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SPECIAL FEATURE: NOTE AND COMMENT

Lessons learned from non-state and subnational climate action

A policy-relevant research agenda to support accelerated industrial decarbonisation in the UK

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Abstract
This paper outlines a policy-relevant research agenda to accelerate industrial decarbonisation in the UK. It highlights recent policy progress, which has largely focused on energy-intensive industrial clusters, and briefly reviews existing research on technologies, sectors, policies, and economic and social dimensions. Four priority areas are proposed for future research: decarbonising dispersed industrial sites, enabling electrification, developing markets for low-carbon products, and advancing resource efficiency. The agenda emphasises the need for integrated technical, economic, and social research to support policy evolution and industry readiness. By addressing these gaps, the UK can foster a just, cost-effective transition to a low carbon industrial sector, ensuring long-term environmental and economic sustainability.

Keywords Industrial decarbonisation · Policies · Research agenda · Electrification · Resource efficiency · Industrial products

Introduction

In 2021, the UK became the first major economy to launch an industrial decarbonisation strategy (IDS) (HM Government 2021). This set out the Government's ambition to cut greenhouse gas (GHG) emissions from industry by at least two-thirds by 2035 and by more than 90% by 2050, as well as outlining the overall approach to achieving these targets. Specific goals were set for 2030 including an initial expectation to capture 3 $MtCO_2$ through carbon capture and storage (CCS) and replacing around 20 TWh of fossil fuels with lower-carbon alternatives (e.g. hydrogen).

The IDS highlighted that delivering these short-term goals would require aligning existing policy with the UK's overall goal of net zero GHG emissions by 2050 and filling remaining policy gaps. Consequently, action would be needed across a range of existing and new policy areas including carbon pricing, competitiveness support to protect vulnerable industries, funding for demonstration and deployment of low-carbon technology and fuels, energy and other network infrastructure support, and demand-side measures. In the following two decades, it was expected that the policy regime would develop further by combining incentives to reduce emissions, carbon leakage mitigation, and supporting policy frameworks to address outstanding barriers to decarbonisation (HM Government 2021).

The strategy made an important distinction between industry located in a relatively small number of largely coastal 'clusters', at the time responsible for around half of total industrial emissions, and those industries that lie outside clusters, denoted as 'dispersed sites'. Its initial focus was on the former, with the aim to establish four low-carbon industrial clusters by 2030 and at least one fully net-zero cluster by 2040.

Key policies for decarbonising UK industry

Since the publication of the IDS and despite a change in government in 2024, the UK has maintained a consistent trajectory in industrial decarbonisation.

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Key cross-cutting policies include the UK Emissions Trading Scheme and longstanding Climate Change Levy, which together incentivise emissions reductions through carbon pricing. The Industrial Decarbonisation Challenge (2019–2024) invested over £370 million in low-carbon technologies across five industrial clusters. Building on this, the Cluster Sequencing process, backed by an initial £22 billion over 25 years, with an additional £9.4 billion announced in 2025, supports CO_2 capture projects and shared CO_2 transport and storage infrastructure; with business models for CCS and hydrogen offering long-term operational support. This investment is intended to create four CCS clusters by 2030, storing 20 to 30 $MtCO_2$ a year. The so-called Track-1 clusters are the East Coast Cluster and HyNet; with Track-2 clusters identified as Acorn and Viking.

The £500 million Industrial Energy Transformation Fund (2020–2025) supported energy efficiency and low-carbon technology adoption across all industrial sectors. The British Industry Supercharger scheme reduces electricity costs for energy-intensive industries, enhancing competitiveness. Smaller companies were the focus of the Local Industrial Decarbonisation Plan competition (2024–2025), which provided £6 million for 13 projects to develop tailored decarbonisation strategies for sites outside clusters. The 2025 Modern Industrial Strategy reinforced these decarbonisation efforts with reforms aimed at lowering electricity costs and promoting electrification, positioning the UK's industrial sector for a low-carbon future.

The future of the UK steel industry has been a particularly contentious issue. Between 1990 and 2023 steel production fell from 17.8 Mt to 5.6 Mt, with only two primary steel-making plants now left in the UK. In September 2024, the Government announced a £500 million grant for the Port Talbot site to help with a £1.25 billion investment to replace the blast furnaces with electric arc furnaces by 2027. This is expected to cut emissions from the plant by over 5 $MtCO_2$ per year. Then in April 2025, the Government intervened to take control of the steel plant in Scunthorpe to prevent its closure. This action is intended to keep the blast furnaces operational in the short term before transitioning to low-carbon production, such as electric arc furnaces, in the future.

Latest research on industrial decarbonisation

A review of published research on UK industrial decarbonisation over the period 2020 to 2025 reveals several prominent themes, but also some gaps. A significant strand of research explores low-carbon technologies and fuels, with a particular focus on CCS and hydrogen, which are often seen as being complementary. Studies have explored the performance and deployment of hydrogen and CCS in UK clusters (Akhurst et al. 2021), the potential for repurposing of submarine pipelines to carry CO_2 and hydrogen (Mahmoud and Dodds 2022), CO_2 storage site selection (Rashidi et al. 2025), economic aspects of CCS (Calvillo et al. 2022; Turner et al. 2021, 2022, 2023a, b) and the benefits, barriers, and justice impacts of industrial decarbonisation using these technologies (Sovacool et al. 2024a). Other studies recommend the establishment of green hydrogen hubs linked to industrial facilities (Dergunova and Lyden 2024) and analyse the costs of generating hydrogen from offshore wind power (Hill et al. 2024). Research on other technologies and fuels is more limited but includes analysis of low-temperature waste heat recovery from industries to decarbonise heat (Muhumuza and Eames 2022) and the implications of network constraints for decarbonising industry through electrification (Gailani and Taylor 2025). Integrated energy system planning tools have also been developed to explore combinations of technologies to decarbonise industrial clusters (Ngwaka et al. 2023; Ogwumike et al. 2024).

Other studies take a sectoral approach to decarbonisation, particularly focusing on foundation industries (Ganzer and Mac Dowell 2023; Hafez et al. 2024; Cooper and Hawkes 2024; Bolson et al. 2026; Whittle et al. 2026). Examples include work on iron and steel (Azimi and van der Spek 2025; Garvey et al. 2022; Geels and Gregory 2023; Griffin and Hammond 2021; Kiessling et al. 2024; Pimm et al. 2021; Richardson-Barlow et al. 2022), cement (Rihner et al. 2025; Sherif et al. 2025; Strunge et al. 2024) chemicals (Oluleye et al. 2024; Patel et al. 2024) and other non-metallic minerals (Griffin et al. 2021; Khalil et al. 2023), plus articles that explore various production processes in food and drink (Garvey et al. 2021; Gao et al. 2025; Malliaroudaki et al. 2023; Rushton-Smith et al. 2025) and paper (Ibn-Mohammed et al. 2025). These studies commonly highlight the need for decarbonisation pathways that embrace a range of technologies, including hydrogen, CCS and electrification, while also stressing the importance of systemic change, such as circular economy strategies, and policy alignment.

Policy frameworks and governance mechanisms are topics of a third strand of research. This reveals that, while government and industry are broadly aligned on their approach to decarbonisation (Hansen et al. 2024), progress has varied across sectors due to a complex interplay of factors, including policy support, international competition, financial performance, and technological feasibility (Koasidis et al. 2020; Geels and Gregory 2024). However, more recent policy developments are showing promise (Sovacool et al. 2024b), although challenges of consistency and comprehensiveness remain (Lockwood et al. 2025). Industrial cluster projects represent a critical focus (Sovacool et al. 2024c) and are diverse in terms of their characteristics (Rattle and Taylor 2025). A key benefit of the cluster approach is it enables feasible and cost-effective deployment of technologies like

CCS and hydrogen fuel switching through coordinated policy, shared infrastructure, and innovation (Herman et al. 2025b; Sovacool et al. 2022) but, as yet, more fundamental transformation of industry is lacking (Finkill et al. 2025). Case studies have explored cluster decarbonisation initiatives in the Teesside (Herman et al. 2025a), Humber (Geels et al. 2023) and Northwest clusters (Clery et al. 2025). To date, there is much less research on how to decarbonise industry outside these clusters (Rattle et al. 2024; Rattle and Taylor 2025).

Research on public acceptance and the social dimensions of the transition highlights that industrial decarbonisation projects are not solely technical endeavours, but are also shaped by social factors, public perceptions, and political considerations (Lewis et al. 2023; Sovacool et al. 2023). The results highlight a critical role for place-based approaches (Devine-Wright 2022; Lai and Devine-Wright 2024; Lai et al. 2025; Smith et al. 2025); stakeholder engagement (Norris et al. 2024) and deliberation (Ostfeld and Reiner 2020), and just transition concepts (Eadson et al. 2023; Upham et al. 2022) in shaping public perceptions (Broecks et al. 2021), expectations (Ambrosio-Albala et al. 2023), discourses (Herman et al. 2024) and support (Gonzalez et al. 2021). A recurring theme is the need for a social licence to operate, especially for technologies like CCS, where trust in institutions and perceived community benefits are essential (Gough and Mander 2022; Clery et al. 2025).

A final strand of research is starting to explore the economic and employment impacts of industrial decarbonisation. This finds that, for most sectors, decarbonisation will have minimal impacts on the overall price of goods, although metals and non-metallic minerals may face more pronounced cost increases (Cooper et al. 2024). However, for some sectors, such as petrochemicals, there may be a conflict between economic and low-carbon reorientation processes (Geels 2022). While decarbonisation has the potential to create new jobs, worker and skills shortages have been identified as a common challenge, with average wage rates increasing as different sectors compete for a limited labour pool (Calvillo et al. 2025).

A policy-relevant research agenda to support UK industrial decarbonisation

Research on industrial decarbonisation in the UK has increased dramatically in recent years, with over twice the number of papers published between 2020 and 2025 compared to the preceding 20 years. The scope of topics covered has also expanded, from a focus on technical studies, to a literature that also explores policy and governance, public perceptions and social and economic dimensions. However, significant gaps remain, with four areas in particular requiring greater attention.

Delivering decarbonisation of dispersed sites

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Dispersed sites now account for more than half of UK industrial greenhouse gas emissions and yet there is relatively little research that focuses on their decarbonisation challenges and possible solutions. As we have previously noted in this journal, challenges include "*the geographical spread of industrial sites*, *the diversity of sectors involved*, *the small size and lack of capacity of many of the companies*, *incomplete information on appropriate abatement options and how these may vary with location*, *the low TRL of some electrification options combined with the high cost of electricity*, *uncertainty around the availability and planning of supporting infrastructure and a lack of institutional capacity and leadership at the local level*" (Rattle et al. 2024 p. 117).

Addressing these challenges will require (i) better datasets and mapping tools to locate and characterise dispersed industrial sites, (ii) more complete evidence on the technical and economic viability of a diverse range of technological options (including electrification, bioenergy, and energy efficiency) in different sectoral and site-specific conditions, (iii) evaluating the need for supporting network infrastructure including upgraded electricity transmission and distribution lines, and new hydrogen and CO_2 pipelines together with the potential for co-locating industries to give better access to these infrastructures, (iv) identifying policy gaps and designing innovative funding and financing mechanisms that are inclusive of dispersed sites and small and medium enterprises, (v) exploring successful local governance models and the role of local authorities in enabling decarbonisation (Greater South East Net Zero Hub 2024), (vi) building capacity and collaborative networks between industry, local authorities, and communities and (vii) aligning industrial decarbonisation approaches with Local Area Energy Plans and Regional Energy Strategic Plans to leverage synergies with transport, housing, and renewable energy developments (Rattle et al. 2024).

Enabling industrial electrification

Until recently, the role of electrification as an industrial decarbonisation option has received relatively little research or policy attention when compared to technologies such as CCS and hydrogen that will be particularly important for industrial clusters. However, electrification is likely to play a much more prominent role outside the clusters where many of the less energy intensive and smaller scale industries dominate. In its modelling for the UK's Seventh Carbon budget (CCC, 2025) the Climate Change Committee found that electrification provides 57% of all emissions reductions in 2040, with heat pumps being particularly important in low-temperature applications.

Many of the cross-cutting electric technologies, such as boilers and heat pumps, are commercially available for lower temperature applications (DESNZ 2024). However, a recent report to government (ERM 2023) highlighted remaining research and demonstration challenges for more complex higher-temperature electrification options in sectors including cement (electric arc calciner), glass (resistance furnace for glass melting), paper (high temperature heat pumps), chemicals (electric crackers), and food and drink (microwave heating). The report notes that many of these challenges relate to developing and demonstrating technologies at a commercial scale, overcoming design challenges and reducing the costs of integration on site with existing systems. It also highlighted wider barriers to electrification, which could also be topics for research, including reducing upfront and operational costs, enabling grid infrastructure upgrades, addressing skills and supply chain shortages and knowledge building.

Further work is also needed to explore how industrial electrification can support system flexibility through demand-side response, whereby industrial users vary or shift electricity demand without compromising production (DESNZ 2025a). This includes research into the technical and economic feasibility of industrial flexibility, its geographical distribution compared to network constraints, plus the role of behind-the-meter generation and storage, and developing the policy frameworks and market incentives required (Rattle et al. 2025).

Developing markets for low carbon industrial products

The UK's current industrial decarbonisation approach relies heavily on government subsidies to support emerging low-carbon technologies and fuels. While effective in the short term, this approach places considerable strain on public finances and is unlikely to be sustainable in the long run. Acknowledging this, the IDS proposes a shift over the next two decades to a combination of carbon pricing and product labelling and standards, as the primary decarbonisation incentives (HM Government 2021). The UK Government has recently consulted on the necessary policy framework for labelling and standards, with an initial focus on steel, cement and concrete products (DESNZ 2025b). Labels can stimulate demand for low-carbon goods by making their environmental impact visible and comparable, such as through A–G rating scales, guiding consumers toward greener choices. Over time they can evolve into enforceable minimum standards, phasing out the most carbon-intensive goods and progressively raising the baseline for environmental performance.

While a voluntary labelling scheme has existed in the UK since 2007 (Carbon Trust, n.d.), further research is essential to ensure that more widespread introduction of labelling and standards effectively reduces carbon emissions, avoids carbon leakage, supports industry readiness, minimises costs, and considers impacts on different social groups (CCC 2020). Key topics include developing an embodied emissions reporting framework for a range of materials and products; defining credible benchmarks for what is "low-carbon" across different products; and developing the specifics of policy design (scope, strictness, evolution over time). Research into data precision, completeness, representativeness and consistency is crucial to ensure that both labels and standards are trustworthy. Studies to understand how labels influence purchasing decisions and how standards can drive demand for low-carbon goods could also help tailor programmes to be more effective.

Realising the potential for resource efficiency

Resource and energy efficiency is recognised as having a significant potential to reduce industrial energy demand and therefore emissions. For instance, Barrett et al. (2022) find that by 2050 industrial energy demand could be reduced by up to 26% from 2020 levels through measures such as improving material efficiency, extending product lifespans, fuel switching, adopting circular economy practices, and using digital technologies to optimise energy use. Most of the savings come from reducing material consumption, rather than improving energy efficiency, for which the further potential is quite small. However, historically there has been little policy attention paid to resource efficiency, when compared to funding for new low carbon fuels and technologies for industrial production (Barrett et al. 2023).

Further research is needed to understand how to deliver these energy and emissions savings while minimising any adverse economic impacts. This includes understanding the barriers to reducing material throughput (e.g., lightweighting, reuse, remanufacturing), exploring Product-Service Systems that incorporate alternative business models to reduce demand by replacing ownership with service-based models (e.g., leasing or sharing platforms) and identifying how co-located industries can realise the potential for industrial symbiosis by sharing resources (e.g., heat, materials). Systemic issues are also worthy of further study, including the impact on production levels and product offerings, broader economic effects of demand-led transitions and how to enact structural change, taking into account the complex issues of investment and stranded assets (Barrett et al. 2022).

Conclusions

Accelerating industrial decarbonisation in the UK demands a coordinated, evidence-based approach that addresses technical, economic and social challenges. While progress has been made in recent years, significant research gaps remain - particularly around dispersed sites, electrification, markets for low carbon products and resource efficiency. A robust research agenda must support policy evolution, industry readiness, and public engagement, ensuring that decarbonisation is economically viable, socially just, and environmentally effective. By bridging these gaps, the UK can lead a resilient transition to a low-carbon industrial future.

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