficiency Improvements:** Digital solutions offer opportunities to optimise industrial processes, leading to more energy-efficient operations. Technologies like IoT, AI, and data analytics can identify inefficiencies, enabling industries to streamline operations, reduce energy consumption, and thus, decrease carbon emissions. After picking the low hanging fruit, advanced tools can build on the data structures to apply simulation and AI technologies to further drive the sustainability envelope.

- **Predictive Maintenance:** Implementing digital solutions allows for predictive maintenance, which can prevent unexpected breakdowns and increase the lifespan of machinery. This leads to better resource utilisation, less waste, and ultimately contributes to the reduction of the industrial carbon footprint. Too many organisations in the UK rely on Condition Monitoring and this, while effective in its own way, does not fully realise the potential of digitalisation solutions.

- **Renewable Energy Integration:** Digital solutions enable better integration of renewable energy sources into industrial operations. Smart grids and energy management systems can help industries efficiently utilise renewable energy, reducing reliance on fossil fuels and subsequently lowering carbon emissions. Today, the power of digitalisation aligned with AI predictive climate forecasting gives a far better supply side model that can be better integrated into grid operations.

- **Innovation and New Business Models:** The adoption of digital technologies fosters innovation in the industrial sector. This can lead to the development of new business models focused on sustainability, such as product-as-a-service models, circular economy practices, and collaborative approaches that prioritise decarbonisation efforts. In particular improving Digitalisation and Visibility across a Value chain from Source to Conversion/Production to Consumption can have huge impact on the entire supply chain

- **Data-Driven Decision Making:** Digital solutions provide access to large volumes of data, allowing for more informed decision-making. This data can help industries

understand their carbon footprint, identify areas for improvement, and track progress towards decarbonisation goals. The insights derived from data analytics empower industries to make more strategic choices in their efforts to reduce emissions.

Utilising innovations in digitalisation provide a method to reduce industrial emissions at a lower cost and at a quicker speed whilst CCUS and hydrogen pathways are maturing. Lisa Wee, Global Head of Sustainability at AVEVA, provided an example of the benefits of digitalisation, "Digitalisation is fundamental to project economics of these sources of new energies. Topsoil is an example here with their solid oxide electrolyser cells. They're able to allow the production of 30% more hydrogen at 30% lower cost from the same volume of electricity. The ability to use an engineering solution, a digital twin solution, very early on was game changing for them to be able to bring their technology to market."

Another example is the use of automation for scaling up innovative carbon capture technologies. Brilliant Planet uses EcoStruxure Automation Expert, linked to AVEVA System Platform software which controls the site's algae cultivation utilising data from a high-frequency satellite. The solution significantly reduces testing and integration time, improves ability to effectively manage and increase yield in an automated closed-loop mannerreduces engineering costs and can be deployed repeatedly.[77]

Further, creating digital twins of industrial plants can cement low-emissions into design. Defined by the digital twin consortium a digital twin is a virtual representation of real-world entities and processes, synchronised at a specified frequency and fidelity:

- Digital twin systems transform business by accelerating holistic understanding, optimal decision-making, and effective action.
- Digital twins use real-time and historical data to represent the past and present and simulate predicted futures.
- Digital twins are motivated by outcomes, tailored to use cases, powered by integration, built on data, guided by domain knowledge, and implemented in IT/OT systems.[78]
- Incorporating digital engineering solutions from the beginning of the planning and design process can enable companies to be more efficient, both in terms of cost and output. Greater understanding of the capabilities of the processes can hasten the implementation of the technologies. Creating a 'Connected Industrial Economy' by working together in the earliest stages, enabled by digital technologies, can reduce the "green premium" cost to the end-customer.

COST OF NOT ZERO

The largest share and growth in gross GHG missions in 2023 resulted from fossil fuels combustion and industrial processes.[79] From a global standpoint, unless industrial emissions are reduced at a drastic rate, the Paris Agreement target to keep the global temperature from rising above 1.5°C above pre-industrial levels will not be met. Looking closer to home, not investing in accelerating the transition to net zero creates a risk of deindustrialisation. Not investing in Net Zero could cost the UK £224 billion in GVA.[80]

Countries and governments are increasingly implementing climate-related regulations with specific, heavy emitting industries targeted. Companies that have not implemented a decarbonisation strategy will not adhere to requirements and risk financial penalisation and losing competitive advantage. On the other hand, if the business models and funding are not put into place, international companies will place their investments elsewhere. The Aldersgate Group's response to the Inflation

Reduction Act provides a clear picture that there is a risk of losing a substantial amount of private investment in the UK to the USA due to the better incentives through subsidies, tax credits and capital. According to the report basic iron and steel is in the top 10 sectors most exposed to trade risks, it had a total of £11,542m in 2022.[81] Therefore, protecting these industries in the UK and supporting them to decarbonise is vital.

THE INTERNATIONAL LANDSCAPE

Industrial clusters alone account for 15%-20% of global CO2 emissions.[82] Thus, industrial decarbonisation has long been recognised as vital to meet global emissions reductions. All countries are seeking to reduce their industrial emissions, and in doing so should be seeking international standards and benchmarks. COP28 has industry on the agenda, focusing on levers and pathways for rapid decarbonisation, job growth and economic opportunity across industrial value chains. However, momentum must be fostered as international examples continue to arise.

The sharing of innovation and research, and the deployment of best practice across jurisdictions presents the opportunity to accelerate industrial decarbonisation globally. International collaborations committed to industrial decarbonisation have emerged in recent years. The G7 Climate Club launched in December 2022, with one of its key pillars being transforming industries. This includes supporting the G7 Industrial Decarbonisation Agenda, the hydrogen action pact and the IEA's Breakthrough Agenda on accelerating sector transitions through stronger international collaboration.[83] The Industrial Decarbonisation Accelerator has also emerged as a United Nations Industrial Development Organisation (UNIDO)-led network of international initiatives, sharing their collective experience and showcasing best practice.[84] In 2021, UNIDO and the Clean Energy Ministerial launched the Industrial Deep Decarbonisation Initiative (IDDI), working to create an enabling environment for the deep decarbonization of industry, starting with steel, cement and concrete. IDDI aims to spur early demand for low and near-zero emission steel, cement and concrete through green public procurement by:

- Developing guidelines to harmonise emission accounting methodologies, and developing standards to define low and near-zero emission products.
- Developing a global framework on low and near-zero emission steel, cement and concrete with publicly accessible data that is easy to navigate using tailored digital tools.
- Establishing globally recognised targets for the public procurement of low and near-zero emission steel, cement and concrete.

Further, the UNIDO and Climate Investment Funds (CIF) have been working together to spark a "chain reaction" in the high-emitting industry sector of climate action across developing countries, supporting the development of net zero roadmaps and honing down on funding gaps. The aim is to use this information to steer low-cost financing through multilateral development banks.[85]

Looking at a country or regional level, COP28 will be the first Global Stocktake, where an assessment can be made on the global advancement on reducing greenhouse gas emissions and the implementation of the Paris Agreement, namely progress on nationally determined contributions (NDCs). Chief Executive of The Association For Renewable Energy and Clean Technology (REA), Dr Nina Skorupska CBE, highlighted that there is evidence that other countries are taking the lead in industrial decarbonisation due to their better frameworks and communication of objectives. Thus, it is important to look to the international floor for examples of leading practice.

The USA IRA is a significant milestone in the country's climate policy.[86] Estimates suggest more than 170,000 jobs have been created as a result of the IRA's clean energy and climate provisions and $110bn of investment in clean energy manufacturing has been announced by private companies.[87] The commitment to climate technologies in the Inflation Reduction Act is well understood, but equally important is the policy innovation around industrial decarbonisation. In particular, the Department for Energy (DOE) has published its Industrial Decarbonisation Roadmap, which provides a detailed, whole-sector, approach to what is needed to strategically decarbonise industry at scale. This is an important overview that rather than focusing specifically on decarbonisation through abatement, takes a wider view of emissions reduction. It sets out a clear strategy of targeting five sectors to address decarbonisation through four horizontal technological approaches. These include:[88]

- **Energy Efficiency:** Energy efficiency is a foundational, crosscutting decarbonization strategy and is the most cost-effective option for greenhouse gas emission reductions in the near term. Decarbonization efforts include:
  - Strategic energy management approaches to optimise performance of industrial processes at the system-level
  - Systems management and optimization of thermal heat from manufacturing process heating, boiler, and combined heat and power sources
  - Smart manufacturing and advanced data analytics to increase energy productivity in manufacturing processes

- **Industrial Electrification:** Leveraging advancements in low-carbon electricity from both grid and onsite renewable generation sources will be critical to decarbonization efforts. Decarbonization efforts include:
  - Electrification of process heat using induction, radiative heating, or advanced heat pumps.
  - Electrification of high-temperature range processes such as those found in iron, steel, and cement making.
  - Replacing thermally-driven processes with electrochemical ones.

- **Low-Carbon Fuels, Feedstocks, and Energy Sources:** Substituting low-and no-carbon fuel and feedstocks reduces combustion associated emissions for industrial processes. Decarbonization efforts include:
  - Development of fuel-flexible processes.
  - Integration of hydrogen fuels and feedstocks into industrial applications.
  - The use of biofuels and bio feedstocks.

- **Carbon Capture, Utilisation, and Storage:** Carbon capture, utilisation, and storage refers to the multicomponent strategy of capturing generated CO2 from a point source and utilising the captured CO2 to make value added products or storing it long-term to avoid release. Decarbonization efforts include:
  - Post-combustion chemical absorption of CO2.
  - Development and manufacturing optimization of advanced CO2 capture materials that improve efficiency and lower cost of capture.
  - Development of processes to utilise captured CO2 to manufacture new materials.

Key recommendations from the USA's Industrial Decarbonisation Roadmap include:

- **Advance early-stage RD&D:** Further applied science necessary for net-zero carbon emissions by 2050.

- **Invest in multiple process strategies:** Continue parallel pathways of electrification; efficiency; low-carbon fuels; carbon capture, utilisation, and storage; and alternative approaches.

- **Scale through demonstrations:** Demonstrate testbeds to accelerate and de-risk deployment.
- **Address process heating:** Most industrial emissions from fuel combustion for heat.
- **Integrate solutions:** Focus on systems impact of carbon reduction technologies on the supply chain.
- **Conduct modeling/systems analyses:** Expand use of lifecycles and techno-economic analyses.

Furthermore, IDRIC shared that "in contrast to the UK cluster sequencing approach, the simplicity and accessibility of the 45Q tax credit under the USA Inflation Reduction Act may be an important factor contributing to current USA leadership in attracting investment in carbon capture. This is occurring at a time where, according to the CCSA, one in three UK CCUS developers have reported that they would consider moving elsewhere due to lack of access to UK Government support and/or key transport and storage infrastructure."

Europe is also focusing on new net zero related manufacturing opportunities. The EU Net Zero Industry Act is part of the Green Deal Industrial Plan's pillar for creating a predictable and simplified regulatory environment.[89] It is an attempt for creating a coherent framework for strengthening manufacturing capacity of net-zero technologies, which not only addresses key issues around investment but also other levers for scaling up net-zero technologies such as innovation, streamlined planning and permitting, support for innovation, and investment in skills and training. There are multiple examples of measures which may be useful for a UK context, for example regulatory sandboxes. In particular, the Act seeks to establish mechanisms for greater coordination and information exchange between multiple stakeholders. Furthermore, the EU Just Transition Fund (JTF) supports regions and communities negatively impacted by the EU's transition to climate neutrality.[90]

We are moving into an era where without comprehensive an industrial decarbonisation vision, the UK risks not carbon leakage but low-carbon leakage. The following section will explore the international landscape and successes in varying countries.

PROGRESS IN CARBON PRICING MECHANISMS

The Net Zero Review recommended that the UK demonstrate leadership on facilitating a CBAM in the future. Since then, the EU launched its 'landmark' Carbon Border Adjustment Mechanism in October. It is designed to put a fair price on the carbon emitted during the production of carbon intensive goods that are imported into the EU, consequently encouraging cleaner production in non-EU countries. It will be gradually introduced as the free allocation of allowances under the EU ETS are phased out. The mechanism avoids carbon leakage and maintains competitiveness of industrial products produced within the EU, as the carbon price of imports will be equivalent to that of domestic production. The CBAM will initially be applied to the following imports: cement, iron and steel, aluminium, fertilisers, electricity and hydrogen. The transitional phase will only require importers to report the volume of the imports and the GHG emissions from their production, without financial obligations. This phase will allow for a learning period and evaluation before the definitive system enters into force.[91]

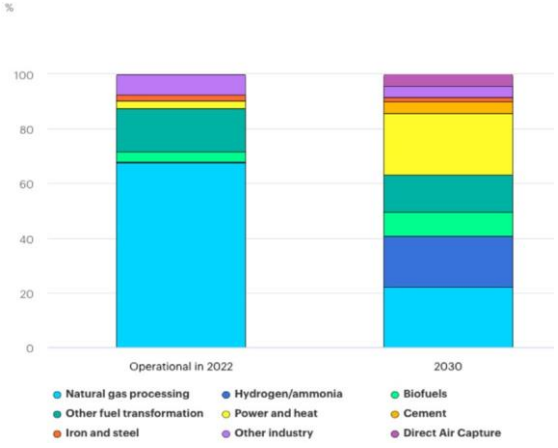
The Australian government is putting $3.9 million forward through their Powering Australia plan over two years to review policy options to reduce carbon leakage, considering an Australian CBAM for steel and cement sectors.[92]

PROGRESS IN CARBON CAPTURE, UTILISATION AND STORAGE

CCUS is also a priority for industrial decarbonisation. However, in 2022 almost 70% of operational global capture capacity is in natural gas processing. The iron and steel sector has just 0.9Mt CO2 capture capacity per year, hydrogen/ ammonia 0.1Mt CO2 and cement is currently not included in operational capacity of more than 100,000 t per year, according to the IEA's database, shown in Figure 6. Planned capacity for 2030 for iron and steel and cement is to increase to 4.8Mt and 13.9Mt CO2 per year, respectively. Hydrogen/ ammonia industry capture capacity is planned to dramatically increase to 59.6Mt C02 per year. Therefore, capacity for the cement industry is expected to rapidly grow. Europe's 2022 operational capture capacity was 2.4Mt C02 per year, planned to increase to 95Mt CO2 per year by 2030 (Figure 7). At present, much of the capacity is planned rather than under construction suggesting significant action is needed to bolster the construction and deployment of CCUS technology (Figure 8).[93, 94]

Certainty of demand is important for attracting investors and creating tangible action, an element the UK policy currently lacks. Germany announced its Carbon Contracts for Difference (CCfD) programme in early 2023, which supports industrial companies, including small and medium-sized companies, in investing in climate-friendly production facilities that would otherwise not be profitable. It provides incentives for the necessary technologies and infrastructure to be built domestically in Germany with immediate effect. The programme will provide €50bn of funding and will pave the way for Germany to become a central location for industry and innovation.[95, 96]

Figure 6. Operational and planned carbon capture capacity by industry



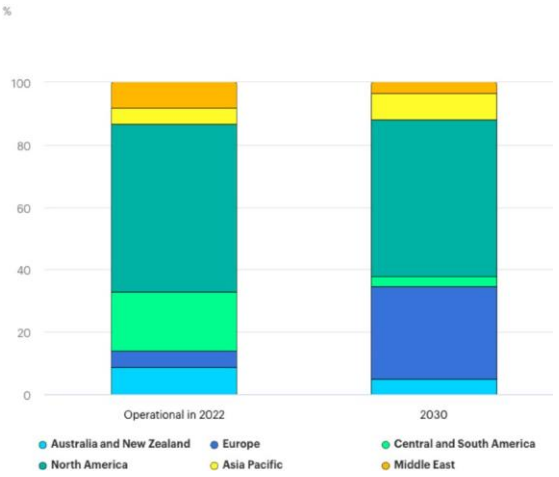


Figure 7. Operational and planned carbon capture capacity by region

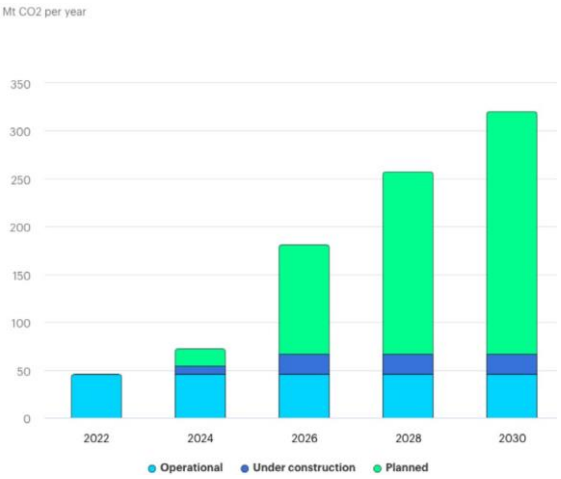


Figure 8. Global capacity, by operational, under construction and planned

In 2022, France released its "France 2030" Investment Plan for heavy industry decarbonisation investment. Within this, the French government committed to invest €5.6bn to reduce the CO2 emissions from industries such as steel, cement and aluminium. €5bn of this funding is for direct support for solutions for industrial sites, mainly hydrogen and carbon capture.The Netherlands introduced a subsidy (SDE++) for operation which closes the cost gap between production without CCUS and production with CCUS. In 2022, €13bn was available for SDE++ funding.[97]

Furthermore, the IEA highlighted the following countries and regions as making notable progress in CCUS:

- The USA passed the Infrastructure Investment and Jobs Act in 2021, under which $12bn of new investment is allocated to supporting CCUS technology.[98] Additionally, the USA's government made changes to the 45Q tax credit under the Inflation Reduction Act (IRA) framework. Thereby, it provides up to USD85 per tonne of CO2 permanently stored, provided emissions reductions can be clearly demonstrated.[99]

- On 16th March 2023, the EU launched the Net Zero Industry Act as part of the Green Deal Industrial Plan's pillar for a predictable and simplified regulatory environment. It is intended to support the strengthening of the European manufacturing capacity of net-zero technologies, as well as to overcome barriers to scaling this capacity. Additionally, the European Commission states that the measures will increase the competitiveness of the net-zero technology industrial base and improve the EU's energy resilience. Its plans include the establishment of Net-Zero academies which will provide dedicated training programmes.[100]

- Indonesia became the first country in Southeast Asia to establish a framework for CCUS activities in March 2023. The framework relies on oil and gas leaseholders to lead CO2 storage development and operation and outlines aspects such as pathways to monetising carbon credits.[101]

- In China, three new CCUS projects became operational in 2023. In July, the country's first commercial scale 109km long CO2 transport line started full operations, serving SINOPEC's Qilu-Shengli CCUS project in Shandong. These projects have already been seen to reduce overall capture cost and overall capture energy consumption.[102]

- Japan has selected seven projects to receive support from the government's Ministry of Trade and Industry for commercialisation by 2030.[103]

The first direct air capture plant opened by Heirloom in California on 9th November, it is expected to capture up to 1,000 tonnes of CO2 a year from the air. Heirloom was awarded a grant from the billions of dollars made available by the USA' Department of Energy.[104]

Additionally, Carbon Clean, a carbon capture technology company that works with customers in the hard-to-abate industries, noted the attractiveness of Canada's CCUS environment. Canada's model outlays a clear and escalating federal carbon price, which will reach CAD 170/t CO2e in 2030.[105] The Output-based Pricing System for large industrial emitters applies in Manitoba, Prince Edward Island, the Yukon, Nunavut, and partially in Saskatchewan, based on performance, whilst a fuel charge on fossil fuels applies in Ontario, Manitoba, Yukon, Alberta, Saskatchewan and Nunavut. Other provinces are able to implement their own pricing systems within the federal benchmark.[106] Additionally, investment tax credits from 2022 to 2023 are set as 60% for investment in equipment to capture CO2 in direct air capture projects, 50% for investment in equipment to capture CO2 in all other

Carbon Clean is a leader in revolutionising carbon capture solutions, delivering cost-effective, modular, space-saving technology that enables hard-to-abate industries to decarbonise at scale. Its mission is to capture 1 billion tonnes of CO2.

Carbon Clean's award-winning CycloneCC technology reduces the overall cost and physical footprint of carbon capture by up to 50%. CycloneCC is modular, compact and its 'plug and play' design makes it cost-effective and scalable. It is prefabricated so it can be installed and operational in a matter of weeks.

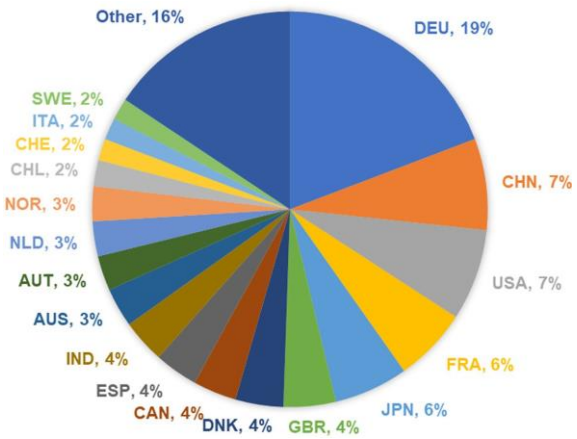
With 49 technology references around the world, Carbon Clean has one of the largest project portfolios of any independent carbon capture business. ADNOC recently selected CycloneCC for a carbon capture project at Fertiglobe's 100%-owned nitrogen fertiliser plant, in the Al Ruways Industrial Complex in Abu Dhabi. The project will be the first deployment of a 10 tonnes per day CycloneCC industrial unit anywhere in the world.

CCUS projects, and 37.5% for investment in equipment for transportation, storage and use. These will be reduced by 50% from 2031 to 2040, which is intended to encourage industry to move quickly.[107] Additionally, Alberta was highlighted as an investable environment for CCUS due to its provincial incentives. The Alberta Government is investing $1.24 billion for up to 15 years in the Quest and Alberta Carbon Trunk Line (ACTL) projects, which have already captured and stored more than 11.5 million tonnes of CO2 since 2015.[108]

PROGRESS IN HYDROGEN

COP28 is expected to be the setting of the public launch of the Declaration of Intent on mutual recognition of low-carbon hydrogen certification scheme[109] and the plan for doubling the current global hydrogen production target to 180 million tonnes a year by 2030.[110] According to the IEA Hydrogen Projects Database, there are 281 operational hydrogen projects across the world. Germany has 54 operational projects, accounting for almost 1/5 of the global total, double that of China and the USA, who have the second highest at 21. The UK is 6th in terms of operational projects, largest project has a capacity of 3MW.[111]

Figure 9. Percentage of Operational Hydrogen Projects by Country (based on data from IEA Hydrogen Projects Database)



Of the 281 operational hydrogen projects, 110 use water electrolysis or biomass supply technologies and use dedicated renewables for electricity supply. Germany and China are leading in this area of hydrogen projects, with 19 and 17 in operation. Currently, the UK has only 4 projects using such technologies with dedicated renewables. 60 of the 110 projects are using the hydrogen for mobility.[112]

There are 43 projects globally in various stages of development which have an end use of iron and steel, counted as the use of hydrogen in steelmaking (direct reduced iron, injection in blast furnaces, hot finishing and other high-temperature processes).[113]

Salzgitter Hydrogen, in Germany, is an example of the use of hydrogen produced for iron and steel. The plant received €1bn in state aid, in the form of a direct grant. The SALCOS programme enables a 95% reduction of CO2 emissions in steel production.[114] Germany's leading stance could be down to the need to decarbonise its largely industrial-based economy if it is to succeed its goal of achieving net zero by 2045. Germany's National Hydrogen Strategy aims to establish hydrogen produced from renewable energy and its downstream products as key elements of the energy transition to reduce greenhouse gas emissions. Also involved in the strategy is the plan of the Federal Government to introduce several funding instruments to help electrolysis plants achieve economic viability. CCfD between the state and companies in energy-intensive industry are designed to compensate for the higher cost of climate-friendly production processes compared with conventional processes. The aim is for them to provide incentives for the early implementation of climate projects."[115] The strategy also lays out a flexible and output-oriented governance structure. In addition to this, H2 Green Steel is a fully integrated, digitalised and circular plant in Boden, northern Sweden. When fully operational, it will reduce CO2 emissions by up to 95% compared to traditional steelmaking. A giga-scale electrolyser is integrated into the production site to provide fossil-free hydrogen. The aim is to eventually decarbonise other heavy industries with these expertise.

The US's $7 billion investment in seven clean hydrogen hubs signifies a pivotal step toward technological innovation, economic growth, and carbon footprint reduction.[116] By encouraging private sector involvement, the initiative prioritises carbon intensity rather than net-zero emissions. This offers diverse frameworks for hydrogen production and carbon capture acknowledging existing industries' challenges. This approach fosters resilience in the energy sector by promoting innovation and reducing dependency on traditional methods. The US is working to position itself as a global leader in clean energy through significant private investment in the initiative's success, emphasising the effective partnership between public and private sectors in advancing sustainable energy solutions.

Overall, the UK is falling behind both in terms of operation and the development of low-carbon hydrogen. Hydrogen UK and ENA developed a Hydrogen Progress Index to compare relative market attractiveness. After the launch of the UK National Hydrogen Strategy, the index ranked the UK as 2nd, behind South Korea. As of summer 2023, the UK had shifted down 6 places to 8th and Germany had taken the leading position.[117] The Index report notes the following:

- Japan was the first country to publish a national strategy for hydrogen, opting for a target production output and payback period for fuel cells, setting out the ambition to be the first country in the world to realise a hydrogen-based society. South Korea followed this with their Hydrogen Act, including the creation of a 'Hydrogen Economy Council' and financial measures such as subsidies, loans and tax exemptions.

The UK increased 2030 target production capacity from 5GW to 10GW, evenly splitting between CCUS-enabled and electrolytic production. However, according to the analysis carried out by Hydrogen UK and ENA, since then other countries have released more detailed and ambitious strategies to lay out measures to accelerate uptake of hydrogen. For example, The USA is to produce 50 Mtpa of clean hydrogen by 2050, with interim targets of 10 Mtpa by 2030 and 20 Mtpa by 2040.

- Aside from domestic production, Japan and Germany were early recognisers that imports would be required to meet consumption targets, resulting in strategies and alliances. Countries such as Chile and Australia are well placed to be partners as the availability of renewable energy overtakes domestic energy consumption. As of August, 2023 the UK had not made progress in this area.

- A notable funding mechanism is that of the USA's Inflation Reduction Act (IRA), which is seen to be more certain and simpler than the UK's approach. It promises developers a fixed subsidy per kilogram of low-carbon hydrogen produced, which is uncapped.

- The USA, China, Germany and Netherlands have moved ahead on the Index regarding storage as a result of superior strategies or deployment. The German National Hydrogen Council is a non-partisan advisory board. It produced the 'Hydrogen storage roadmap 2030 for Germany' which details demand, timelines, costs along with measures to be implemented before 2024. Additionally, The Netherlands published plans to have four salt caverns operational by 2030.

- In terms of transportation, The Netherlands and the USA are leaders in pipeline development, with 1,000km and 2500km of dedicated pipelines, respectively. Further, the H2Med pipeline is aiming to connect Spain, Portugal, France and Germany and the SoutH2 scheme wishes to link Africa to Germany through Italy. Further afield, China's National Energy Administration has made plans for a 400km hydrogen pipeline.

- The Netherlands launched the world's first five live trials for hydrogen heated homes in December 2022. In contrast to the UK, other countries have expressed a clearer statement on the role that hydrogen should play in their domestic power generation mix. Many Asian and European countries have detailed strategies with stated targets for HRS and vehicle deployment. The recently approved EU AFIR regulation mandates the construction of one HRS every 200 km on the TEN-T core network by the end of 2030, as well as one HRS in every urban node. Importantly, the stations will be accessible to all modes of road transport, not just heavy goods vehicles.

- Spain is ranked to have the most mature hydrogen carbon intensity standard, which is in use for funding eligibility and guarantees of origin certificates.

Green Hydrogen Industrial Clusters (GHICs) are clusters of industrial entities that share green hydrogen and renewable energy. Benefits of the clusters include reducing greenhouse gas emissions, encouraging investment, local employment, fostering socially and environmentally sustainable economic growth.The United Nations' Industrial Development Organisation (UNIDO) highlighted GreenLab in Skive, Denmark as a best practice example of a GHIC.[118] It is a green and circular industrial park which generates sustainable energy for supply to the local businesses, becoming a commercially successful concept.[119] UNIDO concludes that the development of green industrial clusters are crucial to accelerate industrial decarbonisation.[120]

More recently, on the 23rd November, the EU Hydrogen Bank opened a pilot auction awarding €800m to renewable hydrogen producers designed to reduce the cost gap between renewable and fossil hydrogen and de-risk European hydrogen projects.[121]

The challenge for the UK government is how to demonstrate similar long term commitments to a stable hydrogen strategy with the necessary investment to match a long term plan for investment in hydrogen for industrial decarbonisation. If the UK government does not continue to implement sufficient measures, it may fall behind as an attractive location for industry and innovation and weaken the country's energy security and opportunities for clean job creation.

PROGRESS IN ELECTRIFICATION

According to Mckinsey & Company's analysis, in 2020 it was already technologically possible to electrify up to half of the global industrial fuel consumption. The most innovative industrial heat pumps supply hot water and steam up to 200°C. For example, Heaten's HeatBooster replaces traditional fossil fuel boiler systems and enables the circulation of waste heat to further save energy.[122] The European Heat Pump Association stated "despite their widely recognised potential, there are several technical, economic and regulatory barriers preventing them from being deployed on a large scale."[123] IRENA summarised progress in electrification, including the current situation with heat pumps, Figure 10 shows that a rapid acceleration of heat pump adoption is needed to reach Paris Agreement targets.[124]

Other academic research indicated that in 2020 78% of industrial energy demand was electrifiable through already established technologies, and 99% electrification could be achieved through using technologies under development.[125] The substitution of fired systems with electric technologies improves efficiency, decreasing the final energy input by up to 20%, if the maximum potential of industry electrification is reached. This would require commercialisation of technologies in development. At the time of the analysis, technology for electrification of processes in heavy industry, such as melting in glass furnaces, reheating of slab in hot strip mills, and calcination of limestone for cement production was still in the research or pilot phase.[126]

In the iron and steel industry, ore electrolysis offers an electric route. Pilot projects at Siderwin, France, and Boston Metal in the USA are expected to lead commercial plant deployment around 2030.[127] SIDERWIN is led by ArcelorMittal and funded by a grant under Horizon 2020's Development of new methodologies for industrial CO2-free steel production by electrowinning for industrial leadership. Its aim is to create an economically feasible steelmaking technology which meets the EU's climate and energy targets for 2030.[128] Boston Metal has created an electrolysis process eliminating the need for coal in steel production, its molten oxide electrolysis (MOE)

Figure 10. Global progress in electrification

	Recent years	2030	2050
Heat pumps in industry (in millions)	<1 [8]	35	80
Heat pumps in buildings (in millions)	58 [9]	447	793
Investment needed in heat pumps (USD billion/year)	64 [10]	237	230

technology is a direct and scalable solution for green steel. Compared to traditional methods that require billions of dollars in capital expenditures, the MOE process requires expenditures in the millions as it eliminates the need for coke production, iron ore processing, blast furnace reduction, and basic oxygen furnace refinement. It is currently in the phase of semi-industrial validation of the MOE cell for steel production.[129] It received $20 million in institutional funding from the World Bank's International Finance Corporation, as well as from various corporate venture funds and Microsoft's Climate Innovation Fund.[130]

PROGRESS IN EFFICIENCY

The Industrial Decarbonisation Accelerator states "the easiest and cheapest clean energy solution lies in the energy we don't use", with immediate reductions in energy use reaching up to 15% through energy efficient technology and management practices.[131] With more robust efficiency policies global emissions cuts could reach 40%, without new technology.[132]

In 2022, several countries announced policies and support for energy efficiency in industry. The EU's RePowerEU Plan lays out joint action on renewable energy and energy efficiency. It increased the EU's 2030 binding energy savings target from 9% to 13%.[133]

Specific examples include the Romanian Ministry of Economy launching a state aid scheme totalling €62 million to support investments in modernisation and energy efficiency. Switzerland's ProKilowatt programme provides state subsidies to electricity saving technologies.[134]

The Government of Alberta's $131-million Industrial Energy Efficiency and CCUS Grant Program supports industrial emitters to reduce emissions, increase competitiveness and improve energy efficiency.[135] So far, seven projects have been awarded funding, including three cogeneration projects, also known as combined heat and power (CHP). CHP is a cost-effective and energy-efficiency solution for delivering electricity and heat,[136] however it is relatively under-prioritised in industrial decarbonisation pathways.

The U.S Office of Energy Efficiency and Renewable Energy has a dedicated office for Industrial Efficiency and Decarbonisation. Its Joint Technology Commercialisation Fund Lab Call has made $6.2 million available for technologies including thermal energy storage and waste recovery and advanced heat pump components.[137]

PROGRESS IN DIGITALISATION

There are already examples of countries advancing in the application of digital tools for the benefit of their industrial sector, mainly from efficiency improvements and cost-saving benefits.

Aker Carbon Capture has reduced the cost for a 100,000 tonne per year plant by 90% since the first test centre in 2012 through modularisation, standardisation and digitalisation. These will also be components in enabling Aker Carbon Capture to reduce their price by up to 50% compared to reference CCUS projects. It has engaged with digitalisation companies to create a digital architecture for harvesting data to be used in a digital twin.[138] It utilises AVEVA E3D Design, which "enables powerful visualisation, clash-free, multi-discipline 3D design, and rapidly generates accurate drawings and reports to reduce costs, timescales and commercial risks of both greenfield and brownfield capital projects."[139]

Digital twins are also a quickly emerging tool for replicating industrial processes which allows for optimisation through design. These tools also enable proof that decarbonisation is occurring, which reassures investment communities.

The Federal Government of Germany is maintaining its leadership in "Industry 4.0" to achieve higher productivity and sustainable competitiveness. Plattform Industrie 4.0 is a network focusing on shaping the digital transformation in manufacturing, backed by Germany's Federal Ministries for Economic Affairs and Climate Action and of Education and Research.[140] The Industrial Digital Twin Association is part of this platform and utilises its Asset Administration Shell (AAS) to make digital twin technology accessible to every company and sets industry standards.[141]

The Power Network Report will address grid technologies in further detail, however it is important to mention that smart grid technologies are an important cog in improving efficiency for industrial manufacturers. Smart grids leverage digital solutions to optimise energy distribution, integrate renewable sources and manage electricity demand, leading to a reduction in emissions. Germany has outlayed digitalisation of distribution grids as a main priority of the German Federal Network Agency in its plans to expand the electricity grid.[142] The USA Department for Energy announced $38 million in funding for advancing R&D through the Grid Modernisation Initiative lab call.[143]

Concerning the barriers data security may impose on digitalisation of industry, the USA Department for Energy's 2022 budget included a $201mn request for the Office of Cybersecurity, Energy Security and Emergency Response's risk management, entailing advancing policies, technologies and initiatives to increase the visibility of physical and cyber threats in the operational technology environment.[144] On the 28th June, the European Parliament and the Council of the EU reached a political agreement on the European Data Act that was proposed by the Commission in February 2022. According to the Commission, "the Data Act aims to boost the EU's data economy by unlocking industrial data, optimising its accessibility and use, and fostering a competitive and reliable European cloud market." The Act includes the following relating to Industry:[145]

- Measures that enable users of connected devices to access the data generated by these devices and by services related to these devices.
- Measures to provide protection from unfair contractual terms that are unilaterally imposed.
- New rules that grant customers the freedom to switch between various cloud data-processing service providers.
- Measures to promote the development of interoperability standards for data-sharing and data processing, in line with the EU Standardisation Strategy.

Chapter Two

THE INDUSTRIAL DECARBONISATION LANDSCAPE

Industry is the most expensive sector to decarbonise.[146] According to a recent report Mace and the University of Chester, approximately £515 billion of capital expenditure will be required by 2050. This includes £286 billion for dispersed sites outside the industrial clusters.[147] Besides the financial cost, it is also a complex landscape to navigate as the different industries such as cement, iron and steel, paper encompass their own challenges.

SWIC identified 7 enablers for industrial decarbonisation:[148]

- Resourcing, skills, and supply chain requirements
- Circular economy principles and carbon accounting
- Generation of clean energy and infrastructure
- Research and innovation
- Legal and planning
- Investment requirements
- Stakeholder engagement

Additionally, broad themes of policy drivers identified by SWIC to ensure these enablers are successful include:

- Internationally competitive energy and carbon policies and support mechanisms
- Business model support for electrification and CCU
- Collaboration

However, achieving industrial decarbonisation is a multi-faceted issue. An industry heavily focused on decarbonisation strategies is iron and steel. The iron and steel industry makes up 14% of industrial emissions in the UK, thus significantly reducing its emissions is required if the UK is to meet its net zero targets.[149] The OECD states that decarbonisation in the steel industry brings challenges which are likely to reshape the industry, such as scaling-up innovative technologies, investments, competitiveness, ensuring a global playing field and markets for near-zero emission steel.[150] These challenges also relate to other EIIs, especially those particular to the UK are addressed in this chapter.

LACK OF A CLEAR VISION AND COORDINATION FOR UK INDUSTRIAL DECARBONISATION

Industry remains the UK's third highest-emitting sector. There has been progress in reducing its industrial emissions, which fell by 17% from 2014 to 2022, an average reduction of 2% each year. Last year, industrial emissions fell by 3% in 2022 to 63 MtCO2e.[151] Yet the government has committed to going further, faster, such as in the CBDP that targets a reduction in industrial emissions of 69% by 2035, relative to 2022 levels. This requires industrial emissions to fall by an annual average of 8% between 2022 and 2030. The need for a co-ordinated, long term, industrial emissions reduction plan is therefore essential if we are to deliver on our NDC commitments.

Yet within this overall decline, there are a number of stagnant areas of industrial emissions that have seen negligible progress, or have even witnessed a worsening situation. As the CCC's 2023 Progress Report sets out:

Emissions from industrial processes – those arising from a range of chemical reactions, such as from the calcination of limestone for cement, rather than combustion – increased slightly in 2022 to 10.2 MtCO2e. Process emissions have been stable for the past 10 years and will need to start falling rapidly to meet emission reduction targets. In the CCC Balanced Pathway process emissions fall by an average of 9% each year between 2023 and 2037.[152]

Progress in low-carbon fuel switching is limited, with the percentage of electricity use in industry decreasing to 24% in 2021 while the percentage of bioenergy use has stalled at 13% since 2020. Industrial electricity use

and hydrogen uptake need to accelerate … Despite electricity use increasing 2% between 2020 and 2021, to 85 TWh, this increase has been outpaced by increases in fossil fuel use. Industrial use of natural gas increased 10% and the use of petroleum increased 3%.[153]

The CCC have also found that, with insufficient progress, there are 'significant risks to decarbonisation of industry. "There are 'insufficient plans' for most of the abatement projected in the CBDP for the Fifth and Sixth Carbon Budgets. The risk is higher than in last year's assessment due largely to a continuing lack of progress in the major areas we have previously highlighted."[154] In particular, the CCC note there is a "need for greater action to support electrification has become even more critical now the Government has made clear it expects the steel sector to decarbonise through electrification" and "there is still no clear plan to support industrial electrification and little evidence that industry is preparing to electrify at scale. The lack of policy is particularly evident in the steel sector … Barriers include the price of electricity, cost and difficulty of upgrading network connections and, for some industries, uncertainty about the most appropriate fuel switching technologies."[155] Overall, "the pace of industrial decarbonisation will need to speed up in the next decade to meet the Government's ambition for this sector."[156]

The UK has framed its initial industrial decarbonisation approach around a focus on its industrial clusters. As the CCC note, this means the CBDP relies less on energy and resource efficiency and more on carbon capture and storage (CCS). Over the Sixth Carbon Budget period (2033- 2037), the CBDP sees an annual average abatement in industry of 6.6 MtCO2e from CCS, compared to 5.3 MtCO2e in the CCC pathway.[157]

The Government also announced up to £20 billion of largely new funding to support deployment of CCUS over the next 20 years. This will help to deliver the Government's targets of 6 MtCO2e of industrial CCS annually by 2030 and 9 MtCO2e by 2035. Yet as the CCC notes, "despite this progress, there remain some risks to delivering these solutions at the scale and speed required. There is also still no clear plan for incentivising CCS and hydrogen outside the 'Track 1' and 'Track 2' clusters."[158]

Moreover, the Industrial Decarbonisation Challenge (IDC) is contributing to the UK's drive for clean growth by supporting the UK's six largest industrial clusters in their mission to decarbonise at scale. Together, the IDC and UK industrial partners will lay the foundation for developing at least one low-carbon industrial cluster by 2030 and the world's first net-zero industrial cluster by 2040. The challenge provides up to £210 million, matched by £261 million from industry, to invest in developing technologies such as carbon capture and storage and hydrogen fuel switching. The technologies will be deployed and scaled up within the UK's largest industrial clusters.

The clusters secure 1.5 million jobs and annually export goods and services worth £320 billion. But they also release around 40 million tonnes of carbon dioxide per year, equating to one third of all business and industrial emissions. Funding from the challenge is split into three workstreams:[159]

- Deployment
- Cluster plans
- Industrial Decarbonisation Research and Innovation Centre (IDRIC).

Additionally, strong collaborative networks, especially those between industry and academia, drive breakthrough research and technologies. They also support the retention and development of research staff that insert knowledge into policy development. This is exemplified by IDRIC, who have generated momentum in the UK's industrial decarbonisation over the past two and a

half years, through an extensive research portfolio and large stakeholder network. The deployment, cluster plans and IDRIC workstreams operate on a collaborative basis through knowledge sharing, industry engagement and collective leadership. The deployment projects aim to provide detailed designs and demonstration of industry-scale technologies and shared infrastructure for the cost-effective deep decarbonisation of industrial clusters.The cluster plan projects provide plans and feasibility studies for net zero industrial clusters.[160] The funding for the IDC and IDRIC, however, ends in 2024. It is essential that this work now develops and moves into an implementation and delivery phase, as well as now expanding its focus to wider industrial decarbonisation and electrification beyond the clusters.

Beyond the lack of progress highlighted in the CCC Progress Report, the Network exuded a general feeling that the lack of a clear vision from the UK government acts as a deterrence for investors in technologies needed for decarbonisation. The split responsibility between different governmental departments, such as the Department for Energy Security and Net Zero and DEFRA, adds to this sense of confusion. Specifically, one of the Network members, SSE Thermal, shared the need for greater pace and scale of deployment of firm low-carbon power during the late 2020s and 2030s, in order to meet Government's power sector ambitions. The Public Accounts Committee Report Support for innovation to deliver net zero, published on the 15th of November also found that the lack of central coordination on net zero innovation in Government is resulting in a lack of oversight and transparency in the transition.[161] SWIC's carbon emission projections depict territorial emissions, shown in Figure 11, based on the current policy trajectory that represents de-industrialisation, de-growth and offshoring emissions, compared to policies which align with investment in a responsible and prosperous region.[162]

Figure 11. SWIC's Emission Projections

This graph represents the total SWIC regional emissions. It does not represent emissions of individual companies. Some companies may not be able to achieve net zero alone but will rely on others within the region to offset, resulting in a net zero overall position.

Due to this lack in vision, there is also uncertainty around funding available now and what will be available in the future. IDRIC is focused on research and innovation to develop implementable and scalable solutions in the UK's industrial heartlands. They provided extensive evidence to the report, stating that "the lack of certainty for research and innovation funding beyond 2024 poses a challenge for developing some of the critical technologies for industrial decarbonisation, which will require considerable public and private investment at various stages of development over the next decades. Short-termism is detrimental for maintaining and nurturing the research ecosystem and collaborations needed to deliver cutting-edge research and innovation. Short project funding cycles make it difficult to maintain the institutional capacity and human capital needed to deliver cutting-edge research."

This is a stark contrast to the USA messaging, as highlighted by REA's Dr Nina Skorupska CBE in the evidence sessions, where companies are receiving clear signals that the government wants to flow a large amount of expenditure into projects focusing on decarbonisation. This is backed by the Public Accounts Committee Report Support for innovation to deliver net zero, which discerned that businesses are finding sources of public sector funding for such technologies to be inaccessible and difficult to navigate.[163]

IDRIC also put forward that "energy-intensive industry sectors trade globally and face stiff competition from producers in countries with less-stringent climate regulation, with a risk of 'carbon leakage'. Increasingly, competition also arises from countries with more generous subsidies for green technologies. While the latter is a positive signal for global climate change mitigation overall, a failure to adequately support industrial decarbonisation in the UK may create the additional 'investment leakage' risks, where critical investments in low carbon technology are being redirected away from the UK." This was further emphasised by Richard Folland, Carbon Tracker's Policy and Government Affairs Adviser, the clarity and commitment provided by the EU gives clearer signals to investors, in contrast to the UK's recent retraction of green policies. There are mixed communications around whose responsibility it is to decarbonise industry, is it down to industry or government to lead the way?

Demand-side measures will be important to create a market for low carbon products, such as product standards and green public procurement. Since the publishing of the summary of responses to the call for evidence for a market for low emissions industrial products the government's stance on this has stalled, despite calls for mandatory product standards to strengthen the UK's net zero position.[164]

Sophie Miremadi from AVEVA described industrial decarbonisation and the energy transition as a "system of systems challenge", requiring a policy framework that seeks to coordinate the changes required not just horizontally along industrial value chains, but also looks out over the medium term to anticipate the investment time frames that are required. Russ Hall from HMVC told the network "it needs to be centrally coordinated, approached as a system with the right energy vector used in the right place, otherwise you end up with technologies in competition with each other."

THE ROLE OF CCUS AND HYDROGEN

As noted by Roy Calder, Industry Principal for New Energies at AVEVA, the technologies for CCUS and hydrogen are established. However, pathways to scale their use and make them commercially viable are still a long way to fruition. HyNet is an example of leading cluster sequencing, although it is yet to abate a single

ton of carbon dioxide, according to David Parkin, Project Director for HyNet North West. The barriers in place are discussed throughout this section.

WHAT IS THE GOVERNMENT'S VISION FOR CCUS AND HYDROGEN?

Effort should be directed towards ensuring CCUS and hydrogen are not only an environmental case, but a business and societal case. Currently, evidence of this is lacking.

The UK does not account for any of the global operational capture capacity in 2022 and currently does not have capture capacity over 100,000 Mt per year planned for the iron and steel industry, and just 0.8Mt CO2 per year for cement, whilst planned capacity for hydrogen/ ammonia accounts for a large proportion at 18.3Mt C02 per year. However, none of this planned capacity is under construction. The earliest operations to commence will be Acorn CCS and Future Biogas plants in 2024. Over a quarter of the planned projects do not have confirmed dates for the final investment decision (FID), as opposed to all planned projects in European countries which all have FID dates.[165] Reasons for these delays include outstanding issues with business models, for example the T&S Regulatory Investment (TRI), Dispatchable Power Agreement (DPA), Industrial Carbon Capture (ICC), and Low Carbon Hydrogen Agreement (LCHA). The absence of clear government targets and pathways to revenue these support contracts was also cited as a key barrier by SSE Thermal for their sector to decarbonise in the next five years. For example, the previously mentioned Keadby Carbon Capture Power Station shows great potential for job creation, however it currently lacks a Dispatchable Power Agreement.

The industrial demand for CCS and hydrogen exceeds that expected from the Track 1 and 2 projects currently in development. The HyNet system Track 1 enables 2.7 million tonnes, the expansion will increase that to 4.5 million. Overall, it is designed now for 10 million tons a year of CCS, however the regional demand is 17 million tons. Members of the Network raised concern that without certainty from the government, specifically from clear and specific targets and allocation of contracts, investment in decarbonisation will stall, especially compared to international progress. In the delivery plan update, the CCSA also highlight that around a third of businesses looking to deploy CCUS (including in hydrogen, sustainable aviation fuel production, and GGRs) are considering locating overseas due to being unsuccessful in receiving CCUS support.[166] David Parkin, Project Director of HyNet North West, shared that "understanding what track one expansion is, what track two is - when they're going to happen, how they're going to be funded - is really important to unlock that next stage of development funding." Additionally, SSE Thermal voiced that as a result of the lack of certainty, projects are being developed at a high risk, making it difficult to release development expenditure (DEVEX) and creating competition for DEVEX with technologies where there is a clearer line of sight to deployment and revenue security. The Industrial Decarbonisation Challenge awarded £210 million to the UK's six largest clusters, supporting the development of the roadmaps.[167] However, as mentioned, funding for beyond 2024 is yet to be confirmed.

Chris WIilliams from South Wales Industrial Cluster (SWIC) succinctly stated, "Not knowing is costing our industries today. For example, in the SWIC CO2 shipping has the potential to unlock a momentum of change and increase competitiveness with European partners. However, without a clear timeframe for when it will be initiated, it prevents industries from making commitments, therefore slowing down the decarbonisation process and resulting in a shift of this potential net zero investment to other countries." SSE Thermal also raised that the lack of firm project

pipelines creates challenges for Original Equipment Manufacturers (OEMs) to invest in manufacturing capability.

Carbon Clean places a top challenge for the market as the need for a clear deployment plan for CCUS and permitting regulations that reflect the urgency of the need to roll out clean technologies. Similarly, IDRIC found that two major challenges involved in planning and permitting for industrial decarbonisation are that policy and regulatory frameworks are not yet reflecting the scale and urgency of net zero and struggling to keep up with technological innovation, and, more generally, there is a fragmentation between and within planning and permitting regulation, creating complex and frequently incoherent assessment criteria, procedures and timelines. They discerned that there was a widespread consensus among stakeholders that early engagement and consistent stakeholder input through the pre-application phase is important to identify and resolve issues and, where needed, design appropriate mitigation measures. However, in practice, early engagement faces multiple challenges, indicating the need for the development of mechanisms for better coordination of these processes. Given the devolved nature of planning, navigating different regulatory regimes can pose particular challenges for developers of projects that cross borders and planning jurisdictions. Fragmentation also exists between regulatory regimes within a single jurisdiction, for example around separate consenting procedures for large scale and complex infrastructure projects. Net zero will require both onshore and offshore developments which introduces further complexity due to the involvement of several regulating bodies with often unclear boundaries between onshore and offshore.

This is echoed by SSE Thermal who cited the importance of coordinated expansion of the supply chain, saying "it is clear that delivery of infrastructure across multiple sectors and technologies will be needed to meet the Sixth Carbon Budget and net zero. There will be considerable competition for skilled labour, products, and raw materials between these sectors/ technologies and the supply chain will take time to adapt and expand to meet these demands."

Finally, a resounding message from the network is the need for hydrogen and CCUS to be combined into the wider decarbonisation value chain. For example, IDRIC stated clarity is also still needed on how emerging CCUS and hydrogen deployment will be integrated into wider regional and national energy system planning.

BUSINESS MODELS

The UK currently has 12 operational hydrogen production projects, all of which use water electrolysis technologies. However, the end-use sectors using the hydrogen produced are mobility, power, grid injection, domestic heat and combined heat and power. Only three projects are commissioned for end-use in iron and steel, two are currently in the feasibility study stage. 24 projects refer to 'other industry' as one of their end-use sectors. The majority are in the feasibility study phase, and 7 are non-green hydrogen products.[168] David Parkin, Project Director of HyNet North West, expressed to the Network that as the hydrogen business models are not planned to be finalised by 2025, this prevents investment and, therefore, blocks development. As a result, a hydrogen system will not be operational in the UK until 2030 or 2031. In the case of HyNet, it would mean it took 15 years to actualise the concept, "a speed which is not acceptable if the UK government is to reach its net zero targets."

The biggest challenge lies in the development phase, especially for pipelines. Business models do not guarantee a return on investments made before the final investment decision. In addition to this, these business models are only accessible to projects selected via

a Government-run competition. If CCUS and hydrogen deployment is going to reach the required scale, there needs to be a model which enables more projects to successfully come forward, rather than requiring a complex, expensive and at-risk application process.

TRANSPORT AND STORAGE

Lack of access to transport and storage infrastructure is also a critical reason for businesses looking to deploy CCUS are relocating overseas, according to the CCSA Delivery Plan Update 2023.[169] SSE Thermal also raised transport network deployment as a challenge for the energy sector to decarbonise. Specific challenges they raised are:

- CO2 pipeline networks need to be planned from the outset with expansion capacity baked-in, to enable rapid expansion of the CCUS sector in the 2020s and 2030s.
- Local 100% hydrogen transport networks should be established in key clusters and supporting regulations/ market frameworks should be put in place
- Frameworks for national hydrogen transmission networks should be established and first stages of infrastructure deployed rapidly, to enable connectivity of key clusters and build resilience of H2 supply
- Hydrogen storage infrastructure should be brought forward as this will play a key role in balancing supply and demand, enabling greater use of renewable (green) hydrogen
- Build out of transport and storage infrastructure, backed by business models, to support a hydrogen economy, provide market liquidity and fuel security
- Large scale storage is likely to need a seven-year development/construction programme to commercial operation

In addition to this, non-pipeline CO2 transport (NPT) business models are yet to be defined but will be crucial for dispersed sites and CO2 utilisation. In their 2023 Delivery plan update, the CCSA highlight that around a third of sites planning to retrofit carbon capture will require NPT, and almost half of the transport & storage capacity will utilise NPT.[170] There is currently no substantial plan for how these sites will be able to deploy carbon capture technology and connect to a CO2 transport network.

CARBON PRICING

The future of industrial decarbonisation relies on decarbonisation itself having not merely an environmental but an economic purpose, creating market based incentives for companies to reduce their emissions. In an international market with global supply chains, this requires providing certainty and support for UK companies to operate globally. The Net Zero Review stated that “any development of the UK ETS carbon pricing regime should consider the risk of carbon leakage and ensure that sufficient mitigation measures are in place.”[171]

Carbon pricing is an important policy tool that helps to drive decarbonisation. The UK Emissions Trading Scheme (ETS) is the UK’s principal mechanism putting a price on carbon and functions as a cap-and-trade system where Government sets an emissions cap and issues emissions allowances consistent with the cap. These emissions allowances can be bought and traded between participants. The purpose of ETS is to create economic incentives for businesses to proactively reduce greenhouse gas emissions and shift towards cleaner technologies.The UK ETS Authority established the UK Emissions Trading Scheme (UK ETS) to replace the EU ETS on 1st January 2021.Its purpose is to increase the climate ambition of the UK’s carbon pricing policy and simultaneously protect the competitiveness of UK businesses. The UK ETS currently covers power, heavy industry, and some of the aviation sector.[172] For firms covered by the ETS, the

carbon price informs decisions by individual businesses about whether it is more cost-effective to invest in decarbonising or to pay to continue emitting. It provides a long-term price signal that, when supported by complementary mechanisms, can deliver a stable investment case for decarbonisation, reduced fossil fuel consumption and optimised energy efficiency, and an incentive to develop the low-emission technologies needed to enable a thriving net zero economy.

Participants receive free allowances, which they can add to by buying from other participants. The Government recognised the cost effectiveness of carbon pricing in delivering decarbonisation in the 2021 Net Zero Review published by HM Treasury, and the UK ETS and the compliance carbon market remains central to achieving Net Zero by 2050.[173] The cap will be reduced over time; in 2022 the total number of allowances available for auction was 81 million, in 2023 79 million and in 2024 just under 69 million will be auctioned, with the implementation of the net zero consistent cap.[174] With the cap on total emissions set to decrease over time, this provides a clear signal to businesses to invest in decarbonisation as the cost of ETS allowances is likely to increase as the cap is reduced. The current legislated ETS cap only runs until 2030, and, as the CCC emphasised in its advice on the Sixth Carbon Budget in December 2020, it is not aligned to delivering net zero by 2050.[175]

The effectiveness of the system has been called into question. According to Dr Nina Skorupska CBE, Chief Executive of the REA, the UK ETS is not well leveraged across industry due to political factors, such as international competitiveness. The World Bank's 2023 Report on the State and Trends of Carbon Pricing shows that the UK's carbon price is within the 2030 Carbon price corridor, however the ETS scheme only covers 20%-40% of the UK's emissions.[176] On top of this, in October 2023 the UK's carbon price dropped to £36 per t/CO2e, which was less than half of the EU's level. Reasons include an oversupply of credits, which lowers incentives to reduce emissions.[177] This is not sustainable and is threatening investment in the needed modernisation of equipment to decarbonise industry. In the evidence collected SSE Thermal stated "the challenges for the ETS are related to its size, which means it is illiquid and volatile." Moreover, a representative from Carbon Tracker highlighted that the EU ETS has reached a robust price due to reaching a balanced supply and demand level, which the UK lacks. This is again partially a result of weak signals of a broader decarbonisation strategy. Stakeholders in the UK believe a low carbon price and uncertainty for carbon markets have so far limited the scheme's potential impact on promoting decarbonisation. Further, SSE Thermal suggested ETS is not a silver bullet, "the ETS is a suitable mechanism for pricing carbon for electricity and industrial sectors but to support investment decisions, Industry needs complementary support mechanisms, like the CfD in the electricity system."

Relating to these issues, HM Treasury acknowledged in the 2021 Net Zero Review that widespread carbon pricing can apply a consistent incentive across all sectors of the economy, allowing the private sector to decide how to decarbonise most efficiently across sectors, and to do it at minimal cost.[178] By 2030, the current sectors covered by the UK ETS will only cover 18% of UK territorial emissions while sectors such as agriculture and international aviation and shipping will continue to increase their share of the UK's emissions towards 2050 as other sectors decarbonise.[179] This highlights the need to expand the scope of the UK ETS in order to ensure a meaningful carbon market of sufficient magnitude and further encourage other sectors to decarbonise.

Additionally, the World Bank's report shows that the revenue generated through ETS is placed into the general budget. Research by the New Economics Foundation suggested that the net zero spending commitments made in

the 2021 Spending Review shows the increase in the government's outlay on climate action is equivalent to around 20% of the estimated rise in revenue generated by the UK ETS.[180]

The inquiry into carbon border adjustment mechanisms closed on October 25th 2021 and the government further "published an exploratory consultation considering a range of potential policy measures to mitigate carbon leakage risk in the future and ensure UK industry has the optimal policy environment to decarbonise" from 30th March 2023 to 22nd June 2023.[181] The government is yet to release a response, however a survey of UK manufacturers carried out by Stack and E3G found that businesses overwhelmingly support the UK government introducing a carbon border tax. Half of the respondents expect a CBAM to improve competitiveness and allow for them to equalise with high-polluting importers, with the knock-on effect of incentivising sourcing primary materials in the UK. Additionally, the majority were in favour of coordinating the UK's CBAM and ETS with the EU's, as to minimise trade friction.[182]

MOVING AWAY FROM FOSSIL FUELS

Although electrification and on-site generation have been shown to have high potential for decarbonising entry, there are current barriers which are holding its development back. If current technologies do not offer a large efficiency gain, there must be an incentive through cost savings, or inversely through high carbon prices.[183] The Network identified challenges such as gaps in support for business models for industrial electrification, infrastructure challenges and uncompetitive electricity prices, partially due to marginal cost pricing.[184]

LACK OF SUPPORT FOR ELECTRIFICATION

IDRIC's Policy Roundtable identified key challenges for industrial electrification, including the need to establish new and upgrade existing grid connections to support step-change increases in demand and the technical challenges associated with electrifying many high-temperature processes and the logistical and capital cost of replacing and retrofitting equipment to make use of electricity.[185]

Additionally, its stakeholder engagement raised concerns that CAPEX support for electrification is currently limited and not on par with support provided for other decarbonisation routes, for example for CCUS, where business models include CAPEX loans.

Electrification is unlikely to be widely adopted without security of supply that comes with grid expansion and development. IDRIC's conversations with stakeholders highlighted that it is currently unclear how the imbalance between patterns of availability and consumption can be managed if large-scale electrification were to take place. However, the plans to expand grid capacity are currently inadequate, which will be addressed in the Power Network Report. Moreover, electrification currently does not have the same support as CCUS and hydrogen, for example there is not an ongoing development of business models.

Furthermore, as IDRIC noted, CAPEX support for electrification is limited, therefore support is needed for development of electrification technologies in order to build confidence in this decarbonisation route. The consultation on the Future of the Industrial Energy Transformation Fund closed on 21st July 2023, aiming to seek views on the future role of the Industrial Energy Transformation Fund (IETF) and the final design of Phase 3. A summary of findings was expected this Autumn.[186]

Regarding industrial heat pumps, the UK's current heat pump investment roadmap focuses on households and non-

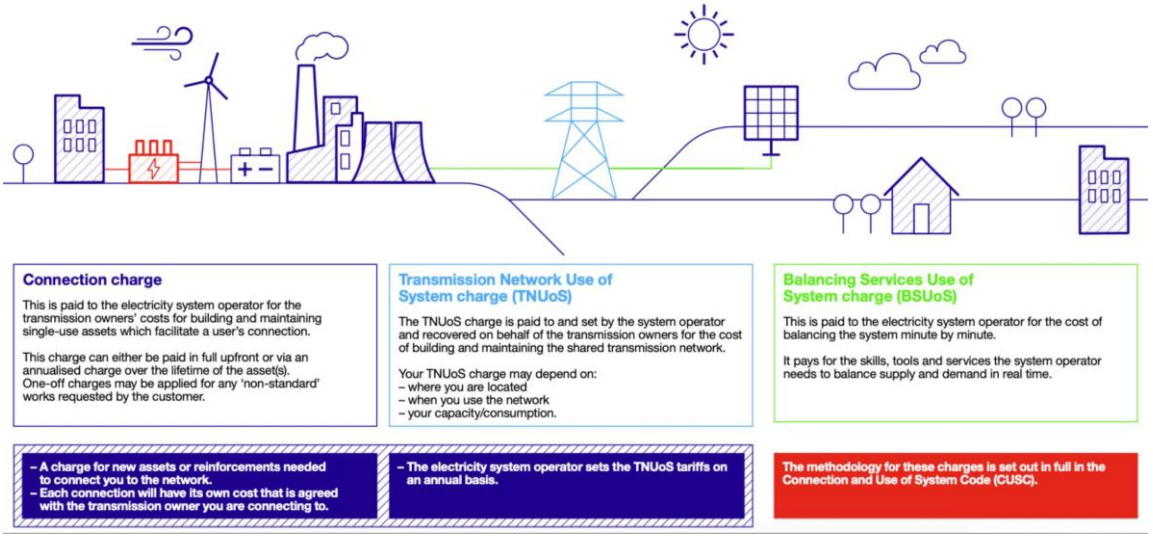


Figure 12. Electricity network charges explained

industrial businesses.[187] Innovate UK has provided £689,000 to FutraHeat to support the development and deployment of Greenstream 360, a 300kW industrial heat pump. The technology recycles low-grade waste heat and increases it by up to 60°C.[188]

ELECTRICITY COSTS

Electricity costs are a central barrier to investment in industrial electrification. The price paid by UK industry is composed of the wholesale price, network charges and policy costs. Despite increasing renewable electricity generation, the price paid for wholesale electricity on the 'spot market', where around two fifths of electricity is thought to be sold, is largely determined by the price of natural gas.[189] Network charges and policy costs make up 95% of the electricity price differential between UK and EU industrial consumers, an overview of network charges is shown in Figure 12.[190] Barriers in place on each component identified by IDRIC's roundtable on barriers to investment in industrial electrification are shown in Table 5.[191]

Table 5. Price components of electricity price paid by UK industry

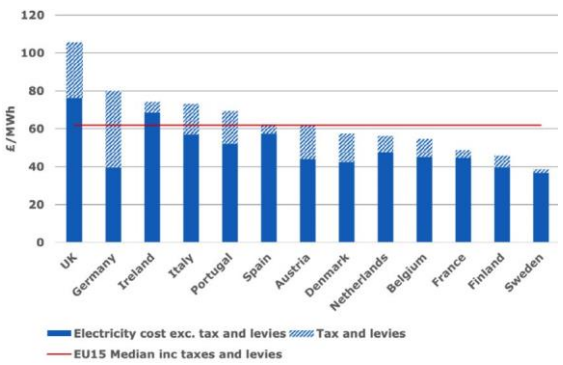
PRICE COMPONENT	DEFINITION	BARRIER
Wholesale price	The wholesale cost of electricity is the price that suppliers have to buy the energy at. They then add a variety of costs (distribution fees etc) before arriving at a price they charge the end customer.[192]	"Despite gas generation making up 40% of electricity production, gas generators usually wholesale electricity prices due to current market design, which sets the wholesale price for all generators at the level of the most expensive producer running."

PRICE COMPONENT	DEFINITION	BARRIER
Network charges	Transmission and distribution charges	"As a consequence of Ofgem's targeted charging reviewreview, network costs faced by industrial consumers currently are significantly higher (£20-30 per MWh) compared to the average of the last 5-6 years (approx. £10 per MWh). Moreover, European competitors generally do not face these costs due to exemptions and government support, particularly those in Germany and France. Participants suggested that Ofgem's historic focus on balancing network charges away from domestic consumers has come at the expense of industrial decarbonisation and competitiveness"
Policy costs	The costs of policies that incentivise the use of renewable generation in the energy system, including Contracts for Difference.[193]	"Similarly, policy costs including renewable levies, taxes and supplier obligations are significant contributors to high UK industrial electricity prices. This includes the Carbon Price Support mechanism, a UK only tax on electricity generation which was added to the carbon price under the EU ETS to drive the move away from coal generation, and which is passed through to industrial consumers through energy bills. A switch which is now largely complete, raising the question of its continued necessity. As with network charges, international competitors are exempt from, or do not face equivalent policy costs. "

The Net Zero Review highlighted the challenges to electrification raised by the Energy Intensive Users' Group and Manufacturers' Climate Change Group "higher energy prices are one of the main challenges and obstacles to industrial decarbonisation…Security of energy supply is an absolute condition to decarbonise. Without security of energy supply, EIIs are unlikely to have confidence to make the investment necessary to reach the net zero target."[194] IDRIC's roundtable found a key challenge to be comparatively high costs of electricity for UK industrial users compared to other countries, including the high electricity prices relative to natural gas prices.[195] An Ofgem report on electricity prices for EIIs found that, on average, EIIs in the UK have faced historically higher electricity prices than other European countries, shown in Figure 13. "Between 2016 and 2020, GB's prices were consistently above the EU median and the most expensive overall. This is the case after excluding any environmental taxes and levies that apply as well."[196] The UK offers relief for some energy intensive businesses; however, the support offered in EU countries is greater, hindering UK EII businesses' international competitiveness.

Further, IDRIC's roundtable found that "due to the price and energy use differentials between gas and electricity, electrifying energy intensive processes (as an alternative to current production methods, e.g. with natural gas) would increase overall energy costs on the order of 3-5x, depending on sector and process efficiency. Moreover, some EIIs are unable to hedge over periods longer than 6 months, which increases their exposure to wholesale energy price volatility. EIIs tend to be low-margin businesses with high energy costs as a proportion of their overall costs, and in which increased production costs as a consequence of fuel switching or electrification cannot easily be passed on to consumers."[197]

Figure 13. Average electricity prices for EIIs in Europe (2016-2020)



ON-SITE GENERATION

Network members from AVEVA and REA highlighted the increase of a shift from industry being energy consumers to prosumers. The REA noted that they see a large number of their members participating with industrial clients who have become prosumers through incorporating on-site renewable energy providers, securing power purchase agreements or fuel switching agreements, as well as taking control. Following the energy crisis, the REA saw a large increase in commercial and industrial sites examining how to install solar battery technology which allows for business success whilst also addressing decarbonisation. On-site renewable energy generation at scale is not without risk and is often not straightforward due to interactions with the grid and fluctuating high demands from industry, industry will require support to de-risk electrification of its processes. Power purchase agreements and fuel-switching agreements are possible but require a degree of knowledge to engage with.

Finally, the delay in electricity grid development is also having a significant impact on not only the renewable energy production capacity, but the demand side of industrial decarbonisation, evidence from IDRIC shows, affecting other decarbonisation options as well as electrification.[198] Grants have been made available in the form of Industrial

Energy Transformation Fund and Public Sector Decarbonisation Scheme, however Dr Nina Skorupska CBE, the Chief Executive of REA, stated that these "remain highly focused and will not support the level of action at the rate that we need to see decarbonisation of industry happen."

EFFICIENCY

During periods of economic uncertainty, a clear business case for going green must be placed on the table. Energy efficiency is one of the first steps an industrial site can take in their industrial decarbonisation journey. The government response to the Net Zero Review lacked a clear plan of unlocking energy efficiency by 2024 beyond the Industrial Energy Efficiency Accelerator. This programme aims to increase the number of technologies available to industry to reduce energy consumption, maximise resource efficiency, and cut carbon emissions.[199] Additionally, the Industrial Energy Transformation Fund announced £315 million of funding in the 2018 Budget available up until 2027 for businesses investing in energy efficiency and low carbon technologies.[200] The Autumn Statement 2022 set the ambition of reducing energy consumption from buildings and industry by 2030. It stated a plan to invest £6.6 billion in energy efficiency.[201] However, current actions show a lack of government urgency to prioritise efficiency as a method of reducing emissions from the start of the value chain.

The indicators for energy efficiency are scarce, those included under the CCC's indicators of progress are energy consumption per tonne of crude steel, energy consumption per tonne of paper and % of industrial firms who report into the energy savings opportunity scheme (ESOS) who have all their sites or energy supplies are covered by ISO 50001.[202]

Dr Nina Skorupska CBE, Chief Executive of the REA, told the Network the Non-domestic Renewable Heat Incentive (NDRHI), launched in 2011 by the Department of Energy and Climate Change (DECC), was a 'ground breaking' support mechanism which provided a "quick-win" for supporting business install renewable heat technologies, such as heat pumps and combined heat and power (CHP) systems. However, since its closure in 2021, there has been no comparable subsidy-based route to market for industries searching to decarbonise.

DIGITALISATION

The potential of digitalisation is only starting to be tapped into. Made Smarter UK is a movement backed by world-renowned manufacturing businesses and the UK government. It primarily helps SME manufacturers on their digital journey, focusing on UK leadership for digitalisation, adoption, innovation and skills.

The recent UK Net Zero Research and Innovation Framework: Delivery Plan, published by DESNZ, has mapped out the estimated £4.2 billion of net zero research and innovation public sector funding to 2025.[203] The National Audits Committee Report finds that whilst this is a step in the right direction, there is "a lack of clarity over who is responsible for overseeing end-to-end progress across the innovation system in the priority areas, what success will look like at key milestones, and what government's risk appetite is in supporting the different priorities within the innovation portfolio." In addition to this, funding routes are complex, making it difficult to track funding and its effectiveness.[204]

Further, valuable data and data analysis is critical. IDRIC highlighted a lack of comprehensive data on industrial production, energy demands, and emissions at national, regional and local levels as a challenge to assess supply and demand scenarios. Insufficient granular emissions data also

inhibits assessing the decarbonisation impact, especially for analysing and comparing emissions reductions and economic benefits of planned projects and clusters. Since 2022, the CCC has called on the Government to review, invest in and reform industrial decarbonisation data collection and reporting.[205]

There is need for closer cross-industries collaboration to optimise new value chains within and outside of clusters to achieve collective, as opposed to individual, decarbonisation goals and a better business case.There is already a large amount of emissions and energy data provided by companies through schemes such as the UK ETS, Streamlined Energy and Carbon Reporting (SECR), and ESOS. This data is collected separately for each scheme, with different requirements and parameters. There is a need to fully understand what data is already being provided by industry and how reporting requirements can be streamlined, and subsequently utilised to monitor and incentivise emissions reduction, without further adding to the administrative burden on companies associated with reporting. AVEVA's New Energies Principal highlighted that where multiple sites with different emission profiles are feeding centralised CCUS facilities a common data structure approach is needed to maintain the economic, process and safety envelopes. IDRIC, alongside the Cross Catapult initiative, are working to develop a pathway to a Unified and Consistent Carbon Accounting Framework (UCF), which is an important step towards accuracy and transparency.[206]

Moreover, ensuring seamless integration between various energy systems and industrial processes is essential. Implementing digital solutions that allow different systems to communicate and work together efficiently is critical for optimising energy consumption and reducing carbon emissions. However, the current data management systems and cybersecurity measures are not equipped or robust enough. These key challenges, amongst others, to digitalising heavy industries were identified by AVEVA's Industry Principal for New Energies, Roy Calder:

- **Complexity of Industrial Processes & Geography:** Industrial processes vary significantly, making it challenging to find standardised digital solutions that can effectively decarbonise each unique process. Tailoring solutions to diverse industries and their specific emissions poses a significant challenge. This issue is exacerbated by the way in which industries with high emissions, for example cement and steel, are geographically spread out in the UK making the ability to move CO2 and store it challenging.

- **Interoperability and Integration:** Many industrial systems and machines were not initially designed to work together or communicate effectively. Integrating various digital solutions into these complex, often legacy, systems pose a significant challenge in achieving a cohesive and efficient decarbonisation strategy.

- **Data Access and Quality:** Access to real-time and historical data is crucial for implementing digital decarbonisation solutions. However, ensuring the availability, quality, and reliability of data from industrial processes can be difficult due to legacy systems, privacy concerns, and different data formats across various platforms. This approach is crucial to build and manage the network structures required to decarbonise industry.

- **Cost and Return on Investment (ROI):** Implementing digital solutions for decarbonisation involves significant investment. Convincing industries to

commit to these expenses, especially when the return on investment might not be immediate or clearly quantifiable, can be a hurdle in adopting these technologies. This also relates to how central and regional governments can drive the business value by offering financial support programs.

- **Regulatory and Policy Frameworks:** The regulatory environment around decarbonisation is evolving. Adapting digital solutions to comply with changing policies and standards while ensuring they remain effective in reducing emissions can be a challenge for industries aiming to decarbonise. Ambiguity or inconsistency in regulations can also hinder progress in implementing digital solutions for decarbonisation in the industrial sector.

Another gap identified by AVEVA's Industry Principal for New Energies, Roy Calder, is that currently in the United Kingdom, the pursuit of decarbonisation faces gaps in operational focus, particularly concerning green hydrogen and carbon intensity certification for processes and products. The challenge lies in robust operation, management, and documentation processes, common across the UK Industrial Landscape. To address this, blockchain is emerging as a key tool, enabling secure virtual networks of data across the supply chain. This technology ensures the traceability and transparency needed for green hydrogen and carbon intensity certification. While utilising the cloud for data storage can enhance security by limiting access points, there is a noticeable reluctance and distrust in fully leveraging cloud capabilities. Overcoming this scepticism is vital to expedite progress.

Disruptive technologies are a core area of the Net Zero Innovation Portfolio, with £4million being committed to funding green AI Initiatives.[207] On 30th October 2023, the Department for Business and Trade published its National Digital Twin Programme (NDTP), intended to grow national capabilities in digital twinning technologies. A core theme of the work is also to create digital twins that are safe, secure, trustworthy and ethical, as well as to enable the exchange of information.[208] Furthermore, digital tools can support the measurement of Scope 2 and 3 emissions in sustainability reporting and carbon accounting. HMVC and Innovate UK are exploring a framework to ensure that manufacturing companies of all sizes are able to measure and report emissions in a consistent form. Scope 3 emissions need specific attention as the current methods and standards are ambiguous, which does not allow for consistent and comparable monitoring. This was further emphasised by Reckitt in the evidence sessions: the Oh Yes! Net Zero campaign is especially helping SMEs in Hull who do not have the right tools to carry out a Scope 3 emissions assessment. This robust measurement approach is needed to help prove that the decarbonisation is occurring across the value chain and provide assurance for the finance community. Again, it is important to note that issues around security may preclude the uptake of digital tools. As such, understanding the barriers of industry is important for supporting adaptation of processes.

An underlying theme is the complexity of digital innovation is a complex landscape, as Dr Nina Skorupska CBE from the REA pointed out, support is needed for industrial actors to understand the standard initial steps to take in order to utilise the plethora of digital offerings. Another challenge arises from ensuring equitable access to digital solutions, especially for smaller and dispersed sites.

DISPERSED SITES

Almost half of UK industrial emissions come from dispersed sites, therefore further action is needed to assess and support

decarbonisation actions for them. The economics of building CCUS and hydrogen infrastructures are likely to be attractive for only the highest emitting sectors and sites, such as cement. However, dispersed sites may often be characterised by SMEs.[209] Furthermore, the CCSA's 2023 Delivery Plan Update states that commercial models for non-pipelines CO2 transport are yet to be defined, however they are essential for dispersed sites and carbon utilisation.[210] Each site requires an assessment of the specific economic and decarbonisation challenges, rendering a model or framework for dispersed sites difficult.

The Local Industrial Decarbonisation Plans competition, run by the DESNZ and Innovate UK, offers £5 million in grant funding to support dispersed industrial clusters not located in existing clusters. It aims to advance place-based plans where collaboration between closely located industrial business and other stakeholders.[211]

JOBS AND SKILLS CREATION

Although industrial decarbonisation is a large opportunity for job creation and skills growth, evidence suggests that the UK's workforce is ill-prepared to grasp it. IDRIC stated that "a shortage of the necessary skilled workforce will also hamper the development of domestic supply chains and discourage inward investment…the need for reskilling is taking place in a wider context of a shortfall of skilled capacity following the UK's exit from the European Union, which is also challenged further by national infrastructure projects that are competing for the same cohort of workers. While there is potential to transfer skill sets from current oil and gas jobs, this sector will continue operation for the immediate future, therefore only part of the net zero workforce can come from such transition sectors."

The new Creed Hydrogen Skills and Innovation Centre "draws together expertise from the public and private sectors, universities and local communities in a ground-breaking collaboration that will deliver the skilled workforce and robust hydrogen technology needed to support the Outer Hebrides ambitions to be Scotland's leading green-hydrogen production hub." It is part of plans to create a world-leading hub for clean energy production in the Western Isles.[212] However, such centres are short in supply in the UK. Recent research into skills shortages for CCUS at Strathclyde University indicate that persistent labour market tightness is a major barrier to progress in decarbonisation and limit to economic benefits of net zero. Current estimates of job creation massively underestimate skill shortages and potential displacement of employment across sectors in tight labour market conditions. For Scotland, predicted sustained job gains in CCUS around the Acorn project could be eroded by up to 70% (in the Scottish CO2 transport and storage case from 3,910 to 1,097 jobs) and GDP gains reduced by around 40%.[213]

Additionally, in a 2022 report for IDRIC by the Energy Institute and CATCH, a large employment gap for the prospective hydrogen sector was highlighted, in particular they noted the need for a significant increase in the number of technicians and engineers to realise the delivery of key infrastructure. Although this will require new skills, predominantly relating to safety and data, it was found that the biggest challenge is the limited base of workers with pre-existing skills in the engineering and construction sectors, as well as competition from other sectors drawing on this base.[214]

IDRIC's policy research and stakeholder engagement also found a lack of awareness and training on net zero and industrial decarbonisation in the public sector, which can delay and stifle decarbonisation activities.

For example, resourcing and skills-constraints of planning authorities and environmental regulators were identified as by far the biggest challenge for timely consenting and permitting processes. They highlighted that as the scale and complexity of required decarbonisation projects increases over the next decade, skills and resourcing bottlenecks will become even more pronounced.

PUBLIC ACCEPTANCE

SSE Thermal highlighted the importance of having a social licence to operate, and bringing communities along on the decarbonisation journey. Additionally, IDRIC observed "evidence of scepticism towards carbon capture and storage and hydrogen among parts of the public highlights the need to secure public consent as a critical prerequisite for the roll-out of key technologies required for tackling emissions in industry". A lack of general education on hydrogen was also voiced as a concern by AVEVA.

Public acceptance is also critically linked to the need for a just transition where costs and benefits of net zero are more equitably spread. This was a clear message from IDRIC's social science research projects which are developing integrated perspectives for industrial decarbonisation activities to be more equitable, inclusive and just in the transition to net-zero.[215] Additionally, the Scottish Government established a 10-year £500 million JTF in 2022 for the North East and Moray to support the regional transition away from carbon-intensive industry. Chapter Three - Future Pathways, Better Solutions for Industrial Decarbonisation.[216]

Chapter Three

FUTURE PATHWAYS, BETTER SOLUTIONS FOR INDUSTRIAL DECARBONISATION

Evidently, CCUS and hydrogen will be fundamental in delivering industrial decarbonisation for industries that are unable to decarbonise through electrification. Yet we cannot afford to wait for these technologies to be fully deployed, important though that may be, given that their potential is unlikely to be realised in the next decade. This chapter seeks to understand how we should ensure that while we deliver a long term programme of investment for hydrogen and CCUS, at the same time, in the near term, we do not leave out our shorter term obligations to reduce emissions by 8% per annum in industry, as set out in the CCC's balanced pathway.[217] This requires policy frameworks that are focused on how we can indeed 'decarbonise now'. Russ Hall from the HVMC asked the question "do we make the emissions problem smaller and then look at how we deploy CCUS? Or do we consider it to be the answer to everything?" This is a question the government should consider. There are numerous avenues that can have an impact in the nearer term to reduce emissions as opposed to relying on CCUS and hydrogen.

SECURING INDUSTRIAL DECARBONISATION

There are basic principles underpinning the required further action, these are investment plans, data and reporting and operational costs. Different decarbonisation technologies should not be seen as either-or, but are frequently deployed in combination and frequently contingent on each other in response to the specific conditions of industrial sites and sectors. A coordinated policy approach to support decarbonisation across technology options is therefore important. This report advocates for a 'twin-track approach' to industrial decarbonisation by first maximising decarbonisation now, with the tools and technologies able to be deployed with the correct policy support, and second, by providing the longer term, more expansive plan for industrial CCUS decarbonisation for all industrial sites and the wider deployment of hydrogen, through industrial pipeline networks. The priority areas above span across both tracks.

INVESTMENT PLANNING

As a lack of a strong policy vision was commonly cited as a barrier to investment, a coherent and credible policy strategy for industrial decarbonisation is needed more than ever to avoid losing momentum. Based on their extensive work with industrial stakeholders IDRIC has articulated key elements to provide a clear direction of travel for investors and communities, such a strategy should include:

- A clear commitment to support a range of critical decarbonisation options to incentivise private investment and support emerging markets
- Developing a clear plan for the envisaged roll-out of infrastructure and integrated energy system that takes into account the needs of different sectors and geographies.
- Going beyond a purely technology-related issues taking into account critical social, economic, political and geographical dimensions of a successful and sustained industrial transition to net zero
- Developing mechanisms for greater coordination across policy domains and between multiple government agencies (including devolved governments), regulators, industry and other stakeholders

The development of a wider industrial decarbonisation roadmap, as the USA have set out, will be vital to provide certainty and long term clarity over the UK's industrial decarbonisation pathway. **The Government should commit to developing and publishing a new Industrial Decarbonisation Policy Strategy which is composed of two crucial**

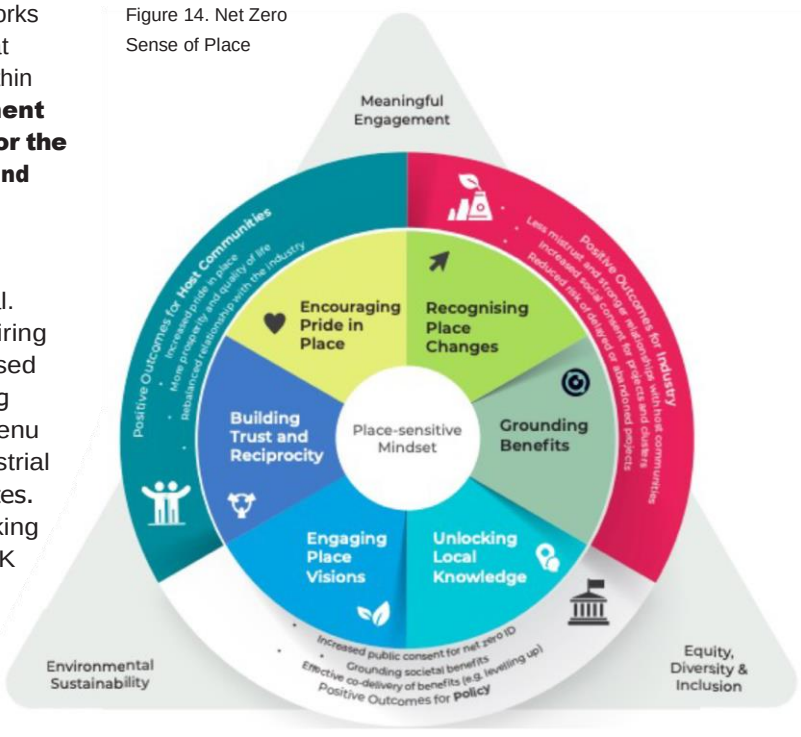
components: an Industrial Decarbonisation Roadmap and Industrial Decarbonisation Investment Plan. The investment plan supports the roadmap with the necessary finance that can help unlock further private investment.

Collaborative approaches to funding and support mechanisms should be placed at the forefront of plans moving forward. IDRIC shared that their Policy Forum with industry, government and academic stakeholders working in and outside the clusters highlighted the importance of non-technical factors such as leadership, vision and strong networks and trust linkages as key elements of successful cluster development. **Following the conclusion of the IDC, the Government should provide support which enables industrial cluster collaborations to deliver against their Net Zero roadmaps**. Evidently, early stage collaboration between academia, R&D, regulators and industry accelerates innovation. There is an urgent need to secure the future of the extensive research networks and knowledge exchange mechanisms that have developed, both through IDRIC and within the clusters. **Critically, the UK government should commit to additional funding for the Industrial Decarbonisation Challenge Fund and IDRIC to at least 2030.**

Understanding place-based contexts for industry across the country will be pivotal. There is a need to identify the sites requiring support to decarbonise, including dispersed sites and, crucially, make specific funding long-term agreements and lay out the menu of mechanisms intended to support industrial decarbonisation across the different routes. A project at the University of Exeter working with industrial communities across the UK highlights that industrial decarbonisation needs to shift from a technology-centred perspective to one that recognises host communities' sense of place, if deployment is to be effective, fair and acceptable, and to avoid risk of delay. The team has developed a framework, shown in Figure 14 aims to guide a place-sensitive approach to industrial decarbonisation and constructive multi-stakeholder dialogue between industry, public sector, community organisations, residents, and other organisations who are involved in or will be impacted by industrial decarbonisation.[218]

On the basis of a national audit, there should be a focus on establishing industrial energy saving zones, with the intention of allowing industries to co-locate or collaborate in geographic locations where they can share critical energy infrastructures. Incentivising these sites through tax incentives, low cost electricity agreements, use of the ETS, could be considered to incentivise co-location and establishment of new industrial energy saving zones. The zones may also be a testing ground for the use of on-site generation and creation of industrial ecosystems. The zones as geographic locations could pioneer Industry

Figure 14. Net Zero Sense of Place



Energy Saving Partnerships (IESPs). **Further, the Industrial Energy Transformation Fund should be extended beyond 2027 and its funding pool enlarged to provide certainty for industrial sites investing in efficiency technologies. Funding for this could be raised through revenues received from the Climate Change Levy, which should be ring fenced specifically for improving the energy efficiency of industry through the research and innovation of technologies and funding mechanisms for adoption.**

The government should revise the 15% energy consumption reduction target, making it more ambitious, laying out a target for industry specifically, followed by a roadmap of specific actions to reach this target.

The government should also establish mechanisms to incentivise change to the encouragement of replacing the old non-energy, efficient equipment. the installation of energy management systems, the improvement of heat, recovery, and reuse, resource, efficiency, and material substitution. As part of this, the government should explore effective methods to mobilise private equity investment. For example, through government guarantees.

Through discussions with the Network, it is understood restoring tax incentives for R&D intensive SMEs would be welcomed, as in both carbon capture and other decarbonisation sectors we will need further innovation to reduce costs, improve performance and accelerate development.

The call for evidence on enabling industrial electrification closed on the 20th October 2023. Electrification should not be placed as a lower priority than CCUS and hydrogen. Urgent investment is needed in the development of electricity grid infrastructure, this aspect will be further discussed in the Power Generation Network. **As such, an Industrial Electrification Strategy should be included in the Roadmap and published in 2024**. Here, the factors specific to investment in industrial electrification are addressed.

Around 45% of all industrial processes require less than 200°C,[219] so existing technologies are available for the transition to electric in these cases, for example through industrial heat pumps and CHP technologies. **An assessment of industrial sites suitable for an immediate switch to heat pump technology should be carried out to bolster adoption, followed by an investment roadmap specific to industrial heat pumps.** Therefore it is a matter of incentivising this switch, such as an industry equivalent of the Boiler Upgrade Scheme. **The government should explore the potential for a targeted emissions CFD scheme, whereby capital investments can be offset on the basis of emission reduction targets within a certain timeframe, in order to provide support mechanisms. The Government should leverage** Made Smarter's **network and support, through a clear funding plan, the establishment of a twin organisation "Made Electrified" to connect industries with skills and technologies needed to go down the electrification path and help deliver the Industrial Electrification Strategy's objectives.**

Additionally, the Net Zero Review called for a demonstrator project approach to develop future technologies that could then be adopted at scale. In Pillar Six of the Review, recommendations were made for funding for several demonstrators, similar to the Faraday Battery Challenge. **An Industrial Decarbonisation Demonstrator Project should be established, focusing on the opportunity to innovate around industrial energy efficiency and electrification, where new forms of industrial heat pumps and combined heat and power technologies should be piloted.** The Innovate UK funding for Futraheat is a good start, however it should be subject to a robust monitoring and evaluation framework.

A systemic and longer-term perspective for research and innovation funding should be developed and clearly communicated, highlighting the need to keep a sustained pipeline of research and innovation. Finally, digitalisation should not be siloed, it should be a cross-cutting theme across the industrial decarbonisation vision and sufficient plans for investment opportunities in disruptive technologies should be developed.

DATA AND REPORTING

The Government should strive for a Connected Industrial Economy. **The Government must take on board the CCC's recommendation to CCC to review, invest in and reform industrial decarbonisation data collection and reporting. The Government should release a Data Strategy that addresses the need to collect comprehensive data on industrial production, energy demands, and emissions at national, regional and local levels**. Moreover, the UK can play an important leadership role in supporting the growth of a robust voluntary carbon market, which requires consistent, clear and stringent requirements in terms of monitoring, regulation and verification of CO2 storage. This is also intertwined with digitalisation as an enabler.

Additionally, when assessing place-based contexts, industrial energy demand needs to be modelled to understand the electricity requirements. IDRIC stresses that "learning from previous experiences (e.g. the expansion of solar PV and more recently battery storage) could help to prepare transmission and distribution networks, planning and system governance for future waves of demand increase." Demonstrator projects should require cost-benefit analyses, and these should be communicated to build confidence in the sustained product quality and economic benefits.

The Government should consult on the use of blockchain and cloud software in order to facilitate a Connected Industrial Economy, recognising it could be a chance for the UK to become a first mover in this area. Additionally, the role of AI in the economy is a popular topic, it undoubtedly will unlock opportunities across sectors. In the industrial world, where terabytes of data are generated on the performance of industrial operations at a microsecond level, the application of AI in support of both productivity and decarbonisation has huge potential. However, applying it in a manner that provides the necessary skills and training to protect existing jobs and potentially create new areas for jobs is important. **As such, an immediate action for policy is to create a comprehensive review of the place for AI in industrial decarbonisation.**

In order to unlock the potential of industrial data in support of both productivity and decarbonisation, the Government should consider bringing forward regulation to promote sharing of industrial data, similar to the EU Data Act.

OPERATIONAL COSTS

There is a clear urgency for business models for industrial electrification to be addressed as a policy priority. A fuel-switching tariff could provide direct support for a route to market and reward companies and industries for taking immediate action. Rebalancing of gas and electricity prices for industrial power agreements must be addressed, in particular through decoupling renewable electricity prices from gas prices to incentivise electrification. As previously mentioned, network charges and policy costs make up 95% of the electricity price differential between UK and EU industrial consumers. The insight report based on the roundtable on barriers to investment in industrial electrification suggest that removing this differential would reduce the price of electricity paid by

industry, which would also lower the price differential to natural gas, incentivising electrification and protecting UK industrial competitiveness.[220] The British Industry Supercharger seeks to address this, therefore its planned implementation in April 2024 must go ahead. When considering the focus on CCUS and hydrogen, it is important to remember electricity is required for the production of clean hydrogen, so expending effort to reduce electricity costs now also extends benefits to the hydrogen market in the future.

R&D in industrial electrification technology should be considered as an important element in order to reduce costs for industrial sites adopting such technologies. Better support is required for innovation programmes. The Government's response to the recent consultation on the Future of the Industrial Energy Transformation Fund should not neglect industrial electrification and should assess the evidence to justify the case for a silo of the fund for this avenue.

ROBUST CARBON PRICING MECHANISMS

The government has now taken the welcome step in their response to the Net Zero Review of committing to a long term ETS pathway to 2050, **however this must be published as soon as possible, demonstrating how the cap will be net zero aligned. The Net Zero-Aligned ETS must also consider recognising and rewarding progress to incentivise accelerated decarbonisation.** The ETS long-term pathway to 2050 requires flexibility and, importantly, should make allowances for capital investment offsets. This means that to generate trust in the ETS system, raising the price of CO2 via the ETS over time should occur in a predictable and transparent manner. Thus, ETS policies need to be set out early. **New ETS policy should also consider how to amend unintended effects of the ETS design, such as payments for closure of industrial facilities, to retain public trust.**

In addition to making the cap net zero aligned, the Authority is also consulting on expanding the UK ETS to the domestic maritime sector by the mid-2020s and has launched a Call for Evidence to expand the UK ETS to waste and energy from waste by the mid- to late-2020s. Through adding these sectors, up to an additional 12MtCO2e of current UK annual emissions could be covered by the UK ETS, depending on scope of the scheme. With an investment horizon of more than 15 years, the Government needs to provide policy stability to the sector. The future form and function of the ETS will depend on ensuring that additional sectors are brought into its scope, however this must be achieved in a managed and measured way. The need for a stable pathway for the future of the ETS was highlighted by the Net Zero Review. The Review highlighted that such a pathway should:

- Set out a vision on the future design and operation of the ETS
- Set out a timeline for expanding the coverage to the rest of the UK economy, as well as sectors consulted on including maritime and waste.
- Address inclusion of GGRs to incentivise early investment in new technologies and potentially nature-based solutions.
- Provide reassurance to businesses around how the Government will mitigate the risk of carbon leakage as a result of expanding the ETS.

The UK ETS also needs to expand to new sectors, including sectors such as domestic transport and heat and buildings by 2030 as these sectors will continue to have a high share of the UK's territorial emissions. However, such a move should be followed by government measures to mitigate the impact of this policy on particularly low-income households and small businesses. Expanding

coverage of the compliance carbon market to cover a larger proportion of the economy and emissions is something other countries have done. Surrender obligations (the obligation to pay the auctioned price for one's emissions) under the New Zealand ETS currently covers 50% of the country's greenhouse gas emissions and transitional arrangements are in place to bring the agriculture sector in by 2025. Similarly, the EU is currently negotiating the EU ETS II to cover transport and buildings.

The future of the ETS to 2050, along with the final design of the scheme and sectors covered by it, should be published as soon as possible and no later than 2024, in order to give certainty to business and industry.

Further, based on the dramatic drop in the UK carbon price, **it is now pressing that action is taken to rectify the discrepancy between the UK and ETS carbon price. In an ideal scenario, alignment between the UK and the EU ETS would provide business and industry, whose supply chains operate across European borders, with the certainty and security they need to understand that there would be a stable market place in which to trade carbon. This would not require the UK to rejoin the EU ETS, but rather commit to the principles of interoperability and alignment between both schemes.**

Adding GGRs (Greenhouse Gas Removals) into the UK ETS could help establish the demand for carbon removal measures by providing a mechanism for companies with existing ETS obligations to use removals in addition to emissions reductions by 2050. The longevity, integrity and long-term policy certainty offered by the UK ETS provides a credible commitment to future demand for GGRs.

In addition to adding GGRs to the UK ETS, there is the wider question whether money raised through the ETS, which currently is essentially a tax upon industry that is then returned to HM Treasury can be re-invested directly into companies and industries that commit to offsetting their ETS. Rather than see the ETS as a cost, it might then be better re-purposed as a scheme that would incentivise investment in both the technologies and processes that can deliver the necessary emissions reductions. Companies would therefore see the ETS as an opportunity, and not a cost. And rather than simply pay the ETS, there would be a direct correlation between spending on the ETS and emissions reductions. Given that there is to be a reduction of available credits by 2026, there is a pressing need for sectors to decarbonise as soon as possible. Moving forward ETS revenues should be allocated into a ring fenced fund for industrial decarbonisation and communication regarding what the funding is contributing to. **Therefore, an ETS investment scheme in capex and opex costs for decarbonisation projects could in the first instance be introduced for 2024 to 2027, with the possibility of extending a sunset clause. Investing the finance raised through the ETS back into emissions reduction would help accelerate industrial decarbonisation and move away from a business as usual approach to a dynamic opportunity for companies and industry to invest in decarbonisation rather than simply pay the ETS charges.**

A CBAM is likely to be needed to avoid carbon leakage and enable the UK to meet its environmental targets. The Government should communicate their decision on this topic as soon as possible, especially with the introduction of the EU CBAM. However, careful consideration should also be given to future scenarios of trading low-carbon products, such as green steel.

COORDINATING POLICY ACTION

2030 may be tomorrow to industrial actors, but this does not diminish the need to capture the possibilities of the realisable

decarbonisation routes during this timeframe. **In order for the Roadmap and the Investment Plan to be effectively enabled, this requires industrial decarbonisation and all policies relating to industrial emissions and pollution to be located in a single department. The Department for Energy Security and Net Zero should be solely responsible, rather than have split responsibilities with DEFRA.** One key recommendation concerns the coordination of the UK's industrial decarbonisation. There is a strong agreement within the Network for a central body which has holistic oversight over the actions and implementation of policies pertaining to industrial decarbonisation. **An Industrial Decarbonisation Taskforce is essential for providing consistency and holding the relevant departments to account and therefore should be considered by the Government.** Specific urgent tasks it should undertake are:

- Assessing the decarbonisation progress and energy efficiency of existing industrial sites.
- Map out the digital solutions already available and their benefits to industry sectors, such as chemicals.
- Ensuring network developments along the individual components, namely electricity, hydrogen, CCUS infrastructure, integrate into a holistic network to support decarbonisation and Net Zero
- Looking at the potential to launch an Industrial Net Zero Catapult fund.
- Assess the current state of Local Industrial Decarbonisation Partnerships for dispersed sites and SMEs.
- Establish before 2030 the research and innovation frameworks needed to meet future decarbonisation needs up to 2050. As delays to tackling industrial emissions stack up, the more urgent decarbonisation becomes, leading to increasing reliance on innovative solutions to achieve statutory emissions reductions.

The Government has committed to publishing a government-industry Net Zero and Nature Workforce Action Plan in the first half of 2024. **The government should follow through on recommendations, ensuring it addresses issues of impact on the workforce during the transition and what support will be provided to mitigate losses.**

Moreover, a socio-economic model for industrial decarbonisation is needed to understand and effectively communicate its impact. **A UK-wide JTF, similar to existing programmes from the Scottish Government and the EU JTF, should be established based on the analysis of place-based contexts to provide support for areas which may suffer short-term economic losses due to the closing of heavy industry.**

Additionally, public engagement strategies should be integrated into the Industrial Decarbonisation Roadmap, including creating awareness of decarbonisation needs as well as addressing concerns about the safety and appropriateness of technologies.

Further, implementing technologies to improve efficiency is a strategy which can be both realised now and strengthened simultaneously as routes such as CCUS and hydrogen are reaching maturity. **The Energy Efficiency Taskforce commissioned in March 2023 had industrial energy efficiency as part of its remit, however it has now been decommissioned. It should be reformed as a separate Industry Energy Efficiency Taskforce and its subsequent recommendations should be published.**

A framework, setting out key steps, for how digital solutions can be explored and utilised should be established, perhaps by the suggested Industrial Decarbonisation Taskforce, in order to demystify the complex landscape. Made Smarter UK supports SME manufacturers on their digital journey, focusing on UK leadership for digitalisation, adoption, innovation and skills. **The government should further explore how to leverage Made Smarter, and other organisations like it, to encourage digitalisation.**

LONGER-TERM VISION FOR INDUSTRIAL DECARBONISATION

A National Industrial Future Plan is needed to create a shared long-term vision for CO2 transport and storage infrastructure. An improved understanding of supply and demand scenarios which incorporate real-world project pipelines and timelines can inform interventions and enable all industrial users to access the low carbon infrastructure needed to decarbonise.

Regarding CCUS and hydrogen, government revenue support, support for innovation and capital investment in production facilities is required to incentivise private investment. Additionally, these actions will bolster markets for critical transition technologies, namely CCUS and low-carbon hydrogen. **Beyond the Business Models put in place and the extension of Track 1 and 2 cluster plans, the government must provide clarity on future timelines, which should also be accelerated.** This includes:

- Clarity on what amount of capacity will be awarded contracts to 2030/2035.
- Clarity on how funding for CCUS will be defined and allocated over the coming decade, to give line of sight to industry.
- Regular, competitive auctions to award contracts with clear ambition of how much capacity should be brought forward in each round.
- Transparency on CO2 T&S build out, pipeline routes, capacity and phasing.
- Approach to non-pipeline transport implemented to support decarbonisation of dispersed sites.
- Build out of transport and storage infrastructure, backed by business models, to support a hydrogen economy, provide market liquidity and fuel security.
- Addressing large scale storage as it is likely to need a seven-year development/ construction programme to commercial operation.

A decision is also needed on which sectors will be prioritised for hydrogen use, ensuring that industrial sectors without alternative decarbonisation options will have access to hydrogen in the required quantity to decarbonise their operations. More generally, more should be done to map demand and ensure a clear understanding of where the most pressing needs are and therefore support should focus on. The delay in FIDs was identified as a clear challenge, a possible solution is the provision of interim grant funding in place, although this does not address the problem of attracting investment not linked to government competitions, which should be further explored as part of the Government's vision. **The Industrial Carbon Capture Business Model should also be evaluated with the potential for guaranteed returns on investments pre-dating FIDs.**

Additionally, the Network underlined a need for a longer-term, outcome-focused strategy for research and innovation. This includes providing a strong signal

of continuity for net zero research and innovation funding beyond 2025, which fosters strong collaborative networks between research and industry, is critical to ensure the UK has the strong research and innovation ecosystem needed to respond to emerging challenges, as well as to seize economic and emissions saving opportunities in industrial decarbonisation. Further, funding into granular data and research into the economic benefits of each activity along the CCUS and hydrogen value chains is needed in order to clearly communicate to the communities in which these activities take place.

In addition to this, if the UK wishes to capture a significant portion of the international CCUS supply chain, it will need to consider local content requirements for those elements which can be produced in the UK. **A plan for dispersed sites should be funded and developed, similar to the UKRI's Plan for UK Industrial Cluster Decarbonisation.**

According to IDRIC, there may be a need for new or updated guidance for permitting with respect to temporary onshore storage of CO2 prior to permanent geological storage or possible future permanent CO2 geological storage in depleted onshore hydrocarbon fields. If hydrogen is going to be used at scale the storage capacity will need to develop quickly, with new and diverse methods. **Specifically, the government should continue research and development to understand the potential for geological hydrogen storage technologies in saline aquifer formations.**

Chapter Four

ACCELERATING THE INTERNATIONAL DECARBONISATION JOURNEY

Industrial decarbonisation is for the benefit of the global community, the UK is well-placed to create an international example for how to provide future climate policy leadership, if the government acts now. As new international frameworks based on carbon are developed, including CBAM mechanisms, as well as the wider Breakthrough Agenda that seeks to decarbonise heavy and high emitting industries, there is a vital role to play in the international agenda on industrial decarbonisation. The Global Stocktake has the potential to highlight the importance of decarbonising industry. New international policy frameworks can help to encourage new forms of international collaboration and cooperation to deliver the decarbonisation of industry, and its greater use of energy efficiency and electrification, in order for all countries to meet their climate targets.

WILL COP28 SET A PRECEDENT FOR INDUSTRIAL DECARBONISATION?

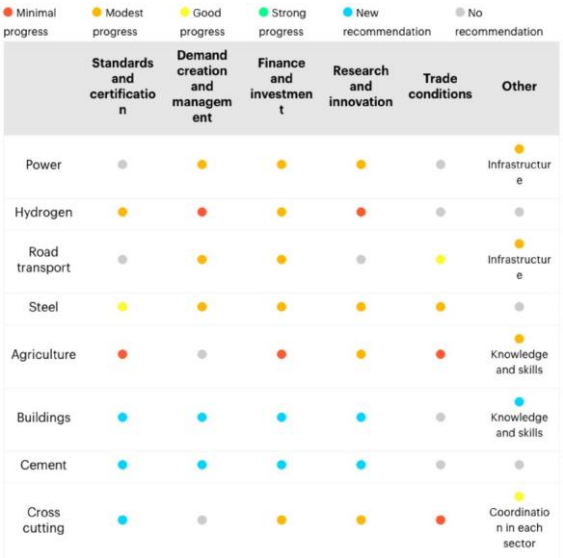
The UK's ambitions to deliver industrial decarbonisation at scale can be best realised and accelerated within an international framework. All countries are seeking to reduce their industrial emissions, and in doing so should be seeking international standards and benchmarks, the sharing of innovation and research, and the deployment of best practice.

The Breakthrough Agenda was launched at the COP26 World Leaders' Summit.[221] It provides a framework for countries, businesses and civil society to join and strengthen actions in key emitting sectors, through a coalition of leading public, private and public-private initiatives. Power, hydrogen and steel are three of the five Breakthroughs, these are core areas for targeting industrial emissions. The IDDI is the largest and most diverse coalition of governments, companies and organisations coordinated by UNIDO and co-led by the UK and India. It works to stimulate demand for low carbon industrial materials, standardise carbon assessments, establish procurement targets, incentivise investment in low-carbon product development and design industry guidelines, starting with steel, cement and concrete.[222] However, the map of the steel sector showed initiatives belonging to the enabling conditions of infrastructure and supply chains, knowledge, capability and skills and social engagement and impact were still under consideration as of November 2022.[223] This presents an opportunity for the UK to mobilise actions towards developing and solidifying these initiatives.

The Breakthrough Agenda Report 2023 found "only modest progress has been made in strengthening international collaboration in the areas where it is most needed." This is summarised in Figure 15.[224]

COP28's Energy and Industry thematic program includes a session on driving emissions reductions in hard-to-abate industries, a showcase event for each of four sectors: Renewables & Clean Power, Energy Efficiency, Heavy Emitting Sectors, and Low-carbon Hydrogen and a high-level roundtable on renewables and energy efficiency. To keep a

Figure 15. Breakthrough Agenda Progress Summary



high level of ambition, this program should seek to create a separate target for industrial emissions reductions for COP29 and COP30, which will assess progress and need for amendment. In October 2023, the COP28 Presidency at the Pre-COP Meeting stated its ambitions for a trebling of renewable power and a doubling of energy efficiency measures by 2030. The COP Presidency, alongside the IRENA, and the Global Renewables Alliance (GRA) launched a joint report "Tripling Renewable Power and Doubling Energy Efficiency by 2030: Crucial Steps Towards 1.5 °C." The report provides actionable policy recommendations for governments and the private sector on how to increase global renewable energy capacity to at least 11,000 GW while also doubling annual average energy efficiency improvements in the target period, with COP28 President Dr. Sultan Al Jaber stating that "Tripling the deployment of renewable power generation and doubling energy efficiency are amongst the most important levers to cut greenhouse gas emissions. I am now calling on everyone to come together, commit to common targets, and take comprehensive domestic and international action, as outlined in this report, to make our ambitions a reality."

Reducing industrial emissions through greater deployment of industrial energy efficiency should be a key part of this commitment, if it is successful in the COP28 negotiations. The report notes that "for industrial sectors, continued energy efficiency improvements play an important role in keeping the overall energy consumption by industry close to unchanged in 2050 from present levels."[225] **There is a significant opportunity, therefore, for both the Breakthrough Agenda, particularly in steel and concrete, as well as the Industrial Deep Decarbonisation Initiative, to demonstrate how industrial decarbonisation and electrification- highlighted in the report- should be an important feature of how to strengthen international collaboration and partnerships to decarbonise industry globally. The UK should seek to play a leading role in this given the international interest in the industrial clusters programme, and should seek to use the platform of industrial decarbonisation to help scale up future international projects, under the advocacy of the doubling of energy efficiency measures.** For example, if targets are agreed for energy efficiency, the industrial target should be set specifically. In addition to this, the role of electrification for industrial processes is relatively undermined in the Breakthrough Agenda and IDDI. As there are strong coalitions for technologies surrounding CCUS and hydrogen, a sense of community needs to be created around electrification. **The UK should mobilise a Global Industrial Electrification Platform.**

Conversations need to take place around international initiatives for standard and rule-setting, including industrial product standards, green public procurement and other demand-side measures, and how accountability can occur. In addition to this, sectoral commitments for heavy industries such as steel, cement, glass and paper should be set out.

As this report has emphasised the potential technology development has on industrial decarbonisation, **COP28 should foster knowledge exchange and finance for industrial decarbonisation, especially for countries of the Global South with large industrial sectors. The UK has a specific role to play in exemplifying the benefits of place-based approaches to industrial decarbonisation. It should lead on emerging mechanisms for sharing knowledge and explore the potential for international collaborations.**

Further, CCUS is viewed to be a key piece of industrial decarbonisation, thus international collaboration needs to occur to agree common

standards across the CCUS supply and value chains. **A more stable carbon market is required and internationally accepted standards in the voluntary carbon market are essential to coordinate approaches and avoid the global consequences of enabling carbon leakage, the UK should take a leading stance on this.**

CREATING A WORLD WHERE DECARBONISED INDUSTRY IS BUSINESS-AS-USUAL

In the pursuit of a sustainable and resilient future, the imperative to decarbonise industry has become a central focus of global efforts. As the consequences of climate change loom larger, the vision of a world where decarbonised industry is business-as-usual emerges as a beacon of hope and practicality. The transition towards a decarbonised industry necessitates a paradigm shift, where decarbonisation is a fundamental principle due to its potential for efficiency and economic value. Industrial decarbonisation demands government determination, as well as collaboration among governments, businesses, and communities.

The role of CCUS and hydrogen, whilst important, should not undermine other routes to decarbonisation which are realisable in a shorter time frame. Embracing digitalisation plays a pivotal role in creating a decarbonised industrial landscape. Smart manufacturing processes, data analytics, and artificial intelligence can optimise resource utilisation, streamline supply chains, and enhance overall efficiency. By integrating these technologies, industries not only reduce their carbon footprint but also gain a competitive edge in the global market. Policy frameworks and incentives provided by governments play a crucial role in fostering the transition to a decarbonised industry. A range of funding mechanisms and regulatory support encourage industrial sites to adopt sustainable practices. Establishing clear emission targets and fostering international cooperation further solidify the commitment to a low-carbon future.

Conclusion

Industrial decarbonisation is a complex process. The costs of reducing industrial emissions are high, while industries cannot switch their emissions off overnight. Success in delivering further reduction in industrial emissions- essential if we are to meet both the UK's Nationally Determined Contribution for 2030, and our net zero commitment for 2050- requires long-term planning and certainty for industry.

Many plants and factories have been operating in situ for decades. To change and adapt may be viewed by some as a risk. But the reality is that there is no alternative but to change and adapt. Countries and companies across the world are now seeking to move towards low carbon materials and technologies. Investments are being made on the basis that they can guarantee lower emissions over time. To stand still and do nothing is not an option. Those that do will find that their businesses and industries become stranded assets, unable to access capital which is willing and waiting to be spent, but only on net zero endeavours.

This is why the Net Zero Review and its Mission Zero report sought to prioritise industrial decarbonisation as a priority, with one of its ten missions focusing on how to deliver the long term certainty, clarity, consistency and continuity of policy frameworks. For industry, this is more pressing than perhaps any other sector. Decisions where to open new factories, or to modernise old ones, are made with return on investment decisions stretching well beyond 2050. For them, the net zero future is already influencing present day decisions.

For this reason, **we must take a twin track approach to industrial decarbonisation that recognises both what will be need for investment today, to enable the technologies of tomorrow to decarbonise, as well as to invest in the technologies of today that are needed to ensure those industries and businesses that can reduce their emissions now, do so and "Decarbonise Now".**

This is the central message of Decarbonise Now, which has sought to set out in further detail additional policy recommendations and frameworks that can help scale up and expand the more rapid deployment of industrial decarbonisation.

The report has highlighted how the UK is not doing this in isolation, but against the backdrop of a rapid international escalation in the deployment of green industries for the future. Again to not act, to stand still, will be to fall behind. This will cost inward investment and ultimately jobs. Instead those jobs will go elsewhere. There is a strategic choice to be made: do we wish to support what is needed to reduce emissions, so that our industries can be world leading and pioneer the low carbon material opportunities of the future, or do we wish for others to lead, and capture the markets of the future?

This should not be a question that needs to be posed, but to answer yes requires also a recognition of the urgency of the situation, and to understand that any further delay may put further jobs at risk.

Decarbonise Now is clear that the central message of the Net Zero Review, of long-term, programmatic planning and investment by government is essential if we are to ensure that the UK realises the opportunity of industrial decarbonisation. **This requires not only a long term Industrial Decarbonisation Roadmap that applies not only to the industrial clusters but to all industrial sites, it also requires an Industrial Decarbonisation Investment Plan to support the roadmap with the necessary finance that can help unlock further private investment.**

In order for the Roadmap and the Investment Plan to be effectively enabled, this requires for **Industrial Decarbonisation and all policies relating to industrial emissions and pollution to be located in a single department, namely**

the Department for Energy Security and Net Zero, rather than have split responsibilities with DEFRA. Ensuring that there is a single link point in government, with a minister responsible for industrial decarbonisation in their portfolio, would help to provide a focus point for the wider industrial sector, and certainty of over policy accountability.

In addition to having a Roadmap, Investment Plan and necessary machinery of government changes, **the work of the industrial taskforce of the energy efficiency taskforce that was recently abolished should be published, or a new industrial decarbonisation taskforce appointed.** It would however be a waste to not utilise the work that had been produced on industrial energy efficiency and better use of resources that had been taken forward.

In any case, a wider cross-sectoral delivery taskforce should be convened to help draw up the necessary Roadmap and Investment Plan. This must set out a wider plan for not only 2030, but for 2040 and 2050, with a detailed audit of what is needed, when and how best to provide a staged approach to decarbonising industry. The work of the Industrial Decarbonisation Challenge Fund by UKRI and the additional work and research taken forward by the Industrial Decarbonisation Research and Innovation Centre (IDRIC) has been instrumental in helping to map out the industrial clusters programme, though its funding is set to end in 2024. **The opportunity should now be taken to extend this funding and to ensure the IDC and IDRIC are involved closely with any further work on a wider industrial decarbonisation roadmap.**

While it is important that greater clarity and investment is made in the cluster projects, and a better understanding of how both CCUS and hydrogen will be deployed, with a clear and consistent approach to the transportation, the shipping and the industrial networks that will need to be created- vital given that many other countries such as Germany and the USA are setting out long term decade long investments and strategies in hydrogen and CCUS - **there should also be an Industrial Electrification Strategy as part of the Roadmap, that recognises that electrification should be a priority for industry, and that almost half of all industrial emissions can be addressed with electrification at scale.** This is obviously an issue that requires wider work on the future of a net zero power grid, and how to deploy grid connections, rebalance gas and electricity prices, but by having a separate electrification strategy would help outline and analyse these future challenges and provide solutions to these.

In addition to electrification, the report has highlighted a range of policy interventions that can ensure industry is able to decarbonise at a more rapid pace. These include digitalisation and AI technologies, better energy efficiency and heat pump equipment, and priority should be given towards how these can be better deployed at scale. A focus on additional innovation, through the use of demonstrator projects, should also be considered.

The importance of ensuring electrification can be progressed at pace, especially to ensure industry decarbonises at the scale needed to meet our 2030 and 2035 NDC targets, means that attention must be urgently paid to removing any barriers and challenges that prevent this from happening. This also includes rebalancing and reducing electricity costs, as well as providing greater certainty, yet also potential flexibility for the future of the Emissions Trading Scheme. Unless industrial decarbonisation and electrification is seen as a benefit and opportunity, and for companies and industry to engage in new low carbon markets and opportunities, then we will not achieve our ambitions. Decarbonisation must be incentivised, and the roadmap should set out how decarbonisation will lead to more additional jobs and economic growth, and never deindustrialisation.

The opportunity for the UK, as the country that has not only decarbonised further faster than any other G20 nation, the first G7 country to sign net zero into law, to lead internationally on how to successfully decarbonise industry and bend the emissions curve further downwards, is an opportunity that we cannot afford to go to waste. Already our Net Zero Industrial Clusters approach is world renowned, yet we can go further and apply this to all industry. The opportunities unlocked by the Energy Act, with the passing of hydrogen and CCUS business models and the future CfD mechanisms now need to be seized.

The UK led at COP26 in Glasgow with the launch of the Breakthrough Agenda, and as a founder member of the Industrial Deep Decarbonisation Initiative, and should now, at COP28 and beyond, make the case for why industrial decarbonisation, through a carefully considered, long term, programmatic approach, is essential if we are to have greener, cleaner and better industries that can thrive in the twenty first century, and adapt to the changing needs of a modern economy that is increasingly only investing in those industries that prioritise reducing their emissions. It is time to decarbonise now.

Appendix

SUMMARY OF ROUNDTABLE ATTENDEES

Roundtable I: 12th May 2023

The Rt Hon Chris Skidmore OBE, Mission Zero Coalition
Russ Hall, High Value Manufacturing Catapult
Andrew Large, Confederation of Paper Industries
Dr Anna Pultar, The Industrial Decarbonisation Research and Innovation Centre
Dan Meredith, E.ON
Harry Spencer, Carbon Clean
Sophie Miremadi, AVEVA
Richard Folland, Carbon Tracker
Tara Schmidt, Lloyds Banking Group
Dr John Ferrier, The Industrial Decarbonisation Research and Innovation Centre
Kofi Mbuk, Carbon Tracker

Roundtable II: 12th June 2023

The Rt Hon Chris Skidmore OBE, Mission Zero Coalition
Russ Hall, High Value Manufacturing Catapult
Andrew Large, Confederation of Paper Industries
Dr Anna Pultar, The Industrial Decarbonisation Research and Innovation Centre
Dr Chris Williams, South Wales Industrial Cluster
Peter Edwards, Reckitt
David Lewy, Reckitt
Laura Gillions, Carbon Clean
Hannah Bronwin, SSE Thermal
Sophie Miremadi, AVEVA
David Parkin, HyNet
Tara Schmidt, Lloyds Banking Group
Dr Nina Skorupska CBE, The Association For Renewable Energy and Clean Technology

Roundtable III: 20th July 2023

The Rt Hon Chris Skidmore OBE, Mission Zero Coalition
Andrew Large, Confederation of Paper Industries
Hannah Wilson, High Value Manufacturing Catapult
Sophie Miremadi, AVEVA
Kofi Mbuk, Carbon Tracker
Prof. Mercedes Maroto-Valer, The Industrial Decarbonisation Research and Innovation Centre
Joy Newton, Lloyds Banking Group
Dr Anna Pultar, The Industrial Decarbonisation Research and Innovation Centre
Dr John Ferrier, The Industrial Decarbonisation Research and Innovation Centre
Dr Nina Skorupska CBE, The Association For Renewable Energy and Clean Technology
Lisa Wee, AVEVA

Recommendations

#	AREA	RECOMMENDATION
1	Securing industrial decarbonisation - Investment planning	The Government should commit to developing and publishing a new Industrial Decarbonisation Policy Strategy which is composed of two crucial components: an Industrial Decarbonisation Roadmap and Industrial Decarbonisation Investment Plan.
2	Securing industrial decarbonisation - Investment planning	Critically, the UK government should commit to additional funding for the Industrial Decarbonisation Challenge Fund and IDRIC to at least 2030.
3	Securing industrial decarbonisation - Investment planning	Following the conclusion of the IDC, the Government should provide support which enables industrial cluster collaborations to deliver against their Net Zero roadmaps.
4	Securing industrial decarbonisation - Investment planning	On the basis of a national audit, there should be a focus on establishing industrial energy saving zones, with the intention of allowing industries to co-locate or collaborate in geographic locations where they can share critical energy infrastructures.
5	Securing industrial decarbonisation - Investment planning	Further, the Industrial Energy Transformation Fund should be extended beyond 2027 and its funding pool enlarged to provide certainty for industrial sites investing in efficiency technologies. Funding for this could be raised through revenues received from the Climate Change Levy, which should be ring fenced specifically for improving the energy efficiency of industry through the research and innovation of technologies and funding mechanisms for adoption.
6	Securing industrial decarbonisation - Investment planning	The government should revise the 15% energy consumption reduction target, making it more ambitious, laying out a target for industry specifically, followed by a roadmap of specific actions to reach this target.
7	Securing industrial decarbonisation - Investment planning	The government should also establish mechanisms to incentivise change to the encouragement of replacing the old non-energy, efficient equipment. the installation of energy management systems, the improvement of heat, recovery, and reuse, resource, efficiency, and material substitution. As part of this, the government should explore effective methods to mobilise private equity investment. For example, through government guarantees.
8	Securing industrial decarbonisation - Investment planning	An Industrial Electrification Strategy should be included in the Roadmap and published in 2024.
9	Securing industrial decarbonisation - Investment planning	The government should explore the potential for a targeted emissions CFD scheme, whereby capital investments can be offset on the basis of emission reduction targets within a certain timeframe, in order to provide support mechanisms.

#	AREA	RECOMMENDATION
10	Securing industrial decarbonisation - Investment planning	An assessment of industrial sites suitable for an immediate switch to heat pump technology should be carried out to bolster adoption, followed by an investment roadmap specific to industrial heat pumps.
11	Securing industrial decarbonisation - Investment planning	The Government should leverage Made Smarter's network and support, through a clear funding plan, the establishment of a twin organisation, "Made Electrified" to connect industries with skills and technologies needed to go down the electrification path and help deliver the Industrial Electrification Strategy's objectives.
12	Securing industrial decarbonisation - Investment planning	An Industrial Decarbonisation Demonstrator Project should be established, focusing on the opportunity to innovate around industrial energy efficiency and electrification, where new forms of industrial heat pumps and combined heat and power technologies should be piloted.
13	Securing industrial decarbonisation - Investment planning	A systemic and longer-term perspective for research and innovation funding should be developed and clearly communicated, highlighting the need to keep a sustained pipeline of research and innovation.
14	Securing industrial decarbonisation - Investment planning	Digitalisation should not be siloed, it should be a cross-cutting theme across the industrial decarbonisation vision and sufficient plans for investment opportunities in disruptive technologies should be developed.
15	Securing industrial decarbonisation - Data and reporting	The Government must take on board the CCC's recommendation to CCC to review, invest in and reform industrial decarbonisation data collection and reporting.
16	Securing industrial decarbonisation - Data and reporting	The Government should release a Data Strategy that addresses the need to collect comprehensive data on industrial production, energy demands, and emissions at national, regional and local levels.
17	Securing industrial decarbonisation - Data and reporting	Additionally, when assessing place-based contexts, industrial energy demand needs to be modelled to understand the electricity requirements.
18	Securing industrial decarbonisation - Data and reporting	In order to unlock the potential of industrial data in support of both productivity and decarbonisation, the Government should consider bringing forward regulation to promote sharing of industrial data, similar to the EU Data Act.
19	Securing industrial decarbonisation - Data and reporting	As such, an immediate action for policy is to create a comprehensive review of the place for AI in industrial decarbonisation.

#	AREA	RECOMMENDATION
20	Securing industrial decarbonisation - Data and reporting	As such, an immediate action for policy is to create a comprehensive review of the place for AI in industrial decarbonisation.
21	Securing industrial decarbonisation - Operational costs	There is a clear urgency for business models for industrial electrification to be addressed as a policy priority. A fuel-switching tariff could provide direct support for a route to market and reward companies and industries for taking immediate action. Rebalancing of gas and electricity prices for industrial power agreements must be addressed, in particular through decoupling renewable electricity prices from gas prices to incentivise electrification.
22	Securing industrial decarbonisation - Operational costs	R&D in industrial electrification technology should be considered as an important element in order to reduce costs for industrial sites adopting such technologies. Better support is required for innovation programmes. The government's response to the recent consultation on the Future of the Industrial Energy Transformation Fund should not neglect industrial electrification and should assess the evidence to justify the case for a silo of the fund for this avenue.
23	Robust carbon pricing mechanisms	The government has now taken the welcome step in their response to the Net Zero Review of committing to a long term ETS pathway to 2050, however this must be published as soon as possible, demonstrating how the cap will be net zero aligned.
24	Robust carbon pricing mechanisms	The Net Zero-Aligned ETS must also consider recognising and rewarding progress to incentivise accelerated decarbonisation.
25	Robust carbon pricing mechanisms	New ETS policy should also consider how to amend unintended effects of the ETS design, such as payments for closure of industrial facilities, to retain public trust.
26	Robust carbon pricing mechanisms	The UK ETS also needs to expand to new sectors, including sectors such as domestic transport and heat and buildings by 2030 as these sectors will continue to have a high share of the UK's territorial emissions. However, such a move should be followed by government measures to mitigate the impact of this policy on particularly low-income households and small businesses.

#	AREA	RECOMMENDATION
27	Robust carbon pricing mechanisms	The future of the ETS to 2050, along with the final design of the scheme and sectors covered by it, should be published as soon as possible and no later than 2024, in order to give certainty to business and industry.
28	Robust carbon pricing mechanisms	It is now pressing that action is taken to rectify the discrepancy between the UK and ETS carbon price. In an ideal scenario, alignment between the UK and the EU ETS would provide business and industry, whose supply chains operate across European borders, with the certainty and security they need to understand that there would be a stable market place in which to trade carbon. This would not require the UK to rejoin the EU ETS, but rather commit to the principles of interoperability and alignment between both schemes.
29	Robust carbon pricing mechanisms	Adding GGRs (Greenhouse Gas Removals) into the UK ETS could help establish the demand for carbon removal measures by providing a mechanism for companies with existing ETS obligations to use removals in addition to emissions reductions by 2050. The longevity, integrity and long-term policy certainty offered by the UK ETS provides a credible commitment to future demand for GGRs.
30	Robust carbon pricing mechanisms	Therefore, an ETS investment scheme in capex and opex costs for decarbonisation projects could in the first instance be introduced for 2024 to 2027, with the possibility of extending a sunset clause. Investing the finance raised through the ETS back into emissions reduction would help accelerate industrial decarbonisation and move away from a business as usual approach to a dynamic opportunity for companies and industry to invest in decarbonisation rather than simply pay the ETS charges.
31	Coordinating policy action	In order for the Roadmap and the Investment Plan to be effectively enabled, this requires industrial decarbonisation and all policies relating to industrial emissions and pollution to be located in a single department. The Department for Energy Security and Net Zero should be solely responsible, rather than have split responsibilities with DEFRA.
32	Coordinating policy action	An Industrial Decarbonisation Taskforce is essential for providing consistency and holding the relevant departments to account and therefore should be considered by Government.
33	Coordinating policy action	The government should follow through on recommendations, ensuring it addresses issues of impact on the workforce during the transition and what support will be provided to mitigate losses. A UK-wide JTF, similar to existing programmes from the Scottish Government and the EU JTF, should be established based on the analysis of place-based contexts to provide support for areas which may suffer short-term economic losses due to the closing of heavy industry.

#	AREA	RECOMMENDATION
34	Coordinating policy action	Additionally, public engagement strategies should be integrated into the Industrial Decarbonisation Roadmap, including creating awareness of decarbonisation needs as well as addressing concerns about the safety and appropriateness of technologies.
35	Coordinating policy action	The Energy Efficiency Taskforce commissioned in March 2023 had industrial energy efficiency as part of its remit, however it has now been decommissioned. It should be reformed as a separate Industry Energy Efficiency Taskforce and its subsequent recommendations should published
36	Coordinating policy action	A framework, setting out key steps, for how digital solutions can be explored and utilised should be established, perhaps by the suggested Industrial Decarbonisation Taskforce, in order to demystify the complex landscape.
37	Coordinating policy action	The government should further explore how to leverage Made Smarter, and other organisations like it, to encourage digitalisation.
38	Longer-term vision for industrial decarbonisation	A National Industrial Future Plan is needed to create a shared long-term vision for CO2 transport and storage infrastructure.
	Longer-term vision for industrial decarbonisation	Beyond the Business Models put in place and the extension of Track 1 and 2 cluster plans, the government must provide clarity on future timelines, which should also be accelerated.
39	Longer-term vision for industrial decarbonisation	A decision is also needed on which sectors will be prioritised for hydrogen use, ensuring that industrial sectors without alternative decarbonisation options will have access to hydrogen in the required quantity to decarbonise their operations.
40	Longer-term vision for industrial decarbonisation	The Industrial Carbon Capture Business Model should also be evaluated with the potential for guaranteed returns on investments pre-dating FIDs.
41	Longer-term vision for industrial decarbonisation	A plan for dispersed sites should be funded and developed, similar to the UKRI's Plan for UK Industrial Cluster Decarbonisation.
42	Longer-term vision for industrial decarbonisation	Specifically, the government should continue research and development to understand the potential for geological hydrogen storage technologies in saline aquifer formations.

#	AREA	RECOMMENDATION
43	COP28's precedent for industrial decarbonisation	There is a significant opportunity, therefore, for both the Breakthrough Agenda, particularly in steel and concrete, as well as the Industrial Deep Decarbonisation Initiative, to demonstrate how industrial decarbonisation and electrification- highlighted in the report- should be an important feature of how to strengthen international collaboration and partnerships to decarbonise industry globally. The UK should seek to play a leading role in this given the international interest in the industrial clusters programme, and should seek to use the platform of industrial decarbonisation to help scale up future international projects, under the advocacy of the doubling of energy efficiency measures.
44	COP28's precedent for industrial decarbonisation	There is a significant opportunity, therefore, for both the Breakthrough Agenda, particularly in steel and concrete, as well as the Industrial Deep Decarbonisation Initiative, to demonstrate how industrial decarbonisation and electrification- highlighted in the report- should be an important feature of how to strengthen international collaboration and partnerships to decarbonise industry globally. The UK should seek to play a leading role in this given the international interest in the industrial clusters programme, and should seek to use the platform of industrial decarbonisation to help scale up future international projects, under the advocacy of the doubling of energy efficiency measures.
45	COP28's precedent for industrial decarbonisation	COP28 should foster knowledge exchange and finance for industrial decarbonisation, especially for countries of the Global South with large industrial sectors. The UK has a specific role to play in exemplifying the benefits of place-based approaches to industrial decarbonisation. It should lead on emerging mechanisms for sharing knowledge and explore the potential for international collaborations
46	COP28's precedent for industrial decarbonisation	The UK should mobilise a Global Industrial Electrification Platform.
47	COP28's precedent for industrial decarbonisation	A more stable carbon market is required and internationally accepted standards in the voluntary carbon market are essential to coordinate approaches and avoid the global consequences of enabling carbon leakage, the UK should take a leading stance on this.

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